




SUSTAINABLE FOREST MANAGEMENT IN AFRICA:

Some Solutions to Natural Forest Management Problems in Africa

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FOREWORD

The bulk of African forests occur in the countries of Central Africa (37%) and Southern Africa (28%). The forests vary from tropical rainforests to warm-temperate forests (at higher altitudes and latitudes) to tropical-subtropical deciduous woodlands and wooded savannas. The forests constitute an immense value but are under severe pressure for harvesting of diverse timber and non-timber forest products for sustainable livelihoods and for clearing for agricultural production and infrastructure. Much information deal with the negative aspects of forest cover loss through degradation and deforestation but more information surfaces on other aspects of forest cover changes, including forest gains, and positive issues of forest management. Relatively little information is available on the assessment of forest productivity and stand dynamics (recruitment, growth and mortality). This knowledge gap is compounded by the practicing of little to no sustainable forest management, and little to no integration between management for forestry, agriculture and nature conservation, for timber and non-timber products, or for industry and rural livelihood needs. The growing population and recent upturn of many African economies provide rapidly growing domestic markets for forest products and services, but there is no assessment of the capacity of the African forests to produce them. Climate change scenarios for Africa and its forest ecosystems add new challenges with great implications for the forests, household livelihoods, and national and economic development; these need to be incorporated into planning climate change response strategies, nationally and internationally.

Perspectives on the role of forests in development have evolved significantly since the Rio Summit in 1992. In many African countries, there is a growing recognition of the need to address the issues of poverty in national development programs, such as Poverty Reduction Strategies to meet the Millennium Development Goals and objectives of the New Economic Partnership for Africa’s Development (NEPAD). Some global initiatives include Tropical Forest Action Plans (TFAPs), National Forestry Programmes (NFPs), the Intergovernmental Panel on Forests (IPF), Intergovernmental Forum on Forests (IFF), and the United Nations Forum on Forests (UNFF). However these initiatives have had little impact on reversing the declining capacity to manage African forests. In part, this has been ascribed to the low participation of Africa in international dialogues on relevant forestry issues and the lack of a forum on the African continent that could facilitate African stakeholders to dialogue on these and other issues.

Technical and scientific exchanges in Africa on both the implications and applications of sustainable forest management for adaptation to climate change without compromising forest ecosystem resilience, and their critical mitigation activities, are therefore important. An Africa-wide dialogue on issues of sustainable forest management needs to be pursued to find African solutions to African problems in the context of sustainable management of the African natural forest ecosystems. What is the true state of African forests and their management? Do the African forest ecosystems have unique features that need to be incorporated into sustainable forest management strategies? Are there scientific and traditional knowledge systems of the African forest ecosystems to guide the world on sound multiple-use, multi-disciplinary and integrated forestry-agriculture-conservation strategies and actions?

The International Symposium on **Sustainable Forest Management in Africa** was hosted in Stellenbosch, South Africa, from 3 to 7 November 2008, to facilitate a discussion of these issues. It was organized by the Department of Forest and Wood Science, **Stellenbosch University,** and the **Commercial Products from the Wild Group**, in collaboration with the **Copperbelt University** (Zambia), **Eduardo Mondlane University** (Mozambique), the **Research Institute in Tropical Ecology of the National Centre for Scientific and Technological Research** (Gabon), the **Centre for International Forestry Research** (CIFOR), the **International Union of Forest Research Organisations** (IUFRO), and the **Food and Agricultural Organization of United Nations** (FAO). The *objectives* for the symposium was to

- bring together national, regional and international policy- and decision-makers, forest scientists, forest ecologists, planners and resource managers (public and private sectors), rural communities, farmers and individuals, the education community, consumers of forest/tree-derived products, NGOs with forest, environment, social and other foci of work, and others;
- share information, concepts and ideas on a broad range of topics (papers and posters);
- facilitate networking among diverse stakeholders in forestry in Africa;
- facilitate development of specific programs, projects and activities that address priority issues, and facilitate coordination, collaboration, dialogue and funding;
- facilitate advocacy activities with the potential to raise the profile of forestry, to highlight threats to forest resources and the environment, and to champion better management of African forests.

The symposium was attended by 102 participants from 23 countries representing 41 institutions. A total of 53 oral papers were presented. This collection of symposium papers includes the four keynote presentations, and 38 papers presented in seven themes.

The mid-symposium excursion took participants to the Newlands urban forest within the Table Mountain National Park on the Cape Peninsula, managed by the South African National Parks. Today 3.4 million people live in and around Cape Town, with associated pressures on the natural areas with their very small patches of natural forest. The forests are affected (positively and negatively) by commercial timber plantations, controlled and uncontrolled fires, outdoor recreation, and illegal plant and bark collection mainly for traditional medicine. The visit focused on options to use the stands of plantation and invader plant species to rehabilitate natural forest, and thereby recover the regeneration and population status of the tree species negatively impacted by bark harvesting.

The post-symposium tour visited the Southern Cape Afrotemperate Forests, the largest natural forest area in South Africa, in collaboration with South African National Parks, who manages most of those forests. The visit focused on forest ecological research and the sustainable multiple-use forest management in which ecosystem conservation (species and processes) remains the overriding management objective. Secondary objectives included the utilization of timber, ferns and medicinal plants, outdoor recreation, research and community development through participatory forest management (PFM). Management of these areas received international recognition through FSC certification in December 2002.

We hope that the enthusiasm with which participants took part in the deliberations and discussions will continue to stimulate research and sustainable forest management in Africa, with more regular dialogue within Africa to find African solutions for African problems in sustainable management of the African forests for the benefit of African Society.

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October 2011

Overview:

THE DRY FORESTS OF SUB-SAHARA AFRICA: MAKING THEIR CASE

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Abstract

The dry forests of Africa are known for their immense support to many forms of life on the continent. It is in these forests that human, animal and forest interactions are very pronounced and threaten there very survival. The agricultural belt is practically sandwiched by forests, making agriculture and animal husbandry encroach on them. Further, these forests support the head waters of many rivers, with many river basins found within them. The dry forests are therefore important in supporting agricultural expansion and in quality supplies of water to man and animals.

Africa is urbanizing fairly rapidly but with low industrialization that is accompanied with high unemployment, increased housing using traditional material and increased dependence on traditional energy sources. Much of the expansion spills over into forests in terms of demand for land for habitation as well as demand for forest products and services.

Many policies continue to create favourable conditions for better management of the dry forests. There is increased global recognition and support to sustainably supply international public goods and services from forests. African stakeholders are increasingly coming together and speaking with one voice on many forestry issues.

There are many opportunities for socio-economic development using forests and tree resources, largely in the form of markets resulting from rapid urbanization, growing markets in Asia, requirements for carbon sequestration and satisfying the needs of a growing African population.

Introduction

The world's forests, oceans and other water bodies are the main life-supporting mechanisms for planet earth. The forests are key to sustaining the biodiversity of natural ecosystems and in regulating the world's climate system. Africa has about 16% of the world’s forests (636 million hectares). The bulk of these forests are found in several countries in Central Africa (37%) and Southern Africa (28%). These two sub-regions account for 65% of the forest resources, with three other sub-regions together account for the remaining 35%: West Africa and North Africa with 11% each; and East Africa with 13%. About 38.4% of the African forest estate is tropical rain forests. The tropical moist deciduous and tropical dry forests cover respectively 24.2% and 29.2% of the forests; i.e. 53.4% of the total forest area. There are about 8 million hectares plantation forests (FAO 2003, 2007). Possibilities also exist to extend the forest area by rehabilitating degraded forests and establishing forestry plantations and agro-forestry farming systems in countries and areas that are wood deficit or where it is environmentally necessary.

Sustainable management of the vast and diverse African natural forest resource is proving to be extremely challenging. There is scanty information on the biophysical aspects of the natural forest estate, and even less on the properties and end use of the various tree species. There is much less information on socio-economic and policy aspects related to the forest condition and responses to the same by users of such resources. In short there is scanty information, and of questionable quality and quantity, to guide rational decision making in planning and managing the resources, and in particular on how to use the resources in ways that alleviate rural poverty and promote environmental protection. Further, large tracts of natural forests in Africa are being treated as open access resources.

There are other constraints that continue to make it difficult for the majority of African countries to manage these forests sustainably. Firstly, the sector continues to receive low government priority in terms of support, and this has worsened because governments are pressurized by economic reforms to reduce public expenditure. The result is insufficient budgetary allocations to the sector. On the other hand, in many African countries, policy and market failures have promoted the liquidation and degradation of the forest resources, sometimes to finance government expenditure and support livelihoods. Secondly, many African countries, in their day-to-day struggle to satisfy the most basic needs of their populations (notably food), cannot accommodate the long-term investment period required for the successful implementation of forestry management programmes. Further, credit is increasingly available at rates of interests that make investments in primary forest production and to some extent in wood processing not attractive. There is in addition, lack of incentives in particular to local communities and the private sector to sustainably manage and use natural forest resources. Thirdly, forestry institutions in many African countries are weak, again mainly due to economic reforms that lead to inadequate funding and constrained recruitment of staff for the sector. This then compounds the problem of adequately conserving and managing the continent's forest resources. Fourthly, the nexus between rapid population growth, poor agricultural performance, rural poverty, environmental degradation, market and policy failures, and the use of inappropriate technologies provides the basic context within which deforestation and forest degradation are taking place in Africa. This seriously hampers sustainable management and use of forest resources.

In the last two and half decades several planning frameworks under such names as National Forestry Action Plans, Forestry Master Plans, Forestry Sector Reviews, and National Forest Programmes have been undertaken in many countries. They have led to revisions and/or instituting forestry policies, legislation and plans. Further, many African governments have participated in numerous forestry related international processes, thereby becoming signatories to various international agreements and conventions. In this regard African countries have underlined their commitment to the sustained production of forestry related international public goods and services. African governments are embracing new paradigms on both political and economic fronts. There is increasing participation of local communities in decision making. This has gradually been extended to managing natural forest resources. Local communities are becoming more empowered to undertake ownership and management functions from central governments. On the economic front there is increased private sector participation in the national economies. This has seen the increasing opening up of the forestry sector to private investment. Industrial plantation management in Africa has not been very challenging because investors could draw upon experiences from other countries.

Further, African governments are increasingly becoming aware of the role of natural forest resources to the socio-economic development and environmental stability of their countries. The forests are valued for their habitats for wildlife, beekeeping, unique natural ecosystems and genetic resources. They occur in the catchments of many rivers that are cornerstones of economic development on the continent. The critical functions of the natural forests in protection of soils and watersheds and the conservation of biological diversity have great economic and social implications in Africa. For example, adequate forest cover is a pre-requisite for sustainable agricultural production systems, wildlife management and tourism in many African countries. There is therefore increasing recognition that forests and agriculture are the pivot of the rural economy in Africa. Efforts to alleviate poverty cannot be successful unless the roles of trees and forests in the rural economy are fully addressed. Sustainable livelihood, especially in rural areas, is partly dependent on the judicious management of forest resources. In addition, the natural forest resources are increasingly receiving global attention because of their share in biological diversity, potential for industrial timber exports, capacity for mitigating adverse effects of global climate change, livelihood 'safety nets', and as levers for rural development.

The majority of the forests that provide these functions on the continent are the dry forests. They are the focus of this paper that briefly attempts to put up their case by outlining the threats to and potentials in them; specifically with highlights on population growth, agricultural expansion, water resources, urbanization, globalization and economic reforms, increasing interest in forestry and climate change.

Distribution and significance of dry forests

Dry forests constitute one of the major terrestrial ecosystems, existing in all developing regions of the world: Africa, Asia, and Latin America. Proportionately, they are most prominent in Africa, where drier forests in all their varieties - from the desert margin scrub to closed woodlands to deciduous forests - support the most people, livestock and wildlife in all the continent’s ecosystems. In Sub-Sahara Africa dry forests cover approximately 17.3 million km^2, and as estimated in 2003, they support nearly 505 million people (Chidumayo

2004). The Congo Basin forests support about 50 million people and are receiving much more attention (and most likely resources) than the dry forests.

Dry forests in Sub-Saharan Africa can be categorized as follows:

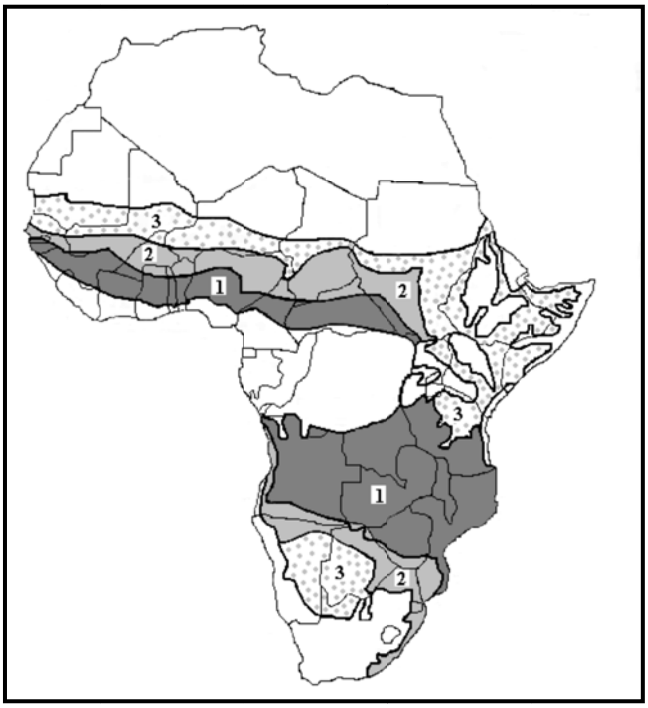
- Warm humid dry forests with a dry season that lasts 1 to 4 months, and with 1,000 – 2,000 mm average annual rainfall.
- Warm sub-humid dry deciduous forests with a dry season that lasts 4 -7 months, and with 800 – 1,500 mm rainfall.
- Warm very dry wooded savannas with a dry season that lasts 7 – 9 months, and with 400 – 800 mm rainfall.

The dry forests are found in 74% of the 41 countries (excluding island states) in Sub-Saharan Africa (Figure 1). They are the dominant vegetation in 63% of the countries (ibid).

According to CIFOR (2007) "Dry forests are found in a band across Africa from Senegal in the west, making a loop around the Congo basin, to Ethiopia in the east and South Africa in the south. Dry forests partly or fully cover Angola, Botswana, Burkina Faso, Cameroon, Central African Republic, Chad, Congo, DRC, Ethiopia, Gabon, Guinea, Kenya, Lesotho, Madagascar, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Senegal, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe. Dry forests cover a spectrum of vegetation types from deciduous forests with a continuous tree canopy to moist savannas, dry deciduous woodlands, dry savannas and very dry scrub. Dry forest landscapes are very variable, with crop lands, grazing lands and woodlands existing side-by-side". Although data on forest productivity are scanty, available estimates indicate wood yields of 0.1 – 1.0 m^3ha^{-1} compared to the potential of 1 – 10 m^3ha^{-1} (Haveraan 1988).

Dry forests are key to rural livelihoods in Africa, for grazing and a range of timber and non-timber forest products and services. While they are critical as safety nets, they also support a diverse range of cash income-generating activities. In some cases up to a third of rural household incomes originate from these forests. The forests play crucial roles in times of crisis (e.g. during and after droughts). Apart from farming and livestock husbandry, alternative economic opportunities to support people in these areas are few and they remain under-developed. The potential of dry forests is not fully known and tapped, making their contributions to be consistently under-estimated. Further, dry forest goods and services are hardly fully captured in national and local planning initiatives.

Like other forest types, the dry forests are also important in maintaining high water quality and protecting soil from erosion. They offer the bulk of fodder for vast livestock and wildlife populations. They provide fuel wood for domestic and rural industry uses, including for drying major agricultural crops and fish. They offer construction material for farm structures and homes for millions of people in both rural and urban areas. They have often unacknowledged and significant support roles for agricultural production. These forests are home to precious woods, such as African ebony, valued in handicraft industries or for quality musical instruments. They provide raw materials for packaging and wares used in homes and in harvesting farm produce. They are the source of important non-timber forest products such as medicines, wild meat, and other foods.



Note: (1) Warm humid dry forests, (2) Warm sub-humid dry forests and (3) Warm very dry wooded savannas. Based on Haveraan (1988). Source: Chidumayo 2004

Figure 1: Distribution of dry forests in Sub-Saharan Africa

Much as the dry forests support most of Africa's wildlife and tourism potential, these wildlife areas are not considered as forests because the primary use is wildlife management. But wildlife needs the fodder, shade and water found in these forests. The degradation and conversion of dry forests to other uses, especially into cropland, is far more advanced than that of wet forests.

There have been many changes in forest management and thinking in Africa and globally, as well as an increase in consumption of forest products and services which justify rekindling of the interest in dry forests. Of particular importance are the following:

- Decentralisation and devolution of administration and increased emphasis on community participation in forest management.
- Changes in forest administration especially through the establishment of more autonomous boards, authorities and commissions.
- Increased role for the private sector in forestry production and processing; this has led to privatisation of public-owned commercial enterprises, including forest industries and plantations in many countries.
- Increasing role of civil society – especially national and international non-governmental organisations - in influencing forest resource management, particularly

through their advocacy role and also through direct involvement in forestry initiatives in supporting community participation.

- Concerns about global changes, especially those stemming from demands that forest also in Africa shall provide global public goods and services, and environmental protection in particular, as reflected in various international arrangements including treaties and conventions (Tieguhong and Nair 2004).

These deserve to be understood better, and the new understanding needs to be brought to the attention of policy makers. This calls for a better way of making the case for the dry forests at national, sub-regional, regional and global levels.

Threats to and opportunities in dry forests

Often the threats to the forests are more emphasised than the opportunities the forests have, for example, to improve livelihoods, national incomes and the environment. In many cases the threats could be turned around into opportunities. For this reason threats and opportunities are treated together in this text, the intention being to highlight opportunities that accompany some of the threats.

Population growth and agricultural expansion

Population growth is one of the stimuli for expanding agriculture in order to feed more people. In Africa this is mainly due to the state of agricultural technologies employed by farmers, making population growth go hand in hand with cropland expansion.

The distribution of the human population on the continent mirrors that of the dry forests (Figures1 and 2). Agricultural expansion is the major cause of forest loss and degradation in Africa. In Sub-Saharan Africa (SSA) practically all agricultural land lies within the dry forests (Figure 3), making forestry and agriculture compete for land.

However, such expansion is necessary for socio-economic development of African countries, much as the opportunity cost is mainly forest loss and degradation. Population growth creates more demand for forest products and services. This in turn opens up employment opportunities to supply such markets and creates incomes at all levels, from rural households to national governments. Not always considered is the trade off in the gains from agricultural expansion against the forest loss and its degradation. One should also consider, in this equation, the trees that are coming up on farms to augment the supply of tree based products.

It is the dry forests that offer most of the potential agricultural expansion frontier in Africa. About 70% of Africans live in rural areas. Also about 80% of the poor in Africa live in rural areas (ECA 2008). In fact about 70% of the people in Africa who live on less that 1US$ a day live in rural areas (ECA 2007).

The African Union's Comprehensive Africa Agriculture Development Programme (CAADP) aims to attain an average annual growth of 6% in agriculture. In the recent years this growth has averaged 3.9% annually, though food security continues to be alarming. In fact the impact of the 'green revolution (1960-2000)' in developing countries is minimal for Sub-Saharan Africa. The subcontinent benefited little from the development of modern or high- yielding crop varieties, an effort that has been championed mainly by international agricultural centers in collaboration with national agricultural institutions. Yield growth made only marginal contributions to growth in crop production. The share of improved crop varieties to yield growth was also low. Production growth is reported to have been almost entirely based on extending the area under cultivation (Evenson and Gollin 2003).

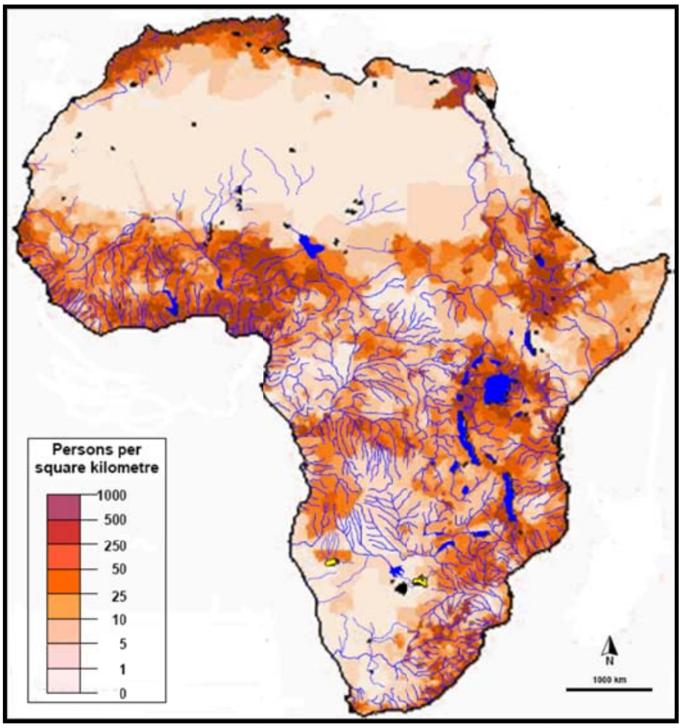
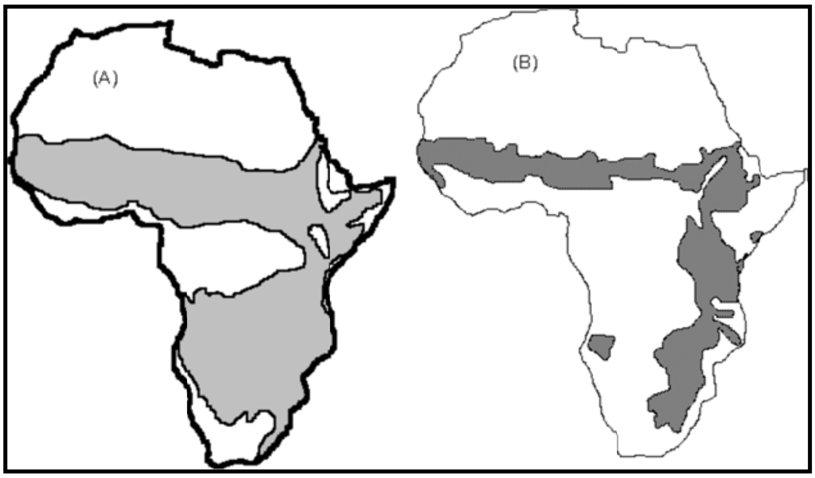


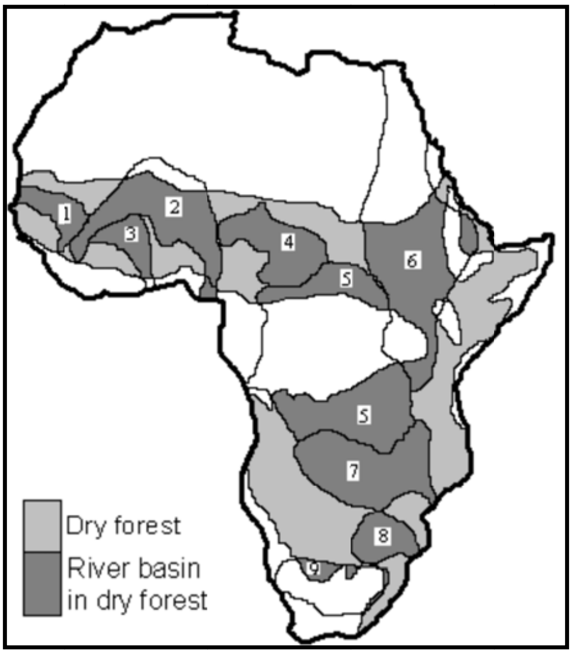
Figure 2: Population distribution in Africa (Adapted from Ashton 2007)



Note: Cropland is based on Mayaux et al. *(2003). Source: Chidumay 2004*

Figure 3: Distribution of dry forests (A) and cropland (B) in Sub-Saharan Africa.

One approach to increasing food supplies and security is to significantly increase its cropland area under irrigation. It is in this context that the dry forests become crucially important because nearly all the major river basins in Sub-Saharan Africa are either located or have most of their headwaters in dry forests (Figure 4).



Note: Senegal (1), Niger (2), Volta (3), Chad (4), Congo (5), Nile (6), Zambezi (7), Limpopo (8) and Orange (9). Source: Chidumayo 2004

Figure 4: Major river basins in dry forests areas in Africa

For irrigated agriculture to materialise, Africa will need to carefully manage the shared water basins. Already in many of them water resources are approaching ‘closure’ with very little water left for additional activities. In other water basins water resources are under increasing pressure and this call for very close cooperation in their management (Figure 5). There are already recorded conflicts over water resources (Figure 6) (Ashton 2007).

Such a water scenario, combined with the prevailing poverty on the continent, the dismal state of technology used by African farmers, among other constraints, dictate that CAADP's objectives, even if attained modestly, will largely be through extensive agriculture that will spill over into dry forests, resulting into more deforestation and forest degradation.

Agriculture is and will continue for the foreseeable future to be the main engine of economic growth in many tropical forest countries. The move from sedentary to more productive ways of agriculture demands a good balance between the unreliable rain-fed agriculture and irrigated agriculture. Rosegrant *et al.* (2002) report that in 1995 rain-fed agriculture contributed about 58% of world cereal production and that rain-fed cereal yields averaged 1.5 metric tons per hectare as compared to 3.3 tons per hectare from irrigated agriculture in developing countries. This underlines the importance of securing water resources for global food security and socio-economic development.

However, much as forests will continuously be lost, more trees are coming up on farms. In some cases households derive a third of their tree based requirements from their farms. The landscape is now a mosaic of a continuous belt of trees as a forest, trees on farms, patches of forests, grasslands and other land cover. The landscape is changing fast and there is little that can be done to stop this.

The challenge facing foresters and other land users is how to manage this change in ways that ensure sustainable supplies of food, fodder, timber and non-timber forest products, and environmental services, among others, to a growing African population and with a surplus for export. This will call for a new and innovative way of doing business in agriculture and forestry. It will therefore require the evolution of new perspectives on forestry, science and techniques of managing the changing landscape to meet people's requirements in a sustainable manner and without compromising on the quality of the environment they live in.

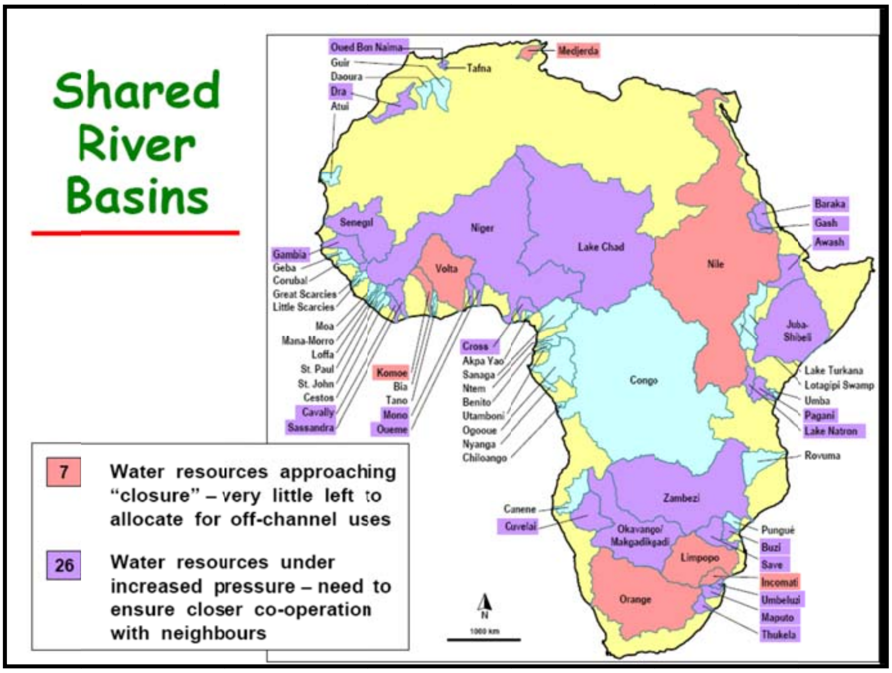


Figure 5: The water resources situation in shared river water basins (Adapted from: Ashton 2007)

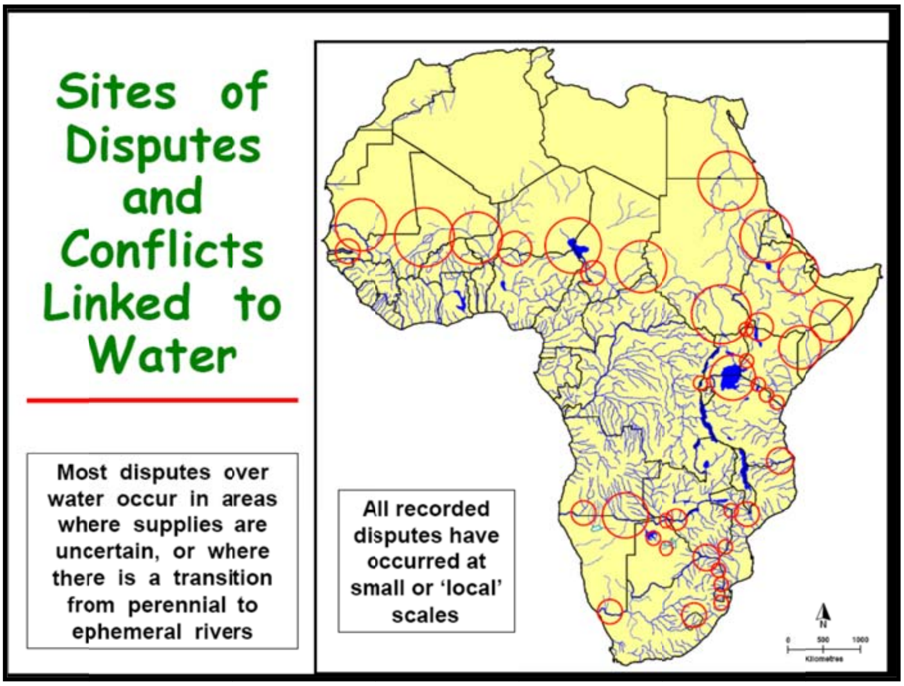


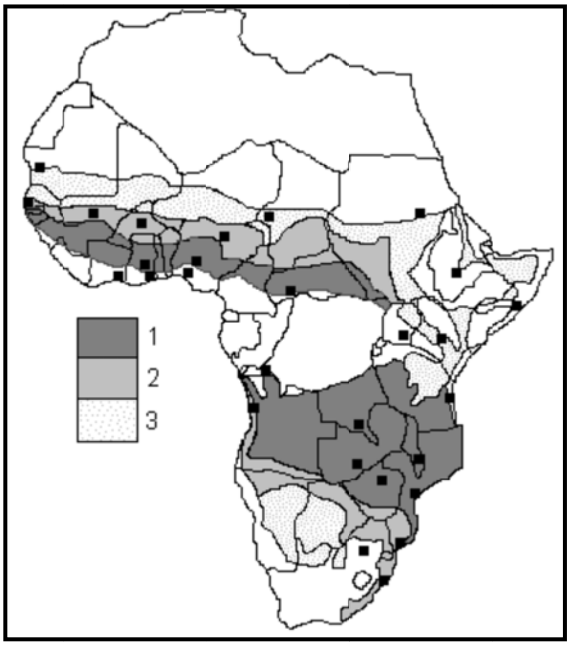
Figure 6: Sites of disputes and conflicts over water resources (Adapted from: Ashton 2007)

Urbanisation

Africa is urbanizing faster than any other region, at rates that ranges from 5-10% per annum. The African rural population growth averages 2.5% per annum. The highest rates are found in the northern and southern parts of the continent (ECA 2008). Unlike Europe, urbanisation in Africa is occurring at rates that are almost three times those experienced by European cities at the height of the industrial revolution. But in SSA urbanization appears to be growing with low industrialization that is accompanied with high unemployment, increased housing construction using traditional material and increased dependence on traditional energy sources (Chidumayo 2004)

There is widespread urban poverty that continues to grow and has made a number of urban households in SSA grow crops or raise livestock in urban environments to supplement their livelihoods. Prevailing high prices for oil, food (due to scarcities) and other commodities and services like education and health, are stretching to the limits the incomes of the already poor societies in urban areas. The consequence is that a significant proportion of the urban dwellers will continue to live in the growing slums that lack basic services and secure tenure.

Chidumayo (2004) reports that there are 43 cities in Africa with populations of over one million people (Figure7). Many of them are within the dry forests belt. These cities are projected to increase to 70 by 2015. A key concern in many countries is the lack of provision of utilities, especially water and energy.



Note: (1) warm humid dry forests, (2) warm sub-humid dry forests and (3) warm very dry wooded savannas. Source: Chidumayo 2004

Figure 7: Major cities and towns (■) in and around dry forests in Africa

While the impact of urbanization is varied, it has important implications on forests, including:

- Increased demand for wood, especially wood fuel, that could result into over-exploitation of forests and woodlands initially close to urban centres and progressively those that are further from such centres. For example, the city of Lusaka in Zambia obtains charcoal from some 300-400 km north of the city. Similar distances have been observed for cities like Maputo (Mozambique), Dar es Salaam (Tanzania), Khartoum (Sudan) and Dakar (Senegal). In some cases charcoal contributes 60-80% of rural household income and is therefore key to poverty reduction (ibid).
- Increased use of charcoal, which requires higher wood input and thus accelerating forest clearance.
- Need to improve the urban environment, especially for green space.
- Increased demand for land that could come from the nearby or surrounding forests.

On the other hand urbanisation is creating an exponential increase in the demand and markets for forest products and services. It should not be viewed solely as a threat to forests but also as an opportunity for the sector to professionally supply the growing markets with the forest products (like firewood, charcoal and poles) and services (like water and carbon sequestration) and on a sustainable basis. The challenge is how to make forestry and urban development plans and programmes that can secure sustainable supplies of forest products and services to urban dwellers.

Improved political climate: democracy and good governance

Democratisation and good governance initiatives are very indirect means by which to actually promote the welfare of rural communities. They are taking root in many African countries. One of the spinoffs of the growing democratization in Africa to the forestry sector is increased participation of stakeholders in key decisions on management, use and ownership of forest resources. This has led to Participatory Forest Management (PFM) practices like Joint Forest Management (JFM) largely between governments and private sector with local communities, and Community Based Forest Management (CBFM) that places the management of forest resources in the hands of local communities. These practices are more pronounced in the dry forests than in the rain forests. In essence these management approaches have evolved due to closer and frequent human interaction with the forest resources. The dry forests are more open and with many more people interacting with the forest resources as compared with the rain forests. The JFM and CBFM have succeeded in putting more forest resources under some kind of administration. These are still emerging approaches on the continent that hold potential to increase the scope of forest management.

However, one of the shortcomings, especially with CBFM is that local communities are in many cases allocated forests of low quality, and are not provided with sufficient information/knowledge, skills and other resources required for managing such resources.

What has been largely achieved is protection of the forest resources, but beyond that their management and efficient use remain questionable. The danger with this is that local communities could lose momentum on CBFM initiatives and the forestry practice could revert to the status quo.

The emphasis on good governance, and especially good forest governance, provides an opportunity to the forestry sector to conduct its business in an ethical, professional and transparent way. However, the presence of institutions such as African Forest Law Enforcement and Governance (AFLEG) on the sub-continent, the frequent news and reports on illegal forest activities, among others, demonstrate that all is not well in the forestry sector.

Emerging trends in trade and markets for forest products

The traditional export markets for industrial wood and wood products from Africa have mainly been in Europe, owing to links dating back to the colonial period. However, trade is increasing between Africa and some Asian countries notably China. With the advent of increased trade in certified timber in European countries, and the fact that many Asian markets are not sensitive to such trade, there is a potential likelihood for increased trade between African and Asian countries in uncertified timber. The Asian markets are not as selective; in fact they absorb timber and related products from many African tree species. This has opened up markets for timber and other products from some otherwise ‘lesser known tree species’.

At a time the African forest sector needs more income to finance its rapidly expanding functions; the availability of such markets should logically be welcome news. However, some concerns have been voiced that these emerging Asian markets could deplete forest resources from some African countries. The challenge is for the sector to position itself to supply, in a sustainable and professional manner, such markets. There is no reason as to why the harvest of these new tree species should not follow the annual allowable cut approach that is used to supply other traditional markets.

Dominance of the informal sector in forestry

Forestry business in many African countries is mainly transacted in the informal sector. This is a sector that operates at the interface of the monetised and traditional economies. The types of activities that characterise the sector include subsistence collection of forest products, processing and trade in firewood, charcoal, forest foods and handicrafts. It is assumed that in some countries, business conducted in the informal forestry sector may contribute more to rural livelihoods than that in the formal forestry sector. The informal sector has no institutional visibility, lacks supportive or enabling policies, plans, development strategies and a champion for its causes. Further, the sector is very amorphous in terms of size, entry and exit, and has players that are largely unknown to national governments and therefore escapes national statistics (Kowero *et al.* 2001). The economic reforms implemented by many African governments should ideally pay greater attention to the informal forestry sector, especially on how the sector functions and how to foster its better performance in the future.

Globalisation and economic reforms

In the recent past there has been an increasing trend in the globalisation of the world economy, and with mixed results. Wade (2003) notes that evidence from many years of globalisation (started around 1980) confirms that more open economies are more prosperous and those economies that liberalise progress faster than those that resist economic liberalization. The World Bank (2002) reports that over the last two decades the number of people living on less than $1 a day has fallen by 200 million, after rising steadily for 200 years. Dollar and Kraay (2002) also report that globalisation has promoted economic equality and reduced poverty. However, Mazur (2000) cited in Wade (2003) as well as Wade (2003) report that globalisation has dramatically increased inequality between and within nations.
The macroeconomic policies, and especially economic reforms implemented by many African countries since the 1980s, have at times increased rural poverty, deforestation and environmental degradation.

The combined result of the effects of globalization and macroeconomic reforms is that rural poverty has increased in many African countries. This has been accompanied by increasing dependency on natural forest resources for survival. Growing populations and rural poverty, increasing demand on diminishing natural forest resources, and industrial pollution have all combined to exacerbate environmental problems, including global warming, droughts and floods. These events have the potential for a vicious cycle that entrenches poverty, especially due to the decreasing capacity of forest resources as safety nets for the rural poor.

Further, globalisation and economic reforms favour private sector initiatives. The entrenchment of the private sector through globalisation and economic reforms, if not tempered with other measures, would most likely concentrate resources such as capital, land, access to information and technology in the hands of a few, who are already largely confined to industrial forestry. It is therefore necessary to evaluate how compliance to economic reforms and globalisation can be maintained while at the same time promoting the value of forest resources, their sustainable management, as well as their capacity to improve the welfare of rural communities.

On the other hand globalisation has also attracted new capital flows from outside Africa. The market growth in telecommunication networks coupled with external investments by multinational corporations are good examples. Such an influx of capital and technology provides a stepping-stone to knowledge and service industries that the forestry sector should take advantage of.

Increased recognition of and cohesion in African forestry

Forestry issues are increasingly receiving prominence in various global, regional, sub-regional and national level discourses. A number of institutions, networks, agreements and conventions, to mention a few, have been put in place to guide dialogue and action on forestry related issues. Recently the world adopted a Non-Legally Binding Instrument (NLBI) on all types of forests, a result of protracted negotiations at the United Nations Forum on Forests (UNFF). Forestry is featuring prominently in climate change debates, in poverty alleviation policies, in provision of environmental services and environmental protection. The regional economic groupings in Africa are taking on board forestry issues in a sub-regional perspective, e.g. a forest policy being developed for ECOWAS countries, a Forest Protocol for Southern African Development Community (SADC) countries, a Forest Law Enforcement and Governance (FLEG) process being initiated in East African Community (EAC) and SADC countries.

African stakeholders are coming together in focused networks and groupings such as: the African Forest Forum (AFF), African Forest Research Network (AFORNET), African Network for Agriculture, Agroforestry and Natural Resources Education (ANAFE), Commission des Forêts d’ Afrique Centrale (COMIFAC), Network for Natural Gum and Resins in Africa (NGARA), African Model Forest, to mention a few. Africa needs to capitalize on the synergies and complementarities in these frameworks, to harmonise its efforts so as to strongly bear on issues in a holistic manner, avoid duplication of activities, and increase efficiency and impact.

Climate change and dry forests

Climate change and variability is not new. Neither is adaptation to and mitigating against its adverse effects. African societies, especially those in the dry forests and drylands demonstrate some of the best examples of successful adaptation, for the people, their food systems and the environment. The cultivation of *Acacia senegal* and *Faidherbia albida* in agroforestry systems in some dry forest and dryland countries demonstrates the capacity of these societies to adapt their production and livestock systems to climate variability. The drylands are also a showcase of ecosystem resilience, from an ecological viewpoint, i.e. the ability to withstand change and recover after adverse effects. The current talk on ‘greening the Sahel’ is a case in point. As compared to the rain forests the dry forests are simpler ecosystems that could be relatively easy to manage, from an ecological point of view, and have even an intrinsic capacity to adapt to climate change and variability. For example there are considerable annual fires and droughts in some of these forests, but the forests eventually recover, if they are left alone.

However, what is happening today with respect to climate change and variability is that the intensity with which it is taking place and the risks and potential grave consequence this could have on mankind and the environment. This is especially of concern to Africa where dependence on natural biophysical resources is high; agriculture is the mainstay of most people, poverty is rampant and infrastructure to support socio-economic development is weak. Climate change is therefore expected to put a lot of strain on the biophysical, economic, social and even political systems that regulate life on the continent, with the Eastern and Southern African regions and the Sahel becoming more vulnerable because of dependence on already marginal lands.

According to the IPCC WGII Fourth Assessment Report (2007), Africa is one of the most vulnerable continents to climate variability and change. The report predicts that by 2020, between 75 and 250 million people are likely to experience increased water stress that would largely be attributed to climate variability and change. Further, agricultural production and overall access to food in many African countries could be severely compromised by climate variability and change, largely because cropland area, cropping seasons and crop productivity are expected to decrease, especially on land that is already marginal, in semi-arid and arid areas.

There is a lot of talk about carbon in forestry discourses these days. There are many stakeholders and money involved in carbon. But this talk is also reminiscent of the great attention given to fuel wood in the 1970s and 1980s. Many papers were written about the impending fuel wood crisis and alarming predictions made on this. A lot of attention and other resources on forestry were on this issue. Many village woodlots and plantations to supply urban areas were established, in addition to better charcoal kilns and cooking stoves. Although the crisis never materialized as forecasted, African countries are still struggling with fuel wood problems, despite the huge investments made. They are a long way from solving these problems.

While climate change is a very serious global issue, and indeed for African forestry, the forestry sector should not diminish its attention to other important forestry issues, because they are also very important to livelihoods and the environment. It would appear that the attention and resources for climate change bear more on the rain forests than on the bulk of the forest resources of Africa; the dry forests. The dry forests support the majority of the people in Africa. They are apparently not receiving attention commensurate to their size and capacity to support livelihoods, livestock and wildlife, and the environment in Africa.

Africa has 14% of the world population and has relatively few consumers of fossil fuels. Further, Africa’s emission of climate-change inducing carbon dioxide is low, estimated at 3.5% of world’s total. The African forests are important sinks for carbon but they are sources of carbon dioxide emissions through annual burning, clearance for agriculture through slash and burn and other ways. But the net effect of the emission from these forests and carbon sequestration is hardly known given the nature of information available. However, they are potentially important as sinks and in carbon trade. Many threats to the forests hold the potential to reduce their capacity as carbon sinks. In individual countries, action to mitigate adverse effects of climate change through trees and forests can be viewed at two levels: the forestry sector and at the national or macroeconomic level.

At the forestry sector level, it is lamentable that the African forestry sector is a very late comer to the climate change debate. Much as the potential to sequester carbon exists in the African forests and trees, the sector has yet to seriously look at other potential implications of climate variability and change on its resources. It is therefore desirable to consider, among others, the following issues, that are not particularly specific to the dry forests but could as well be extended to other forest conditions:

- The limited understanding of the responses of dry forests and trees to climate change. The little information available suggests that the sensitivity of dry forest tree species is both species-specific and possibly varies among different growth phases: seed, seedling, sapling and adult phases.
- How the different phenological processes in dry forest trees are affected by climate variables.
- The effects of short-term and medium-term climate variations on dry forest growth and productivity.
- The effects of interactions between climate variations and anthropogenic fire in dry forests.
- The potential effects of climate variability and climate change on forest growth and productivity. This might affect returns on investment in forest management, including plantation forestry.
- How land tenure and different types of forest management models (i.e., public, private, communal, etc.) impact on the ability of forests to mitigate climate change.
- Which forest management practices (fire protection, select felling, controlled grazing, enrichment planting, and agroforestry) yield the best climate change mitigation potential.
- What should be the response of the African forest sector to climate change. Certainly it is not just carbon sequestration and trade.

There is a variety of forest management models and practices in Africa. However, the efficiency of these models and practices in adapting to and militating against climate change has not been adequately evaluated. The approach, impact and carbon sequestration potential are likely to vary between models and practices.

While addressing these and other relevant issues, the African forestry sector could also take advantage of the expanding carbon trade and other incentives related to reduction of carbon dioxide emissions.

At the macroeconomic or national level, mitigation policies must address the factors or economic sectors in which significant reduction of emissions and/or carbon sequestration are possible. This means formulating policies which address the core causes of deforestation. By and large, African forests are lost through clearing for farming and pasture, extraction of wood fuel and fodder, and harvesting timber for industry and domestic consumption. The policies that promote agricultural production, consumption and trade in forest products, general economic development that has a bearing on type and quantity of energy consumed, and the institutions that promote good governance and compliance to law are outside the forestry sector. It is therefore important to look outside the sector to identify other action areas that could contribute to mitigation of climate change through reduced and avoided deforestation as well as through increased afforestation and reforestation.

Further, the information on climate change in Africa is growing rapidly. However, much of this information is based on highly aggregated data from the IPCC Data Distribution Centre and General Circulation Models (GCM). Further, the climate data used in African agriculture is generated by a few key international organizations, including the Hardley Centre (UK Met Office), the National Oceanic and Atmospheric Administration (NOAA) of the USA and the Centre National de la Recherché Scientifique (CNRS) of France. The use of data from these sources is not always to suit the problem situation, but more often because of their accessibility and familiarity to users (Ziervogel *et al.* 2008). Africa therefore needs to increase its capacity to understand and work with the information available, build its own information sources, create networks that can increase critical mass to bear on problems as well as share information and experiences, and develop and support good adaptation and mitigation measures for climate change.

Conclusions

Africa is facing a number of challenges in the forestry sector, but some of the more serious ones include:

- The rapid deforestation of natural forests and slow growth in plantation forests. These could combine to create serious industrial wood shortages. Already some countries that were net exporters of timber products are now net importers of the same.
- Many policies hold potential for better forest management as well as threats to these resources.
- The forestry sector is undergoing rapid changes in line with national economic reforms. However, the peculiarities of the sector and its demands are not adequately addressed.
- Constrained recruitment of forestry staff due to economic reforms and loss of the same through natural attrition and HIV/AIDS and other serious diseases like malaria.
- Lack of adequate capacity (human, financial and otherwise) to bear on these challenges.

It is noteworthy that the African forest landscape and policy scene is changing. The way forests are viewed and managed is also changing. The challenge is how to manage these changes. These challenges are not insurmountable.

On the other hand, there are many opportunities to the sector. The key ones include:

- The many opportunities, largely in form of markets, resulting from rapid urbanisation, requirements for carbon sequestration, and satisfying needs of a rapidly growing African population.
- There are also exponentially growing markets in Asia for products from otherwise under-utilised or even unused tree species from African forests. These markets had better not be seen as threats to African forests, but rather as opportunities that the forest sector should position itself to take advantage of and in a very professional manner.
- Many trees are coming up on farms. Many household needs of forest/tree nature are met this way.
- Many African economies are growing; democracy and good governance are becoming a way of life in many countries.
- Increased global recognition and support to sustained supply of international public goods and services from forests.
- The African forestry stakeholders are gradually coming together and speaking with one voice on many issues.

All these combine to create a favourable environment for forestry business. There is therefore a potentially favourable future for African forestry.

There is no information available on the scale of funding needed to address the challenges confronting the African forestry sector and taking advantage of the opportunities in the sector. It is clear that much more funding than is currently being provided to the sector is needed to move forest management on the continent away from unsustainable to sustainable practices; and eventually increasing the sectors contribution to socio-economic development and protection of the environment. Increased funding per se is not sufficient to address the challenges and the opportunities. Increased levels of funding should be accompanied by sustained political will and commitment; incentives to attract local communities, the private sector and other interested players to participate in forest development, management and utilization; and strengthening of forestry and related institutions at all levels (local community, private sector, government and other players). All these have to be done within a conducive policy and legal framework that supports sustainable forestry management in Africa.

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CURRENT STATUS AND TRENDS OF FOREST MANAGEMENT IN TROPICAL AFRICA

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Abstract

A significant extent of African forests continues to be destroyed and the remaining managed improperly resulting in considerable deforestation. More efforts are needed to quantify the social benefits of the forest, to define their ownership and to introduce economics into long-term forest management planning for more realistic decision-making and projection especially by the private forestry sector. The collection, analysis and reporting of forestry information needs to be intensified. Progress, however, is being made as the area of forest under a management plan has slightly increased from previous years. Other positive changes are noticeable in the management, conservation, protection and sustainable use of Africa's forests as many countries have started to take significant steps in the forestry sector through institutional reforms, enhancement of political awareness, intersectorial and international dialogue and the exploration of new opportunities for goods and services from the forests rather than concentrating solely on the harvesting of timber. Yet the challenges facing sustainable forest management are still very great in Africa; some examples include an increase in logging intensity without a significant improvement in the quality of the operations; high levels of illegal logging; weaknesses of community-based forest management initiatives, reduced participation of minority groups in the benefits of forest management, a serious lack of trained forest technicians, and above all a worrying scarcity of information, statistics and data in general about African forests to name a few. This paper documents the current situation of forest management in Africa based on internationally recognized criteria and looks at its trends and tendencies relating to socio-economic, institutional, financial and technical aspects and mechanisms for promoting better forest management practices within the framework of national forest programmes. It also highlights the needs to consider ecological principles when planning forest management.

Introduction

The most ecologically and endangered ecosystem of the world is Africa's 500 million hectares of tropical forest. This resource is disappearing at a faster rate than any other, creating international concern but apparently less at national level. According to FAO *et al.* (2005) annual global deforestation in the tropics amounted to 14 million ha during 1990-2000 against 13 million ha during 2000-2005. These figures show that the rate of global deforestation is decreasing; however, the total area deforested is still significant.

In most cases the deforestation and degradation of the tropical forest is the result of non existent, overlapping and sometimes contradictory agricultural and forest policies. However, poor forest management planning and implementation may very well be the main cause of the destruction of the resource. It is common to see forests being 'managed' under a plan, when in reality such plan is usually taken as an authorization to cut trees. Once the extraction of the logs is completed, forest management activities are likewise discontinued even though most plans prescribe post-harvest silvicultural activities; in practice these consist of the establishment of permanent sampling plots to estimate future volume growth. Unfortunately, often these are abandoned after a few years of measurement.

Current situation of forest management in tropical Africa

Progress towards sustainable forest management (SFM) is not easy to assess unless there are common harmonized grounds and definitions of what it really means. This led to the intensification of efforts by regional and international processes, which resulted in the development of the following criteria for forest management: extent of forest resources, biological diversity, forest health and vitality, productive and protective functions of forests, socio economic functions and a legal, policy and institutional framework (FAO 2003a). Most new global assessments and reporting on progress towards SFM are based on some of these criteria.

Extent of forest resources in Africa

A forest resources assessment report (FAO 2006) sets the extent of forests in Africa as 635.4 million ha or about 16.1% of the world's forest cover. Other wooded lands account for 406 million ha or 29.5% of the total. Western and central Africa, eastern and southern Africa report a higher forest cover than that of northern Africa, with 277.8, 226.5 and 131.0 million ha of the total forest area, respectively. Gabon is the country in Africa with the highest forest cover: 84.5% of the total land area.

Deforestation has taken its toll of Africa. The calculated annual rate (1990-2005) was 4.4 million ha, i.e. -0.64%/year. Between 2000-2005 the rate decreased to -0.62% per year or 4.0 million ha. The improvement may be due to the fact that by 2005 the extent of productive forest plantations in Africa was estimated at 10.8 million ha, or 2.5% of the total forest area.

Biological diversity

Timber production continues to dominate the use of forests. However, consumers keep demanding other products, uses and forms of forest life. Assessing biological diversity is not easy. Often estimates of this criterion are based mainly on parameters related to primary forests, where the richness of diversity is found, and to conservation and protected forests. It is estimated that Africa has a total of 37.7 million ha of primary forest; this represents only 2.3% of the world's total primary forests and 8.7% of global total forest area. Gabon has the highest percentage of primary forests in Africa with 81%.

The current area of forest designated for conservation of biodiversity in Africa is 38.8 million ha (FAO 2006) representing 3.75% of the global area set aside for conservation and 33% of the total forest cover of the continent. Up to 2000 the annual change rate of designated areas for conservation was 0.2% per year increasing to 1.8% during 2000-2005. Native tree species richness is high in central Africa, particularly in Madagascar, yet the percentage of threatened tree species as compared to the total number of native tree species is around 7%; the highest being in eastern and southern Africa.

Forest health and vitality

Several criteria can be used to assess forest health and vitality, such as defoliation, post-logging woody debris, invasive tree species and pollution; but technically these are difficult and expensive to measure. Most African countries lack the technical know-how, equipment and financial resources to establish long-term programmes to assess these criteria. Consequently, monitoring of forest health and vitality may be restricted to monitoring forest fires, insects and diseases and occasionally damages by animals. This causes a serious lack of good quality information and Africa is not the exception.

A global survey reports that Africa repeatedly registers the most fires (FAO 2007). In 2000 some 2.3 million ha burned in Africa, i.e. 7.7% of the continent and 54% of the global number of fires. Another study by the US National Aeronautics and Space Administration in 2004 registered the same percentage for 2000. Burning in 2000 was most extensive in eastern Africa (873,840 km^2 or 15% of the forest area), central Africa (539,225 km^2, 13.5%) and southern Africa (677,123 km^2, 11.5%) (FAO 2006).

Chad seems to be the most vulnerable African country to fires. However, annual land use fires seriously affect extensive areas in Angola, Botswana, Democratic Republic of the Congo, Namibia, South Africa, Zambia and Zimbabwe. An essential problem in most countries of sub-Saharan Africa is the lack of prevention programmes and basic knowledge of fire behaviour. Unfortunately, most African countries designate resources for controlling fires rather than to preventing them.

A literature review did not reveal specific data for the area of forests affected by insects and diseases and by invasive tree species in Africa; and, when found, reports were based on few countries making it difficult to make inferences. However, there are reports on the types and behaviour of some forest insects in Africa such as the introduction of the cypress aphid (*Cinara cupressivora*), pine woody aphid (*Pineus boerneri*) and the pine needle aphid (*Eulachnus rileyi*) in eastern and southern Africa. A recently established Forest Invasive Species Network for Africa (FISNA) has started to network with African countries on issues related to invasive forest species. Other FAO web sites give information on the status of some insects, diseases and invasive forest species in Africa.

Productive functions of forests

The productive functions of forests are easier to assess and report by measuring the area designated as productive forest, area under plantations and removal of wood products. Growing stock, including commercial, and removals of non-wood forest products (NWFPs) are also indicators for this criterion. On a regional basis the tendency is to over harvest the forests under a sustained yield production approach: potential production versus volume actually harvested or “equilibrium harvesting”.

The volume of wood products harvested in Africa varies by region: in central Africa, more wood volume is extracted than what is produced standing. In western Africa the ratio can be as much as 200% of the potential including illegal logging. Additionally due to international market demands, logging is commonly concentrated in a few species of known high economic value. In spite of this, the calculated average extraction is around 40 m^3/ha.

In general the area designated for the extraction of wood in Africa is about 30% of the total forest area; the trend decreased by -0.58% per year by 2000 and -0.76% by 2005. This is in part because the area of protected forests has increased.

In 2005, 2.5% of the total forest area of the continent consisted of plantations; these are concentrated in a few countries and are gradually changing people’s attitude towards a more multiple use approach. 51% of the plantations are in eastern and southern Africa. South Africa is among the top ten developing countries with approximately 1.4 million ha of plantations, mainly *Pinus*, averaging 15 m^3 and *Eucalyptus* with 20 m^3 per hectare per year. In western and central Africa 71% of the plantations in this region is found in Côte d’Ivoire, Nigeria, Rwanda and Senegal. Except for northern Africa, all the other regions of the continent show an increase in productive forest plantations, yet some progress in the establishment of forest plantations is reported in Ethiopia, Morocco and Sudan.

Wood removals in Africa are among the highest in the world with western and central Africa leading the figures (661 million m^3 in 2005). The trend has increased from 499 million m^3 in 1990 to 661 million m^3 in 2005. 88.5% of removals constitute firewood and only about 12%

is industrial round wood. Madagascar is the only country in Africa that reported a decrease (FAO 2006).

Although the importance of NWFPs is recognized, data concerning volumes of removals are rare or unreliable. In Africa this category usually includes the removals of live animals, hides and skins, trophies, wild honey and wax. Bush meat is another important NWFP but statistics are also not readily available.

Protective functions of forest resources

Forests influence climatic conditions. They protect against wind, help reduce erosion, serve as pollution filters and protect water sources. Statistics for Africa on this criterion are found for western and central Africa but are generally scarce. However, 4.6% (20.8 million ha) of its total forest area in 2005 was designated primarily for protection; this trend has remained steady since 1990.

Protective functions of plantations are also recognized. According to FAO (2006), Algeria and Sudan were among the 10 countries with the largest area of protective forest plantations. In general, the area of plantations for protection in Africa has increased since 1990 (1.9 million ha) to some 2.4 million ha in 2005 with the higher increase found in northern Africa.

Socio-economic functions

Three parameters commonly used to quantify these functions include: value of removals of wood and NWFPs, employment in forestry activities and ownership of the forest. Others include the area of forests designated for social services and for the extraction of firewood but these are usually not recorded or not adequately reported.

Globally firewood accounts for US$7 billion, or 11% of the total world value of removals. Round wood amounted to US$57 billion in 2005. In Africa the income from industrial round wood removals has been on the rise since 1990 (US$999 million); in 2000 and 2005 those figures more than doubled to US$1826 and US$2361 million, respectively. Africa shows the third highest income among all continents from NWFPs but with a small steady increase during 1990-2005 (US$847 to 897 million).

The number of persons employed in forestry activities is also another important socio-economic parameter but figures are either difficult to find or unavailable for Africa. Yet information in FAO shows that in Africa in 2000 some 870,000 person-years' were employed in the production of primary wood goods, guides in parks and safaris. South Africa is the largest industrial round wood producer in Africa employing 60,000 people plus up to another 50,000 in the secondary products sector (Barklund and Teketay 2004).

Private forest ownership in Africa is still unclear and in most countries forests are public domain and government controlled (FAO 2006); many still belong to local communities. In South Africa private ownership of forests is one of the highest in the continent with around 37% and the extent of public forests is more than 62%. In some cases user and customary rights, permits to hunt and to collect dead wood and NWFPs are leased by the state to indigenous communities and user groups. The trend from public to private ownership is positive but slow; Ghana was once owned by traditional communities and indigenous groups and now is almost entirely government owned (Repetto and Gillis 1988).

Not everything is bad: forest under a forest management plan

ITTO (2006) reported that about 14.2% of Africa's natural forests have a management plan of which only 6.1% are "sustainably managed". This indicates that there are cases of forest management in Africa that are positive; from these good forest management experiences can be drawn, but little is known about them outside their context mainly due to the lack of funding to document and share them with others.

Forest management in Africa is changing from timber harvesting, as the main objective, to a multiple use approach. A study identified and described 14 cases as exemplary (FAO 2003b), which are an encouraging step towards SFM in Africa. One conclusion drawn from the study is that after decades of implementing forest management exclusively for timber, multiple use forest management is becoming increasingly popular. Up to then, management models had generally failed to incorporate other forest products and services. In addition, only in the last decade, communities and indigenous groups in Africa have gained legal access to large tracts of forest. This has created interest among communities, governments and other stakeholders in promoting this new approach.

Some African governments are trying to implement better forest management by introducing reduced impact logging practices but with questionable results (De Blas and Ruiz Pérez 2008). Many projects also have developed "best management guidelines" and manage their forests using software, developed by them, which may be used with smaller electronic devices, becoming good tools to help implement forest management. Concessions of larger tracts of forests, especially those owned by governments and practiced in some parts of Africa, can substantially help improve forest management but better regulations are necessary (Karsenty *et al.* 2008).

Tendencies and perspectives of forest management practices in Africa

In the more developed countries a positive attitude towards forestry continues to grow especially in respect of forest industry, as their population is convinced it generates welfare for the livelihood of all. Unfortunately, one cannot say the same for other parts of the developing world. Forest management in Africa continues to be under scrutiny by the world population. Its results and effects are continuously questioned and is commonly considered a destructive activity and not socially acceptable. The public opinion is partly correct as in most tropical countries officially approved forest management plans are not fully implemented and continue to be seen just as a “permit to harvest”.

According to ITTO (2006), 27% and 32%, respectively, of all natural production forests and plantations in the permanent tropical forest estate have a management plan. But only about 7.1% of the world’s permanent total natural production forest estate is managed sustainably. To improve that figure, many countries have reviewed their forest management plan policies and have simplified plans for improving forest management.

International organizations, as well as the donor community, continue to devote a considerable amount of funds to knowledge building and sharing of forest management in Africa. In an attempt to fill gaps in information sharing, the “Knowledge Reference Data Base” of FAO houses several hundred case studies of SFM available on the Web.

Governance and participation have become important issues in achieving SFM. For example, in an attempt to apply the principle of “governance”, forest authorities of Ghana and Togo have given indigenous people and peasant communities the opportunity to manage their own forests. To make this more effective, decentralization of forest administration is necessary but the lack of technical skills and financial means on the part of the communities and forestry administration, along with not clearly defined forest policies, continue to be a problem to the detriment of SFM.

The need to find extra funding and/or incentives to help reduce management costs, and consequently make the activity more attractive, has resulted in a slight increase in certified forests in Africa. In 2003 Africa had 1.6 million ha certified (Barklund and Teketay 2004) i.e. 4% of the world’s certified forests; today it has 1.5 million ha. South Africa registers the highest. An estimated 1.48 million ha or 2% of the natural forests with a management plan are certified (ITTO 2006). It is expected that certification in Africa will continue to be a “catalyst for change” and incentive for good forest management.

There is limited information on the “economics of forest management” and not only on harvesting costs as is often the case. Forest management is commonly out-competed by other land uses and thus it is often assumed that it “does not pay”. This is difficult to assess, as in most cases production, mainly timber, is done based on growth increments of the remaining forests and not necessarily on economic projections over several rotation scenarios. This indicates that there is an urgent need to put more economics into forest management in order to be able to determine over a long period whether the activity is sustainable or not.

Payment for environmental services is another scheme for financing forest management but this practice is more commonly applied in the establishment and management of planted forests. However, some incentives do apply for the management of the forest itself. This modality has been practised in various countries for several years and the changes are noticeable. Exemplary cases of this modality are found in Maloti Drakensberg Bioregion between South Africa and Lesotho, in Susumua and Shapole (Kenya); in Bwindi and Mgahinga (Uganda) and Fouta Djallon (Guinea). But accessing those funds is difficult; it is also hard to estimate how much has been granted in Africa (Holopainen and Wit 2008).

"Carbon markets" could be a partial answer to complementing the financing of forest management but the level of understanding of the protocol is rather low among stakeholders. Designing projects for funding under the scheme has proven to be difficult, financial risks may be involved and there is a lack of understanding of legal implications for CDM projects. Extensive training is needed if this scheme is to be effective in the future in Africa. These can be the reason why Africa accounts for only 3% of CDM projects (Holopainen and Wit 2008).

The lack of legal access to forest land, the high value of some timber species, reduced capacity of forestry administrations to supervise forest management activities may be the principal causes of illegal logging in Africa. For example, Swaziland has only about 15 foresters to manage the entire country's forest resources; the number of trained forest technicians in Namibia is also very low. In general there is a decrease in the number of forest technicians in Africa (FAO *et al.* 2005). Some African countries have tried solving illegal logging by declaring logging bans or promoting boycotts to the trade of tropical timber. Neither of these seems to work as in most cases the bulk of the timber harvested is consumed at the national level. Cameroon and Liberia have designed methodologies to monitor the movement of logs from the forest up to the export yard; Liberia has developed its own reduced impact logging guidelines. However, the bottleneck continues to be the high costs of the equipment and machinery needed for reducing environmental impacts and the lack of trained personnel to implement such guidelines.

The latest issue influencing forest management is climate change. Countries now are faced with providing answers to questions such as "what needs to be done for forestry to respond to climate change?" Providing answers to new demands requires that forest planning and management be implemented with the participation of all stakeholders and that large areas may have to be set aside untouched for conservation and protection. Planted forests for landscape restoration, rehabilitation and protection have been increasing but need to be augmented as a possible solution to climate change mitigation. A recent international meeting on climate change, forest management and health implies that this subject will need to be addressed also by African countries.

South Africa, Burundi and Mauritania have embarked on the development of national guidelines for planted forests and their adaptation to national overall socio economic, environmental and political conditions. Such guidelines are important to help countries introduce changes in reforestation policies, design strategic and economic planning, train the general public on the benefits of plantations, network for intensive tree planting and identify ways to involve all stakeholders in reforestation programmes, to give a few examples.

Forest fires influence forest management considerably. Although this practice continues to be used mainly for agricultural purposes, unfortunately the end results over the years is land use change. Efforts need to be made to teach users that fires can be an "environmental friendly" tool in support of forest management. National guidelines for fire management are necessary to help curb the area burnt annually. Networking for the proper use of fire and the establishment of international alliances for supporting initiatives by less developed countries in preventing forest fires is a means to reduce their incidence. Examples of cooperative agreements need to be enhanced, for example between networks like AfriFireNet and other topical networks and partners such as the Global Observation of Forest Cover/Global Observation of Landcover Dynamics - Fire Mapping and Monitoring Regional Southern Africa Team.

A vision of dealing with forest management is through a landscape and ecosystem management approach. This approach looks at the entire surroundings and the effects that forest practices can have on the landscape and on the livelihoods of the communities. Model forests – with their regional coverage concept and partnership approach – can be an answer to promoting participatory forest management. At present some 40 model forests have been established, representing approximately 20 million ha. Cameroon is the only African country with pilot model forest sites in Campo Ma'an and Dja and Mpomo.

Much needs to be done on the social aspects of forest management. Working conditions for labourers, especially in harvesting and sawmilling operations in general, are not appropriate: training, leisure facilities, proper working and protective clothing and job security in most operations are non existent. Most logging camps lack good quality food, running water, dormitory facilities and bathrooms.

Tree ecology has received limited consideration in forest conservation and management decisions in some countries. Consequently, several cases of forest management in the tropics are being seriously questioned and in some cases even certification licences are being rejected (Mount Elgon, Uganda). It is essential to define new practical silvicultural recommendations based on ecology with the aim of maintaining productivity (Peña-Claros *et al.* 2008; De Freitas and Pinard 2008).

Reaching sustainability of forest management is not only a technical matter. Much needs to be done in the political arena by continuing to participate in international discussions such as in UNFF, CBD, CITES and FAO's forestry commissions. Unfortunately, most African countries lack the financial means to participate, thus missing out on important discussions that affect forest management. Such debate should continue with all stakeholders and the more developed nations should facilitate the participation of poorer African countries.

Conclusions

Forest management planning and policies are hampered by the lack of quality forest data as in some African countries where often information is not reported maybe because they do not have it or do not see the importance to share it. Reporting in itself requires not only the necessary means and the know-how but also a commitment to share the information with the national and the international communities.

However, progress is being achieved in this respect as several African countries have taken the lead to obtain and share such information by strengthening national forest programmes. Cameroon, Republic of Congo, Kenya and Zambia have carried out national forest assessments through which countries get information not only on tree population, biomass and species distribution but also on social and economic aspects of forests such as who is living in the forests and what uses are being made of the resource. Angola, Burkina Faso, Cap-Vert, Chad, Guinea Bissau, Mali, Niger, Nigeria, Senegal, South Africa, Tanzania, Gambia, Uganda and Yemen have also seen the importance of these assessments and are planning to do their own assessments.

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BEYOND TIMBER: MAKING MULTIPLE –USE FOREST MANAGMENT A REALITY IN CENTRAL AFRICA

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Abstract

Multiple-use forest management is considered by many as a preferable alternative to single-use (generally timber-dominant) management models. In the Congo Basin, integration of timber and non-timber forest resources plays a key role in the subsistence and market economies of rural communities, enhancing their well-being and reducing economic risk. This is however largely happening as an informal sector economy. Managing for multiple use in "legal" designated land-use types (industrial logging concessions, protected areas or cash-crop plantations) appears hampered by the spatial overlap of different interests and bargaining power, the multiple-uses of some favorite timber species, inadequate institutional support, inappropriate policies and incentives, poor law enforcement and unclear (or at least unrecognized) tenure and use rights. This paper explores the main land-use and management models in Central Africa. Most of the current land-use types and associated management models focus on only one or two goods or services in one management unit while, for the most advanced, trying as much as possible to reduce disturbance and degradation of the other non-managed forest goods and services. The only 'true' multiple-use management system appears to be traditional shifting cultivation but this is not a forest land use and it induces important changes in the flora and fauna. A few promising but yet 'unfinished' examples of multiple-use management models do exist. We contend however that true multiple-use could be realized through new innovative land-use units, integrated production and conservation territories, allowing a spatial cohabitation of the interests of local people, conservation proponents and extractive industries in the same land-use unit.

Introduction

Multiple-use forest management (MUM) for timber, non-timber forest products and environmental services is considered broadly by many as a preferable alternative to single-use (generally timber-dominant) management models. MUM implies more equitable strategies of satisfying the demands from multiple stakeholders, and a more benign harvesting approach. It should add more value to forests and make them more robust to conversion. It has become a common and prime management objective under the sustainable forest management (SFM) paradigm (Garcia-Fernández *et al.* 2008). Its implementation in the tropics has however been lagging behind expectations.

In the Congo Basin, integration of timber and non-timber forest resources plays a key role in the subsistence and market economies of rural communities, enhancing their well-being and reducing economic risk (Ndoye and Tieguhong 2004). This is however largely happening as an informal sector economy. Managing for multiple use in "legal" designated land-use types (industrial logging concessions, protected areas or cash-crop plantations) appears hampered by the spatial overlap of different interests and bargaining power, the multiple-uses of some favorite timber species, inadequate institutional support, inappropriate policies and incentives, poor law enforcement and unclear (or at least unrecognized) tenure and use rights.

What is indeed the actual situation in Central Africa? Does MUM exist already? What are the prospects for a wide implementation of this concept?

Congo basin forests are more than timber

The six countries (Table 1) of the Congo Basin (Cameroon, Central African Republic – CAR, Congo, Democratic Republic of Congo – DRC, Equatorial Guinea and Gabon) represent the second largest contiguous block of tropical rainforests after the Amazon Basin. They represent also a significant part of African open forests and woodlands that, though less emblematic, are home of a rich biodiversity and source of many goods and services. The population density averages 23 inhabitants/km^2. About 40% live in cities (32% in DRC, 84% in Gabon) making the rural population density 14.5 inhabitants/km^2 and, generally less than 1 inhabitant/km^2 in dense forest areas. The rural people and in some cases a great part of the urban people rely heavily on forest goods and services for their everyday life. The countries rely overall on natural resources such as minerals and forests for their development but tend to consider forests only as a source of timber or a reservoir of land for alternative land uses like perennial crop plantations (oil palm). Still forests are much more than timber. In Gabon, for example, the estimated annual value of the bushmeat trade is about 40 million US$ (Wilkie *et al.* 2006). Also in Gabon, protected areas cover 2.86 million hectares; if we assume that one hectare of intact tropical forest stocks about 150 tonnes of carbon (IPCC 2006) and a market value of 4.10 US$ per tonne of carbon offset in 2006 (Hamilton *et al.* 2008), then the overall carbon offset value of the Gabonese protected areas would hypothetically be up to 1.76 billion US$ or annually, based on a 25 year cycle (like timber), 70 million US$. These values are to be compared with the value of exported timber products estimated at about 401 million US$ in 2006 (ITTO 2007). Table 2 gives some examples of the economic value of different goods and services extracted for specific total economic valuation studies and highlight the significant value of non- timber products and environmental services. These values should be recognized, and forests accordingly managed for multiple uses.

Current land uses and related management practices

The two principal "legal" land uses in the Congo Basin sub-region (Table 3) are industrial logging concessions (59.5 million ha) and protected areas (44.5 million ha). The most common agriculture system (shifting cultivation) is not easy to detect using low resolution satellite imagery but as a first approximation could be estimated at 30.9 million ha (Mosaic Forest/Croplands of Table 4) and thus represents the third largest land use type (though some areas overlap with logging concessions and protected areas). Community forests exist only in Cameroon (though they are mentioned in recent forestry laws of the DRC and Gabon) and represent around 6,300 km^2. The few significantly sized industrial plantations are the 430 km^2 (CDC website) of the Cameroon Development Corporation (oil palm, rubber, bananas), 260 km^2 of SOCAPALM (oil palm) and the 480 km^2 of Eucalyptus Fibre Congo (EFC) clonal eucalypts plantations (MAG Industries website).

Industrial logging concessions

Out of the 369 allocated logging concessions in 2008 representing 558,828 km^2, 151 (41%) were engaged in forest management (Table 5). The 218 (59%) concessions not yet engaged in developing a proper management plan can safely be considered as having a single use management system, with timber as the sole commodity for an immediate profit, and without long term sustainability concerns.

Most current forest management plans in the Congo Basin are built around a common set of principles and differ only marginally from each other (Nasi *et al.* 2006). Depending on available remote sensing and cartographic documents, a set of base maps is developed and a management inventory carried out to provide an assessment of the timber resource. At the same time additional information (tree regeneration, fauna, non-timber forest products, human activities, etc.) is collected. If sites of particular importance (biodiversity or cultural aspects) are identified during the inventory, specific studies can be commissioned or the sites immediately taken out of the production area and assigned to the protection area of the concession. A study of the socio-economic characteristics of the concession and its surrounding area is carried out to obtain data on the human settlements and of the various forest uses by local people. When all this baseline information has been collected the determination of the specific management parameters for the concession is conducted as a negotiation between the firm preparing the plan, the logging company, the national forestry administration and eventually local authorities. We can characterize such management with optimization for a single good (timber being the only managed good) but with consideration given to the preservation of other goods and services for long term sustainability, in the form of constraints to timber profit maximization.

Protected areas

Not surprisingly, protected areas are managed for protection (though a significant part is neither managed nor protected). About 60% of the forest protected areas belong to IUCN categories Ia (strict nature reserves) and II (national parks); the remaining 40% belong to categories IV (Habitat/Species Management Area) 16% and VI (Managed Resource Protected Areas) 24%. The dominant paradigm (76%) is therefore strict conservation and the only activities officially recognized in these protected areas are research and recreation (eco-tourism). Protected areas in Central Africa are managed for two services (biodiversity and recreation) with consideration given to the preservation of other goods and services.

Shifting cultivation

Shifting cultivation as practiced in the tropics is characterized by a shift between fields rather than between crops on the same field, short (1-3 year) cropping periods alternating with longer fallow periods (4-60 years), cutting and burning of the fallow vegetation at the commencement of each cropping period, and the almost exclusive use of human energy in land management operations (Watters 1971). It creates unique landscapes composed of a shifting patchwork of crop fields, fallows of various ages, secondary forest derived from fallows, and remnants of the original vegetation which appear as a mosaic of forests and croplands on low resolution satellite imagery. The presence of fallows, defined by Burgers *et al.* (2000) as the vegetation and associated fauna occupying land cleared for cultivation but not currently so used, with their associated multiple uses (provision of firewood or non-timber forest products, hunting grounds, etc.) makes shifting cultivation a multiple use management system. This is however primarily an agricultural land use system whose purpose is to fulfil nutritional and income needs of local farmers even if it creates landscapes that could maintain high levels of biodiversity (Finegan and Nasi 2004).

Community forests

Formal community forests exist only in Cameroon with provisions for such land use in the recent forestry laws of Gabon, DRC and CAR. In Cameroon, a community forest is a forest area from the non-permanent forest domain, smaller than 5,000 ha where full use rights to forest resources is granted to a community for a 25-year period. Therefore, community forest status does not carry permanent property rights to the area allocated and is similar to a concession (De Blas *et al.* in press).

Results from a recent survey (De Blas and Ruiz Pérez 2005) show that in the South Province in Cameroon all management plans make an assessment of the NTFP potential but once implemented communities focus on logging production as the main income activity and give up the option to develop NTFPs, because of the high labor cost compared to the benefits. In contrast, the western provinces with high demographic pressure, relatively poorer forests and more organized user groups (honey collectors, carvers, trappers of small mammals, medicinal plant collectors, herders, etc.) are managed for the commercialization of NTFPs. This shows that NTFPs are usually a second-best option compared to timber and are extracted when opportunities are available. However, for some niche products like *Prunus africana* bark, they can yield a substantial income (Ruiz-Pérez *et al.* 2004).

Industrial plantations

These are the epitome of single-use management with generally high intensity management practices, limited diversity and improved planting materials. This does not mean that they are necessarily evil and indeed Eucalypts Fibre Congo is trying to achieve an FSC certification but they represent the single-use end of the single- multiple-use spectrum.

In conclusion of this brief review, most of the current land-use types and associated management models focus on only one or two goods or services in one management unit while, for the most advanced, trying as much as possible to reduce disturbance and degradation of the other non-managed forest goods and services. The only ‘true’ multiple-use management system appears to be traditional shifting cultivation but this is not a forest land use and it induces important changes in the flora and fauna.

Table 1: Some indicators for Central Africa countries

Country	Total area	Population (est. 2008)		GDP/capita (est. 2007)		Forest cover (2000)			HDI (2005)	
	Km^2	(x1000 hab.)	Growth rate %	US$	Growth rate %	Dense forests (x1000ha)	Mosaics (x1000ha)	Open forests (x1000ha)	Value	Rank (out of 177)
Cameroon	475 440	18,467	2.22	2,100	3.3	21,436	7378	10951	0,532	144
C.A.R.	622 984	4,434	1.49	700	4.2	8,227	21395	24746	0,384	171
Congo	342 000	3,903	2.60	3,700	-1.6	25,914	1221	1421	0,548	139
D.R. Congo	2 345 410	66,514	3.24	300	6.3	124,566	22707	53879	0,411	168
Gabon	267 667	1,486	1.95	14,100	2.1	21,190	1006	219	0,677	119
Eq. Guinea.	28 051	616	2.73	28,200	5.6	1,843	312	15	0,642	127
Congo Basin	4,081,552	95, 420		1,201		203,176	54,019	145,250	0.444	161-162

Sources: Total area, Population and GDP: CIA World Fact Book 2008; Urban %: World Urbanization Prospects: The 2007 Revision Population Database,Forest cover: Mayaux et al. *(2003); HDI (Human Development Index): Human Development Report, 2007*

Table 2: Example of estimated economic values of forest goods and services

Forest Goods or Services (in discounted US$/ha or in US$/ha/yr)	General (Pearce and Pearce 2001)	Cameroon (Lescuyer 2007)	Gabon (National Park) (Lescuyer 2006)	Cameroon (community forests) (Akoa Akoa 2007)
Timber	200 - 4,400	560	98	25-78
Fuel wood	40	61	Not assessed	165
NTFPs	0 - 100	41 - 70	3	172
Genetic resources	0 - 3,000	7	1<	Not assessed
Recreation	2 - 470	19	4	34
Watershed benefits	15 - 850	54 - 270	0	998
Climate benefits	360 - 2,200	842 - 2,265	211	632
Option values	2 -12	3	Not assessed	Not assessed
Non-use values	4,400	19 - 32	24	Not assessed

Table 3: Area estimates by country and affectation (logging, protection)

Countries	Land area (km^2)	Designated for protection		Designated for logging	
		Area (km^2)	%[i]	Area (km^2)	%[i]
Cameroon	465,445	37,450	8.05	60,935	13.09
Central African Republic	620,152	76,743	12.37	34,293	5.53
Congo	342,766	35,993	10.50	147,127	42.93
Democratic Rep. of Congo	2,328,225	261,063	11.21	248,276	10.66
Equatorial Guinea	26,730	5,104	19.09	14,375	42.93
Gabon	262,538	28,620	10.96	90,375	34.60
CONGO BASIN	4,045,856	444,973	11.00	595,381	14.72

i:% of land area

Table 4: Area (ha) estimates by land-cover classes and affectation (logging, protection)

Land cover class	Area (x1000ha)	% subregion	Protected (x1000ha)	% land cover class protected	Allocated for logging (x1000ha)	% land cover class for logging
Closed evergreen lowland forest	155,615	38%	18,788	12%	48,168	31%
Submontane forest (900-1500m)	11,192	3%	2,329	21%	153	1%
Montane forest (>1500m)	2,354	1%	787	33%	2	0%
Swamp forest	13,298	3%	1,028	8%	2,857	21%
Mangrove	194	0%	24	12%	2	1%
Total humid forests	**182,672**	**45%**	**22,958**	**13%**	**51,183**	**28%**
Mosaic forest/croplands	30,916	8%	1,300	4%	4,586	20%
Mosaic forest/savanna	54,492	13%	4,987	9%	1,628	3%
Closed deciduous forest	20,682	5%	1,622	8%	472	2%
Deciduous woodland	63,089	16%	6,435	10%	168	0%
Open deciduous shrubland, sparse trees	30,122	7%	4,607	15%	1,078	4%
TOTAL Subregion (Congo Basin)	**404,588**	**100%**	**44,497**	**11%**	**59,538**	**15%**

Source: GLC 2000, FORAF

Table 5: Industrial logging concessions

Country	Logging concessions		MnP in preparation		MnP approved, implemented		Certified for legality		Certified for SFM		No management	
	N	ha	N	ha	N	ha	N	ha	N	ha	N	ha
Cameroon	103	6,074,033	38	1,866,171	65	4,207,862	21	1,722,786	7	558,114	0	0
CAR	11	2,321,844	4	999,435	8	1,739,055	1	195,500	0	0	5	1,096,049
Congo	48	10,833,973	26	4,005,758	3	1,907,843	4	2,183,839	2	834,302	19	4,920,372
DRC	156	22,200,962	46	6,590,628	0	0	3	723,873	0	0	110	15,610,334
Gabon	50	10,027,405	9	1,471,567	9	2,917,888	2	622,399	4	1,813,658	32	5,637,950
Total	**368**	**51,458,217**	**123**	**14,933,559**	**85**	**10,772,648**	**31**	**5,448,397**	**13**	**3,206,074**	**166**	**27,264,705**

Towards an integrated production/ conservation territory

Can we go further and develop true multiple use management for the Congo Basin forests?

The suggestion is to combine (at least) the two major land use types, a logging concession and a protected area with community-based managed areas in one land-use management unit that could become an integrated production/conservation landscape. The overall result would be a protected area inserted in the local economic context and a multiple-use production area sustainably managed ensuring the long term funding of conservation and local livelihoods. This cohabitation would allow defining large territories with a mixed production/conservation vocation optimizing economic potential and long term protection of environmental services.

It is possible to envision a temporal cohabitation with a first logging cycle using the best available techniques followed by a conservation cycle of similar length. This option however may have the following problems:

- It will be more difficult to organize on a temporal basis with cycles of at least 25 years.
- Uses by local people might become problematic during the conservation cycle depending on the land and resource right allocation and on who ‘manages’ the land.
- What will happen to the extractive industry during the conservation cycle?
- Etc.

We thus suggest a spatial cohabitation model of conservation and production where regular income from the production side could be used to help the conservation side. In addition, a well designed spatial cohabitation will allow benefiting optimally from source-sink dynamics for wildlife management

Utopia or possible?

An interesting example of integrated landscape management is found in Guyana. Acting under a mandate from Guyana and the Commonwealth to develop sustainable management of the Iwokrama forest, the Iwokrama International Centre for Rainforest Conservation and Development (IIC) has invested significant capital in surveying and inventorying the Iwokrama Forest resources. Of the total forest area of 371,681 ha, 184,506 ha are designated as a Sustainable Utilisation Area (SUA); the other 186,175 ha being set aside permanently as Wilderness Preserve (WP). The SUA is managed for logging under FSC certification by a joint venture company with private partners and shares attributed to IIC, private partner and local communities. The WP is managed for ecotourism with active participation of the communities. Local communities keep the right to use natural resources within the Iwokrama forest and benefit from employment and economic diversification (for more details consult the Iwokrama website).

In the Congo Basin there are few initiatives of such integrated management for multiple uses; promising but still incomplete in design and institutionally fragile. They depend heavily on external funding and not really achieving integration and multiple uses.

Since 2002, the Congo Basin Forest Partnership (CBFP) has organized its interventions around 11 large landscapes integrating protected areas and other adjacent areas (concessions, customary lands, etc). Most of the work is funded through the USAID CARPE program. After six years however it appears that though the results in terms of conservation are real, there is no true integration of conservation and development through multiple use management. Yet, promising agreements exist between environmental non-governmental organizations (ENGOs) and various logging companies operating in the Dja-Minkébé-Odzala Tri National landscape (Pallisco/WWF, Bordamur/WWF and CIB/WCS). These collaborations have contributed to the mainstreaming of conservation approaches in the logging concession and to the appropriation of biodiversity concerns (mainly linked to bushmeat hunting) by concession managers. Reciprocally it helped the ENGOs to better understand the rules of the game and the constraints faced by forest managers.

In Cameroon, the so-called Operational Technical Units (UTO) are also an unfinished case of integration and multiple use management at the landscape level. The Campo Ma'an UTO is a 700,000 ha area comprising a national park, several logging concessions, a multiple-use area for local people and industrial agricultural plantations. The national park and logging concessions are part of the permanent forest domain, the multiple-use area part of the non-permanent forest domain. The UTO is a decentralized management structure attached to the Ministry of Forests in charge of the national park, the sustainable management of forest resources and to develop an integrated coastal management plan while ensuring participation of local communities to management and coordinating police operation (illegal logging, poaching). A management committee with members from the state, the logging operators and the local communities reviews and approves annual work plans. Most of the activities are financed through GEF funding abounded by oil companies as a compensation for the Chad-Cameroon pipeline.

Is MUM possible in the Congo basin?

In a recent paper Garcia-Fernández *et al.* (2008) conclude that "multiple-use forest management remains a valid management alternative under specifically favourable local context conditions, especially when practiced at the landscape scale, but these conditions are less frequent than commonly assumed" and that "special scenarios with favourable preconditions are required for MUM to work, including a new mindset and incentives to successfully compete with more specialized land-use options".

We believe that in spite of the enormous problems of governance and unclear land tenure or use rights it is possible to develop multiple-use forest management units at the landscape scales gathering local people, conservation proponents and extractive industry actors backstopped by formal recognition at the national level (like in the Iwokrama case).

One could envision (Billand and Nasi 2008) specific charters for these conservation/production territories fostering policy incentives involving both conservation and exploitation players. These partnerships would go much further than existing ENGOs-companies collaborating towards the co-management with communities' involvement of large landscapes while ensuring a local redistribution of the benefits of the production side to the communities and to the protection side. This could be done following several options:

- Wherever possible, try to realize the economic potential of the conservation side (eco-tourism, biological prospection, payment for environmental services, etc);
- Manage and valorize informal sectors like hunting, fishing or NTFP extraction outside of the conservation area for local livelihoods;
- Use part of the income generated by the industrial production side for the management of the conservation area in search of reciprocal benefits (image of the logging sector, certification of management or labelled products, cash for conservation activities or to compensate local people, etc.)

Some minimal enabling conditions have to be put into place for such an integrated approach:

- Some starting funds are needed to cover initial transaction costs either from international donors, from the extractive industry or both). This money should go together with the presence of some coordination platform or agent.
- The willingness for the production sector to engage into certification otherwise there is no valid reason for the industrial operators to go further than the classical timber-based forest management plan approach.
- A political support either proactive (creating specific land-use units, accepting a redistribution or a waiver on royalties from extractive industries) or, at least, neutral (no undue interference from the State).

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AFRICAN FORESTS AND CLIMATE CHANGE: OPPORTUNITIES AND CHALLENGES

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Abstract

Forestry for climate change mitigation and adaptation introduces new opportunities and challenges for sustainable forest management in Africa. Climate change forestry could help provide additional funding for sustainable forest management through carbon and other environmental services markets while reducing deforestation. This presentation examines Africa's performance in current UNFCCC and related carbon forestry mechanisms (Clean Development Mechanism-CDM, Reduced Emissions from Deforestation and Degradation-REDD and other markets) and adaptation. It also reviews conditions necessary for successful implementation of climate change forestry in Africa, including improving Africa's participation in ongoing climate change talks, the need for strategic approaches to planning forestry for climate change, inter-departmental collaboration at national level, the need for better research and technology development and stronger sub-regional action. Lastly, specific sub-regional policy challenges for enhancing the contribution of climate change forestry to poverty alleviation and sustainable livelihoods are highlighted.

Introduction

According to the Fourth Assessment Report of the IPCC (IPCC 2007) Sub-Saharan Africa (SSA) is likely to be the most affected by climate change especially in dry, urban and coastal areas. Most countries in SSA are experiencing increasing variability in temperature and rainfall. Climate change is likely to aggravate these stresses as well as create new impacts. Unfortunately, with widespread poverty, slow economic development and low education levels, adaptive and mitigation capacity of societies in the region is low (Boko et el. 2007, UNFCCC 2007).

Little attention has been given to understanding how forestry might contribute to mitigation and adaptation to climate change in Africa. This paper reviews that state of forestry for climate change in Africa. It examines the stakes, what is currently being done and highlights the challenges for enabling sustainable forestry that also adequately serve climate change.

What are the climate change stakes for Africa?

Africa's stakes in climate change can be seen from three main angles. Firstly, climate change brings with it a specific challenge for Africa due to the enormous proportions of the expected impacts of climate change to various sectors of life on the continent. Secondly, besides the enormity of projected impacts, the continent is classified as very vulnerable due to the extremely low adaptive capacity. Thirdly, the current climate change policy architecture provides specific opportunities for Africa to take necessary action to improve adaptive capacity, reduce vulnerability and take advantage of carbon market opportunities.

Cross sectoral impacts

The IPCC predicts that global changes in temperature and rainfall patterns due to anthropogenic factors would aggravate current impact of rainfall variability in SSA and drive changes in forests and land use management with varied impacts on other related sectors. These sectors include water, terrestrial ecosystems, agriculture and food security, coastal zones and health (Figure 1).

Sources: Anna Ballance, 2002.

Figure 1: Climate change vulnerability in Africa

Water stress and scarcity is expected to increase with between 75 and 250 million people projected to be exposed to increased water stress (i.e. less than 1,500 m^3 /capita/year) by 2020 (IPCC 2007, FAO 2005). Terrestrial ecosystems would experience vast changes. Climate change is projected to increase semi-arid and arid land areas in Africa between 5-8% by 2080. The IPCC estimates that loss of land to desertification, especially in Sahelian and Southern Africa, would lead to degradation of forests in these areas and consequently about 20-40% of species in the continent would be endangered. Coastal areas in West Africa and the woodlands in East and Southern Africa are particularly threatened by potential sea level rise and increasing aridity respectively. Climate Change induced temperature increases and rainfall changes are expected to reduce yields from rain-fed agriculture by up to 50% by 2020 and net revenues from crop yields could drop by as much as 90% by 2100 in Africa (IPCC 2007). Pressure on Africa's forest resource base is increasing due to climate change induced declining productivity of agricultural land. Declining agricultural productivity is driving extensification at the expense of forests.

In terms of health, spatial and temporal transmission patterns of disease vectors for malaria, dengue fever, meningitis, cholera and others would be altered. For example, previously malaria free highlands in Ethiopia, Kenya, Rwanda and Burundi could experience improved suitability conditions for malaria by 2070 (Boko *et al.* 2007).

Peculiar vulnerability

Sub-Saharan Africa is considered the most vulnerable region to climate change owing to a number of factors. First, it is a continent already under pressure from extreme climatic events, and secondly, it is a region facing huge developmental challenges including widespread poverty, HIV-Aids, conflicts and others.

Most of Africa is currently experiencing increasing frequencies and intensities of extreme events such as droughts and floods, and high climatic variability (especially inter-annual variability in rainfall and temperature), with events occurring in new areas. The widespread disruption of socio-economic well-being and famine that is caused by these events and variability would be aggravated by the impacts of climate change.

The many developmental challenges facing the African continent are likely to contribute to and compound the impacts of climate change and also limit the adaptive capacity (ability to cope with) of the region. These challenges include widespread and endemic poverty, weak institutions, limited infrastructure, low levels of education, low levels of technology and information, poor planning, poor access to resources (financial, technological) etc. (UNFCCC 2007, Boko *et al.* 2007).

Benefiting from carbon market opportunities

Climate change is influencing the commoditization and growth in markets for ecosystem services such as carbon sequestration. For example, carbon markets worth US$64 billion in 2007 are growing by almost 50% from USD 31 billion in 2006 with Africa having only about 5% of the market share (Capoor and Ambrosi 2006, 2008). There are two kinds of market mechanisms, i.e. regulated carbon markets within the UNFCCC processes, and voluntary markets. Regulated markets include the Clean Development Mechanism (CDM) and possibly Reduced Emissions from Deforestation and Degradation in Developing countries (REDD) - a mechanism under discussion for the post 2012 climate regime. Current UNFCCC mitigation rules allow for developing country participation in a carbon market mechanism known as Clean Development Mechanism (CDM). The best known example of a voluntary market system is the Chicago Climate Exchange (CCX).

Clean Development Mechanism (CDM): The CDM is one of three "flexible mechanisms" in the Kyoto Protocol designed to accomplish the objectives of the UNFCCC. It makes provision for investment by industrialized countries and industry in projects related to carbon emission reduction and carbon sequestration in developing countries. These projects should contribute to sustainable development in developing countries (i.e. Non-Annex 1 countries) while enabling developed countries (i.e. Annex 1 countries with quantified emission reduction targets) to meet the Kyoto emission reduction and quantified emission limitation targets (Art. 12.2 of the Kyoto Protocol). CDM rules are only valid for the first commitment period of the Kyoto Protocol from 2008 – 2012. Only afforestation and reforestation are eligible during the first commitment period. Negotiations for the second commitment period are underway and the future of the CDM post 2012 is unclear.

Reduced Emissions from Deforestation and Degradation (REDD): During the 13th COP / MOP in Bali Indonesia a decision was reached, on a procedure and guidelines for negotiating modalities for Reduced Emissions from Deforestation and Degradation (REDD) as a potential mechanism for a post 2012 climate agreement (Decision 2 CP.13). It opens the possibilities of including avoided deforestation and forest management as eligible forestry activities during the post 2012 period.

The REDD idea suggests a mechanism in which countries that elect to reduce national level deforestation to below an agreed baseline would receive post facto compensation, whilst they commit themselves to stabilize or further reduce deforestation in the future. Besides a number of proposals put forward for discussions (Achard *et al.* 2005, Santili *et al.* 2005), no specific rules have been agreed for REDD. However, some indicative guidance for engaging in REDD demonstration activities was given in the Bali road map as follows:

- Demonstration activities should be undertaken with the approval of the host Party.
- Estimates of reductions or increases of emissions should be results based, demonstrable, transparent, and verifiable, and estimated consistently over time.

- The use of the methodologies is encouraged as a basis for estimating and monitoring emissions.
- Emission reductions from national demonstration activities should be assessed on the basis of national emissions from deforestation and forest degradation.
- Sub-national demonstration activities should be assessed within the boundary used for the demonstration, and for associated displacement of emissions.
- Reductions in emissions or increases resulting from the demonstration activity should be based on historical emissions, taking into account national circumstances.
- Sub-national approaches, where applied, should constitute a step towards the development of national approaches, reference levels and estimates.
- Demonstration activities should be consistent with sustainable forest management and considers the relevant provisions of the United Nations Forum on Forests, United Nations Convention to Combat Desertification and the Convention on Biological Diversity.

How is Africa doing on climate forestry?

Adaptation - reducing vulnerability and increasing adaptive capacity

African countries can leverage urgently needed climate change adaptation funding through various mechanisms within the UNFCCC. The Stern Review highlighted that the costs of strong and urgent action on climate change will be less than the costs thereby avoided of the impacts of climate change under business as usual (Stern 2006). African countries are already experiencing the impacts of climate change, yet they are poor and have very little adaptive capacity (human, financial and technological). Adaptation to climate change is urgent and costly, hence would put tremendous pressure on the budgets of these poor countries. These African countries would therefore benefit by taking urgent measures to plan adaptation within the context of sustainable development in order to be cost effective and also benefit from current ODA funding for climate change adaptation (UNFCCC 2007)

Only about 24 African countries have prepared National Adaptation Plans of Action (NAPA; www.unfccc.int). Almost all of these plans have been done with the support of the UNFCCC. Few countries, outside the UNFCCC list of Least Developed Countries have prepared NAPAs. Hence, most strategic action on adaptation is donor driven. Implementation of planned adaptation action identified by the NAPAs has been slow to start due to lack of funding and other institutional challenges. Furthermore, few NAPAs articulate the role of sustainable forest management.

Most climate change adaptation activities in Africa are small project-based activities done in specific project areas at sub-national level by several international bodies. Some examples include the IDRC –DFID Climate Change Adaptation in Africa (CCAA) research and capacity building project, the UNDP-GEF community-based adaptation project, Coping with

Drought and Climate Change (in Mozambique, Zimbabwe and Ethiopia), Adaptation to Climate and Coastal Change in West Africa (ACCC) (in Senegal, Cape Verde, Guinea Bissau, Gambia and Mauritania) and Adaptation to Climate Change in Eastern and Southern Africa (ACCESA) - Kenya, Mozambique and Rwanda. These projects cover a wide range of adaptation activities including adaptive capacity, improving resilience and reducing vulnerability.

Carbon forestry

Africa's participation in current climate change mechanisms has been extremely weak. In addition, participation in climate change talks towards a post 2012 climate regime has also been poor. Participation in carbon market mechanisms (CDM and voluntary markets) needs to be improved. Only four CDM forestry projects from Africa are being considered from a list of 37 forestry projects (as at September 2008): one Afforestation Project from Mali and three Reforestation projects from Congo DRC, Tanzania and Uganda respectively. All four projects are at the validation stage hence are a long way from trading carbon credits. However, only one CDM forestry project has received carbon credits so far in the world.

Regarding voluntary markets, about 60 forestry-based carbon sequestration related projects or planned projects have been identified in Africa (Jindal *et al.* 2008). East Africa is hosting about half of these projects while Central Africa is hosting only three projects. Most of these projects are at planning level with fewer than five projects actually trading or making any form of payments.

Tremendous potential for REDD exists in the countries around the Guinea forests of West Africa and in the Congo Basin (Gibbs and Brown 2007) (Figure 2). In addition, African countries are amongst those with the highest deforestation rates and deforestation by area over the last decade. Between 2000-2005 Africa recorded seven of the ten countries with the largest annual net negative forest change rates with the first five being Comoros (-7.4%); Burundi (-5.2%); Togo (-4.5%); Mauritania (-3.4%); and Nigeria (-3.3%) (FAO 2005). On the other hand only one country was counted amongst the countries with the largest positive annual net forest change, i.e. Rwanda (6.9%) (ibid). Africa also counted six countries amongst the top ten countries with largest annual net loss in forest area, i.e. totalling 2.5 million ha per year with Sudan (-589,000 ha/yr), Zambia (-445,000 ha/yr) and Tanzania (-412,000 ha/yr) leading (ibid).

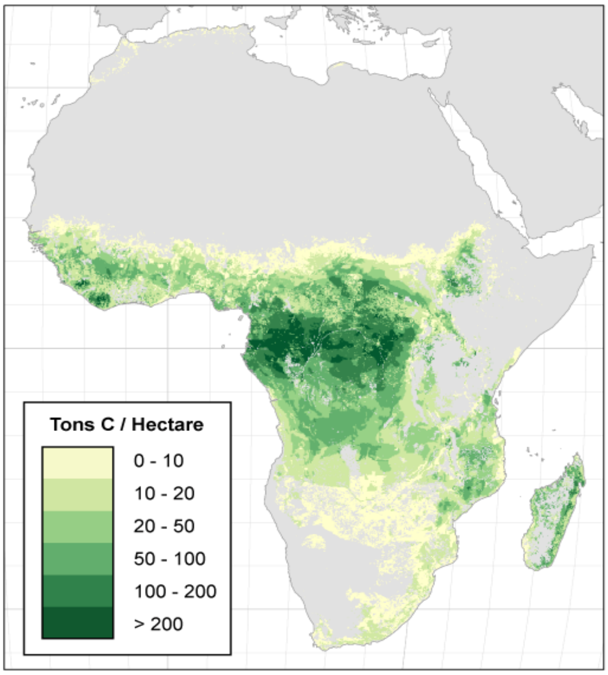

Figure 2: Carbon sequestration potential in Africa (Source: Gibbs and Brown 2007)

Unlike the CDM, a few countries are making some progress with respect to readiness for any REDD mechanism in a post 2012 era. About 15 countries have made an effort to plan for REDD through the development of REDD Readiness Plan Idea Notes (R-PINs) demanded by the Forest Carbon Partnership Facility of the World Bank. Tanzania and DRC are also receiving support from the Norwegian Government and UN REDD respectively to help prepare for participation in any eventual REDD framework. However, many of the R-PINs were done in a hurry and by a small number of "insiders" or consultants. No country has undertaken the kind of concerted REDD planning analysis or inclusive consultation that was held in Indonesia in late 2007.

What are the challenges for climate forestry in Africa?

Improving negotiations

Current bargaining positions and participation in UNFCCC post 2012 negotiations are weak. Most countries are represented by one or two negotiators compared to tens in European or US delegations. The issues being assessed are complex and multi-disciplinary hence delegations need technical expertise on their teams to respond to such complexity as well as large enough teams to attend multiple and often parallel sessions. Hence countries must increase the capacity of the negotiating teams in terms of numbers and the diversity of knowledge and skills involved.

Though a very diverse continent, Africa shares common interests in many of the issues being discussed within the UNFCCC. Yet African countries often negotiate individually with smaller delegations and little technical capacity. African countries stand greater chances if they adopt common position during these discussions. However, there is a consensus that any common position needs to adequately recognize the diversity in interests in the continent with respect to humid forests, dry forests and woodlands.

One challenge in addressing climate change mitigation is to overcome the emerging inequality between dry and humid forest countries. The shift in focus from CDM forestry to REDD seems to be marginalizing dry forest countries with funding for REDD readiness and negotiations concentrating on the humid forest countries. With the exception of Kenya and Zambia, few dry countries have received any direct support for mitigation activities. It is interesting to note that countries such as Sudan and Mauritania feature amongst the highest in terms of areas and rates of deforestation respectively (FAO 2005). REDD projects in drier areas may yield significant adaptation benefits (Verchot *et al.* 2007). The COMESA declaration on REDD during its Ministerial meeting held in Nairobi in November 2008 indicates how relatively drier countries are articulating their interests in REDD by calling for broad landscape carbon stock accounting.

Improving knowledge and technology

The knowledge and technological requirements for understanding and acting on climate change remain a huge challenge for Africa. This is aggravated by the fact that Africa is an extremely data scarce environment in the area of natural resource management (Dalal-Clayton *et al.* 2003). There is general consensus that remote sensing (with appropriate ground truthing) could be the main method for carbon estimation and monitoring (see summary reports of the UNFCCC REDD Methodology workshops held in Rome, Cairns and Tokyo at www.iisd.ca or www.iisdrs.org). Forest degradation might be more expensive to measure. Regarding adaptation, few countries have adequate hydro-meteorological data and know-how to model local climate change impacts (Ziervogel *et al.* 2008). Data infrastructures for forestry and meteorology are not sufficiently equipped for climate change responses in most parts of Africa, yet they need to develop cost-effective methodologies for REDD planning and monitoring.

Countries need to understand the drivers of deforestation in their countries if they want to devise the right policy incentives for REDD. They would also need to understand the opportunity costs of REDD and trade-offs involved in climate forestry - especially relating to how these might affect livelihoods and other development alternatives (Swallow *et al.* 2007, Minang *et al.* 2008a).

Capacity thus needs to be built on the continent to enable an adequate response to the challenges of climate change at multiple levels. National, macro and meso level data infrastructure for forestry, agriculture and land use need to be developed in this regard

(Minang *et al.* 2008b). This would require huge investments in training and research in African countries.

Institutional challenges

Making forestry work for climate change in Africa would require adapting the forestry institutional landscape to the needs and exigencies of climate change mitigation and adaptation. The UNFCCC climate change framework requires institutions for various purposes. National institutions are required to develop national communications on climate change and for promoting and validating CDM projects. More African designated operational entities are required for project verification and certification in order to reduce costs given the relatively high costs of foreign based designated operational entity involvement.

Current proposals for REDD imply that countries might take responsibility for reducing deforestation and degradation and hence would need institutional arrangements to ensure that it happens. Institutions would be required to measure and monitor changes, to oversee demonstration activities, to manage risks such as fires and curb illegal logging and to ensure any payments are equitably distributed to those who contributed to reduced emissions on the ground. These institutions would be needed at multiple levels of government in the country.

Most countries would need to reinforce collaborative action between various ministerial departments. Climate change focal points in most African countries are hosted by Ministries of Environment and often delinked from other key ministries such as forestry, agriculture, energy, planning etc. Given the cross-sectoral nature of potential impacts of climate change in Africa, it is only logical that action on climate change is coordinated and involves all the actors concerned. However inter-ministerial commissions in Africa often face funding challenges and representatives are changed too often (Michealowa 2003, Minang *et al.* 2007). These challenges need to be given specific attention if progress is to be made.

Tackling some of the challenges of climate change such as increased water stress and measuring and monitoring REDD might be optimized at a regional level. A great part of the continent is covered by transboundary / transnational water basins, therefore having whole basin approaches in the management of water issues within adaptation would be helpful. The cost of monitoring REDD might also be very high for individual countries especially regarding the use of remote sensing. These countries would thus benefit from economies of scale in instances where regional approaches are adopted. The Congo Basin satellite monitoring initiative might be an example to learn from.

Policy and legal challenges

Policy gaps and poor policy implementation has widely hampered the development of climate change mitigation activities in Africa (Desanker 2005). The following policy and legal aspects appear important:

- Providing definitions of forest as required by current rules under the CDM;
- Clarifying rights and ownership of carbon and carbon revenues;
- Improving investment environments to enable CDM project development;
- Developing policy incentives for carbon project development; and
- Mainstreaming climate adaptation into development policy.

Most African countries are yet to provide definitions of forest to the CDM executive board, hence projects being submitted from these countries for CDM forestry cannot be considered by the executive board. Countries have to adopt a definition within the parameters of canopy cover (between 10%-30%), tree height (2- 5m) and minimum area (between 0.05 – 1ha) and submit to the CDM executive board to enable advancements in carbon forestry.

Tenure rights to carbon services and revenues from these services remain unclear in many countries. This provides a disincentive for investments at multiple-level carbon forestry activities in Africa. Fear of usurpation of revenues from these activities by government or brokers is a genuine concern for the development of carbon forestry projects. However, there is evidence of *ad hoc* arrangements being made in order to move forward with initiatives. For example, the Greenbelt Movement in Kenya was able to sign an agreement with the government acknowledging community rights to carbon and carbon payments in a bid to secure community ownership rights to ecosystem services remain unclear in Kenya as in most of Africa. While such arrangements can secure rights in the short term, more long term solutions are needed.

Investment incentives for carbon forestry need to be improved. Most carbon forestry projects need considerable upfront investments with payments being offer only upon delivery of certified emission credits. Raising these resources is difficult and specific tax breaks and or subsidies and other incentives should be considered as means of motivating potential investors.

Mainstreaming adoption remains a serious challenge for African policy makers. Current National Adaptation Plan of Action (NAPA) does not sufficiently link with forestry, poverty reduction strategies and other key programs in the country. Many of these NAPAs are yet to be implemented, and activities need to be scaled out in few instances where local projects are being implemented in different countries if significant adaptation objectives are to be attained.

Conclusion

This paper set out to review the state of climate change forestry in Africa. The potential impacts of climate change on Africa, low adaptive capacity and little climate action calls for accelerated and proactive action on climate change adaptation. Africa's participation in current climate change mechanisms have been very poor, with Africa having less that 5% of the carbon market share.

Africa stands to benefit more by embracing and utilizing current opportunities within global climate change architecture. For this to happen, Africans must adopt proactive and strategic approaches to climate change. Important conditions for achieving success need to be addressed as part of the strategic approach. These include, improving their negotiation skills to cater for the diverse interests of each sub-region, building knowledge, technology and skills, improving the climate change institutional infrastructure and the policy and legal frameworks for climate change. These challenges show that improving the political economy of climate change forestry is as important as the technical challenges and must both be addressed with sufficient attention.

Even more important for enabling significant contributions from forestry to climate change mitigation and adaptation, is the necessity for Africa to recognize and adopt a new sustainable forest management paradigm, i.e. one that uses a business approach capable of fulfilling the certification requirements for CDM and/or any eventual REDD mechanism, while recognizing the role of forests in poverty alleviation and development. Such a paradigm would best operate by combining the provision of carbon, water and biodiversity services in order to optimize profitability. Africa lags behind Asia and Latin America in exploring the combined opportunities that climate change, energy and environmental service markets offer (Ferro 2007, Jindal *et al.* 2008). Africa needs to take quick action in this regard.

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Forest disturbance and recovery processes:

DISTURBANCE AND RECOVERY IN NATURAL FORESTS AND WOODLANDS IN AFRICA: SOME CONCEPTS FOR THE DESIGN OF SUSTAINABLE FOREST MANAGEMENT AND REHABILITATION PRACTICES

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Abstract

The general perception of people is that disturbance is bad and should be avoided. Yet, disturbances at different scales are a natural part of all vegetation formations. Species, the biological components of all vegetation types, are adaptations to different disturbance regimes, and form part of and have their optimum development in different recovery stages of the vegetation. Hence the total biodiversity of a particular vegetation formation depends on the maintenance of the different disturbance-recovery processes in that vegetation. Human activities in a forest simulate the natural disturbances to which that natural forest system and its components are adapted. However, different scales of disturbance (disturbance regimes) require different recovery processes and therefore different periods of recovery towards the original condition of the forest prior to the disturbance event. Our general perceptions and actions in forest management and rehabilitation indicate that we often ignore the basic ecological understanding that is required to manage the forest systems sustainably. This paper conceptually compares the natural and human disturbances at different scales, and the associated recovery processes, from small damage to part of one tree to total removal of a forest and the substrate on which it was growing. Two examples are used to demonstrate what kind of management interventions would be required to ensure recovery of the resource and the system in timber harvesting. The concepts used have implications for all our management activities in natural forests and woodlands.

Introduction

Many people perceive that a disturbance is bad, consider it as synonymous with degradation, and think that it should be avoided or prevented, particularly when they talk about natural forests. Think of the images we see on TV, in newspapers, or even in real situations, of the impacts of resource use (timber harvesting, cutting of poles, bark harvesting, charcoal production, traditional slash-and-burn agriculture, mining, etc), fire, plant invasions, and infrastructure developments (road construction, power lines, residential developments, settlements), i.e. issues that many people consider as very bad for the natural forests/woodlands. How should we think about or evaluate different scales of timber harvesting operations in a forest? People have very general perceptions around forest management issues, such as

- African forests are declining.
- We need to protect forests by all means.
- Fire is a major cause of forest destruction and should be stopped.
- Slash-and-burn traditional agriculture is a major cause for forest loss.
- Alien invader plants threaten forests.
- Harvesting of timber and other products from forests cannot be managed sustainably.

Maybe such generalized perceptions, responses and actions are a reflection of the status of our understanding of how natural forest and woodland systems function and of the ecological processes that underlie and maintain forest biodiversity and productivity. Maybe we have to think beyond our fixed and often emotional mindsets.

Disturbances at different scales are a natural part of all types of vegetation, and also of natural forests and woodlands. A forest is not a museum piece – it is actually a very dynamic system to have survived some severe landscape and habitat changes over millions of years! Human activities in a forest simulate some kind of natural disturbance to which that natural forest system and its components are adapted. It is possible that what looks good is not always ecologically good, and what looks bad may in reality be good, at least for some components of the forests. Our challenge is to determine for ourselves what criteria should we use for an objective assessment of each situation - visual appearance of what we perceive as good or bad, or mode and rate of recovery of affected components?

Every time I am confronted with such situations of apparent forest disturbance and degradation in the real world, I ask myself: Is this acceptable or bad? If it is bad, how bad? Why? Can it be restored? Is human resource use always bad? Or is conservation always good? I suggest that we have to differentiate between perceptions and objective assessment, without taking out the emotions that the forest environment generates within the minds of people. In this paper I describe how I perceive a disturbance and then I try to give perspective to three questions that often cross my mind when I have to deal with sustainable forest management:

- What disturbance-recovery processes form part of this forest/woodland system and how did they shape the species and appearance of this woody system?
- What multiple-use forest management systems will simulate the natural processes that would help me to maintain the natural diversity and productivity of this system when I harvest forest products and use the services that the forests can provide?
- Is it possible to rehabilitate natural complexities (mixed-species, mixed-age) in degraded forests?

What is a disturbance?

A disturbance is a discrete event (volcanic eruption, fire, browsing, tree fall, branch break, etc.) that changes the species composition, the looks (physiognomy/structure) and/or physiological processes and resources, such as light, temperature and nutrients, in any vegetation system. Many disturbances happen but we do not even know about them. Others leave a long-term scar in the biological components which experience such an extreme event, or the landscape. A disturbance operates in a specific regime (frequency of recurrence, area of impact, and intensity of change). Frequency can mean dry/wet season sequences (annually), drought/flood intervals (decades), extreme fire/frost events (centuries); long-term climate cycles (10^5 years); and sporadic plate tectonics (10^7 years). Extremes in all these types of change occur very infrequently, such as Tsunami floods or earthquakes or cyclones/hurricanes, or black frost. The area or spatial dimension of a disturbance can have nested levels such as at level of the individual, a population of similar individuals (species), a community of different species, a landscape of different communities, and so on. Intensity of impact may relate to the season of its occurrence or duration of the event.

We generally have three categories of a disturbance: a non-event (NE) if the frequency or intensity is too minor to elicit a response; an incorporated disturbance (ID) if the entity is adapted to the scale of a disturbance event which then becomes necessary to maintain the entity in its present state; or a disaster (D) if the scale of the disturbance forces the entity into a new state (Hansen and Walker 1985). The frequency of such disasters is likely to occur within the life cycles of successive generations and increases the fitness of the entity through natural selection. The entity could be an individual, a population, a community, an ecosystem or the landscape. It is therefore necessary to categorize a disturbance in relation to the level of the entity. For example, a disaster at the population level may be an incorporated disturbance at the community level and a non-event at the ecosystem level.

The interaction between the regime of a particular type of disturbance and the habitat/site within which a suite of species live, determine how the species adapt to survive in that particular environment. This process of interaction and adaptation contributes to the vegetation and biodiversity patterns we see in the landscapes around us; the main type of disturbance becomes the driver of the system. The evergreen forests are generally driven by shade-tolerance of the different species as they have adapted to gap size to become either shade-tolerant or light-demanding. The deciduous woodlands are generally driven by tolerance to fire in the dry season to become tolerant or intolerant to fire, with adaptation to grazing/browsing becoming an important secondary driver. The dominant species represent adaptations to different disturbance regimes as shown by their suite of different growth/life forms such as trees, shrubs, herbs, etc., their different kinds of bark, different kinds of leaves, different kinds of fruit/seed types, etc. The suite of life/growth forms in a tropical moist forest is different from those in typical warm-temperate Afromontane evergreen forests or dry deciduous woodland. Tropical moist forest generally has smooth surface barks when compared to the generally rough barks of fire-adapted woodland trees. Tree fruits are often large and fleshy in tropical moist forest, small and fleshy in warm-temperate evergreen forests or dry and hard in dry deciduous woodland. Further, the impact of a disturbance may vary depending on its regime, the species that form a dominant part of the particular system and their adaptations. We may therefore see grassland, shrubland, thicket, woodland and forest in different zones all in the same area, or different communities in the same forest.

Disturbances at different scales are a natural component of all vegetation formations. The species (biological components) of all vegetation types therefore generally represent adaptations to different disturbance regimes, and also form part of different recovery stages of the vegetation. The total biodiversity of a particular vegetation system therefore depends on the maintenance of different natural disturbance-recovery processes in that vegetation to which the different component species are adapted to. If we totally protect a system, we may lose important biodiversity components of the system. We therefore need to understand the dominant disturbance-recovery regimes of the different evergreen forest and deciduous woodland systems in Africa, and how they determine their floristic and structural composition, and their stand dynamics (changes).

Natural versus human-caused disturbances

All/most human activities in a forest simulate some natural disturbance to which that natural forest system and its components are adapted. It is therefore necessary to understand to what natural disturbance regime our resource use activities relate and what response could be expected. In the following paragraphs the different human activities at different entity levels are assessed by the category of disturbance (NE, ID or D) and compared with similar natural disturbances.

i) Human disturbances at individual level (parts of a tree). This may include the harvesting of bark or roots for use as medicine, food, fibre or construction, or branch pruning or cutting of one of several stems in a multi-stem tree or shrub. Similar natural disturbance events may include bark damage by branch/tree falls, elephant or porcupine or fire, or branch or crown breaks caused by strong winds. The impact of the disturbance would depend on the species and severity of damage. For example, some species such as *Rapanea melanophloeos* and *Parinari curatellifolia* easily die (disaster) from bark harvesting, but for other species such as *Ocotea bullata*, *Prunus africana* and *Pterocarpus angolensis* bark harvesting would be an incorporated disturbance (quick recovery of the wound through bark edge or sheet regrowth) (Geldenhuys *et al.* 2007). At the population and higher levels such a disturbance is generally a non-event, depending on the number of trees affected.

ii) Human disturbances at the population level (whole tree[s] of one species). This may include single or group harvesting of trees of specific species for timber, poles and/or firewood, or protection of a forest without disturbances for light or fire demands of key species to enable their regeneration. For example, changing of the fire regime towards protection in Zambian Undifferentiated Woodland in western Zimbabwe prevented tree regeneration and caused crown die-back of mature trees of the fire-tolerant *Pterocarpus angolensis* but facilitated abundant regeneration of the fire-sensitive *Baikiaea plurijuga* (CJ Geldenhuys, personal observation, 1975) Or timber harvesting caused water-logged conditions that caused the group die-back of *Ocotea bullata* in the Southern Cape Afrotemperate forests (Lübbe and Geldenhuys 1990). Natural disturbance events may include insect pests or fungal/bacterial disease causing crown dieback of specific species, selective damage or push over of trees of specific species by animals, and windfalls and water-logging (from floods) of sensitive species. The impact of the disturbance would depend on the species and the number of trees affected. It would be a disaster if many small and big trees of a species are lost or if the conditions are not suitable for the regeneration of specific species. It would be an incorporated disturbance if the species regenerates well from seed and/or from sprouting. It is usually a non-event for the population, community or ecosystem if single/few trees are dead, dying or harvested, and the degree of stand structure change.

iii) Human disturbance at <u>community level</u> (different tree species). This occurs during uncontrolled, over-use of resources for different needs: timber, poles, firewood, bark medicines and fibre, or insensitive group-felling of trees of several species during timber harvesting, or impacts of invasive alien plants (destroying grassland but nursing establishment of shade-tolerant forest species) (Geldenhuys 1997, Loumeto and Huttel 1997). Natural disturbance events may include windfalls from strong wind and cyclones/hurricanes, lightning (with no fire) or wild fires (only kill the trees). The impact of the disturbance would be a disaster for shade-tolerant species with large gaps, for light-demanding species with small gaps, for fire-tolerant species with fire control, or for fire-sensitive species with frequent fires. It would be an incorporated disturbance if the invader plant stands facilitate recovery of shade-tolerant species, or gaps are of intermediate size. It would be a non-event if the gaps are small (shade tolerant species) or gaps are large (light-demanding species).

iv) Human disturbance at <u>total community level</u> (woody & herbaceous). This happen during uncontrolled and overuse of timber, non-timber and non-wood forest products, clearing forest stands for slash-and-burn traditional agriculture and the preparation of charcoal. Such events benefit the light-demanding and fire-tolerant species of the different systems. In nature similar scale disturbances occur during intense wildfires, lightning with fire (as in Bloukrans Pass in Southern Cape Afrotemperate forests, Geldenhuys *et al.* 1994) and river floods. The impact would be a disaster at the individual and population level for many species, and if the disturbance event is repeated at short intervals. It will be an incorporated disturbance if the changed site is small in relation to the forest canopy height. It could be a non-event if the period of resource use is short with long fallow periods.

v) Human disturbance at <u>ecosystem level</u> (all vegetation and topsoil). This occurs in areas of surface mining (diamonds, coal, bauxite, etc), conversion of forest and woodland to intensive crop cultivation, and high density urban development with clearing all vegetation. Natural disturbance events may include floods with sheet erosion and landslides. The impact would be a disaster with a continued activity, with no corridors provided, or an incorporated disturbance if the land use activity is abandoned or restored with pioneer tree species or suitable invaders, and a non-event if light-demanding pioneer tree species establish on the site.

When we look at disturbances in these different situations we have to acknowledge that all our resource use and development activities simulate natural disturbance events. The important points to consider are that:

- the actions of a disaster to one level may benefit species and vegetation systems at another level. For example, the breakdown of community structures of the mature forest may benefit the populations of pioneer or early regrowth species.
- a disturbance to one level may benefit another component at the same level. For example, the lack of regeneration of pioneer species (disaster for the pioneer species) in a stand of such a pioneer species may benefit regeneration of more shade-tolerant species (incorporated disturbance or non-event).
- a greater disaster of disturbance at the more complex levels (ecosystem to landscape) needs a longer period of recovery of that component/level.
- we need to keep human resource use disturbances and rural developments to the level of a non-event or an incorporated disturbance at the level of a population and community.

Allowable scales of disturbance and recovery in sustainable resource use and development

Understanding the disturbance and recovery processes and rates of change provides the basis for silviculture and sustainable forest management (applied ecology). It is therefore necessary to compare the impact and rate of recovery of what we do in the natural forests and woodlands to what happens with the natural processes. We also need to understand the species we use from these systems: in what kind of system do they grow naturally and productively; under what conditions do they regenerate and become established; how do they respond when they are damaged or cut – do they regrow from seed or from sprouts, and how fast, and how would the bark regrow if damaged by different means? For example, the bark of *Ocotea bullata* regrows well and fast as long as the tree is not ring-barked, and if it is dying it is necessary to cut the tree before it is dead - even if this causes a conflict in the minds of many people (Geldenhuys 2004). If a dying *O. bullata* tree is cut before it is dead, we actually help the tree to survive by reducing the stress on the root system with stored reserves; the sprouting stems on the cut stump grow fast (3 to 4.5 m height in 18 months) because of the established root system; and all the bark and the timber of one cut tree could be used and fewer trees will be damaged.

Silviculture applied as disturbance-recovery ecology of different forest systems in developing forest product harvesting systems

Disturbance-recovery processes and rates of change are the basis for silviculture and sustainable forest management. Species dominance changes from early regrowth stands towards mature forest and our target species have their optimum development and growth in some of these development stages. The appropriate silvicultural system depends on the position of our key species (economically and ecologically) within the vegetation development stages of the disturbance-recovery processes/regimes. We need to focus at the development stage in which our target species develops optimally. The challenge is to develop an appropriate silvicultural management system for the target species within the context of the forest as a whole, particularly when we know very little of the target species in an area with very little or no ecological information.

The forest inventory is an important tool to develop a first approximation of the silvicultural system. The following process should be followed:

1. Classify forest communities and calculate the importance values of species across different communities (biodiversity). This will provide an understanding of the association of the target species with other species in the different communities in which the species is present.

2. Calculate grain of the particular type of forest to understand the scale of the ecological processes (ecological processes underlying biodiversity), i.e. what determines the relationship between the composition of canopy species in the regeneration and canopy of the same stand (Midgley *et al.* 1990, Everard *et al.* 1995, Geldenhuys 1996a). For example, in the gap-size driven Southern Cape Afrotemperate Forest in South Africa, the mountain forests are coarse-grained and the coastal platform forests are fine-grained (Geldenhuys 1996a). In the Mountain forests the composition of canopy species is very different between the canopy and the understorey of the same stand. The canopy is dominated by light-demanding species (*Ocotea bullata and Cunonia capensis*) typical of early regrowth forest, but the understorey is dominated by regeneration and pole-sized stems of the shade-tolerant species that dominate the canopy of the mature fine-grained Coastal Platform forests (*Podocarpus latifolius* and *Olea capansis* subsp *macrocarpa*), where these species are also abundant in the understorey seedlings, saplings and poles. In the fire-driven Undifferentiated Zambezian deciduous woodlands in northern Namibia the fire-tolerant *Pterocarpus angolensis* dominates in the fine-grained woodland with regular fire, whereas the fire-sensitive *Baikiaea plurijuga* dominates in the coarse-grained woodland where conditions preclude regular fire, or regenerates in abundance when fire is controlled (Geldenhuys 1993).

3. Calculate stem diameter distributions for important species over different communities to determine regeneration requirements or constraints and resource status for the specific species (Geldenhuys 1993, 1996a, 1996b). The Inverse J-shaped stem diameter distribution is typical of the species that regenerate regularly under the specific conditions of the closed evergreen forests (shade-tolerant *Podocarpus latifolius* and *Olea capensis* subsp *macrocarpa*) or the deciduous woodlands with regular fire (fire-tolerant *Pterocarpus angolensis*). The Bell-shaped stem diameter distribution is typical of the species that require different conditions than those prevailing in the system, such as species that require disturbed conditions of a large gap in the evergreen forest (light-demanding *Cunonia capensis* and *Ocotea bullata,* and invasive alien tree species), or species that require the control or elimination of fire in the deciduous woodlands (fire-sensitive *Baikiaea plurijuga* in Namibian woodlands or *Millettia stuhlmannii* in Mozambican Miombo woodland). Regeneration events for these bell-shaped species occur at infrequent intervals.

The grain analysis and the stem diameter distributions analysed from the resource inventories are therefore useful tools to determine the specific shade or fire tolerance characteristics of key tree species, as a first approximation. This could be further developed and refined through appropriate monitoring feedbacks. A fine-grained forest/woodland with inverse J-shaped curves for the dominant canopy species suggest that the canopy species are generally adapted to small gaps (shade tolerant) or regular fires (fire tolerant). This means that the canopy species regenerate regularly within the stand under the evergreen forest canopy or with regular fires in the woodland. Silvicultural management should implement single-tree selection system with small gaps for the main species to maintain good regeneration of shade-tolerant canopy species in the evergreen forest, or should maintain regular fires to maintain good regeneration of fire-tolerant canopy species in deciduous woodland. A coarse-grained forest/woodland with bell-shaped curves for the dominant canopy species suggest that the canopy species are generally adapted to large gaps or disturbed conditions (light-demanding) or infrequent occurrence of fires (fire sensitive). This means that the canopy species can only regenerate sporadically within part of the stand with the formation of large gaps in the evergreen forest canopy or with control of fires in the woodland. Silvicultural management should implement a group-felling system with larger gaps for the light-demanding species and single-tree harvesting with small gaps for shade-tolerant species, or should maintain regular fires in communities where fire-tolerant species dominate, and control fires in communities where fire-sensitive species dominate, to maintain good regeneration of the different types of species.

Forest rehabilitation through management of succession

Similar concepts can be used to develop rehabilitation strategies to recover processes towards regrowth stands of diverse species and structure. Forest pioneer stands and stands of light-demanding introduced plantation and/or invader plant species (Geldenhuys 1997, Loumeto and Huttel 1997) develop from mono-specific pioneer stages to complex advanced stages of recovering forest. Natural pioneer/regrowth stands on the evergreen forest margin or large gaps facilitate several targeted timber species to establish after fire in abandoned slash-and-burn and charcoal production sites (with pioneer species). Planting should be confined to species that will not easily become established. The natural regeneration through pioneer tree species (indigenous and/or introduced species) is financially a better option because such species have a much better adaptation to establish under the disturbed conditions, while they grow fast to cover the site, control erosion, contribute to restoring the nutrient cycling through litter and organic material, and facilitate the natural regeneration of the shade-tolerant forest species.

Conclusions

The African forests and woodlands are diverse in terms of species, growth forms and size ranges of stems. They represent many diverse adaptations to ecological processes and drivers such as shade or fire tolerances and grazing/browsing by animals (from insects to elephants). We can accommodate such diversity through silvicultural management when we consider species in the context of their natural development stages. We need multiple management systems and approaches to accommodate diverse adaptations of key economic/ecological species in management of forest complexity in relation to diverse resource use needs.

The same principles and concepts apply in rehabilitation of such complexities in degraded or cleared forests. It is important to put the natural processes (vegetation cover, stand microclimate, erosion control, litter input, seed dispersal) in place to facilitate a faster, more diverse recovery of the diverse forest systems, at relatively low cost, towards the recovery of complex structure and diversity of mature forest – over many years, particularly if the disturbance was severe.

Different scales of disturbance require different recovery processes and therefore different periods of recovery towards the original condition of the forest prior to the disturbance event. Our general perceptions and actions in forest management and rehabilitation indicate that we often ignore the basic ecological understanding that is required to manage the forest systems cost-effectively and sustainably. We change towards reduced impact logging (which many people perceive as keeping gaps small) when our target species are light-demanding and need large logging gaps. We do rehabilitation plantings with species not always suitable for the disturbed state, at high costs with doubtful success. If we re-assess the perceptions listed in the introduction, then maybe we will think differently about the apparent degrading forest activities. Some disturbances are definitely not good, but others are necessary!

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LINKING DISTURBANCES TO SUSTAINABLE MANAGEMENT OF THE COPPERBELT MIOMBO WOODLAND ECOSYSTEMS OF ZAMBIA

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Abstract

Deforestation of woodlands and forests all over the world is an emotional topic of popular environmental debate today. Many people concerned about the environment have been persuaded by graphic images of either burning forests or the sight of the complex ancient forests being felled by commercial loggers, or slash-and-burn agriculturalists or charcoal producers who seem to care little for the losses to global heritage, biodiversity and impact on the global climate. This mindset created by this paradigm links loss to forests with degradation of the environment. The mindset has led to the formulation of a variety of policies that seek to protect forests and their ecosystems from the local communities who utilize the forests for charcoal production and slash-and-burn agriculture in preference for single tree selection harvesting. However, recent research has shown the regrowth of a wide range of species over areas previously deforested. Perhaps what is important is to try and classify the impact of these forms of forest utilization at both population and stand level. This paper summarizes and synthesizes information from various studies undertaken to determine the regeneration and recovery potential of miombo woodland under different disturbance factors. It characterizes the miombo woodland response to these disturbances based on the size class profiles exhibited at both population and stand levels. It also compares these with the undisturbed woodland. The results indicate that single tree selection as a disturbance at stand level is a non event while at population level, this disturbance may be a disaster. Additionally, the results also reveal that miombo woodland is dominated by mostly light-demanding species. Such species require large gaps for regeneration establishment and development. As such, the dominant species perform better in open areas than under closed canopy. The study concludes that these species are better adapted to the kind of disturbance-recovery processes associated with charcoal production and slash-and-burn agriculture. The study recommends the need for integrating these forms of forest utilization on a controlled basis into the forest management programs so as to reduce undesired destruction of the woodlands.

Introduction

Deforestation, not only of the Zambian Copperbelt woodlands but of many forests all over the world, is an emotional topic of the popular environmental debate today. Graphic images of burning forest, or the sight of complex ancient forests being felled in minutes by commercial loggers, or slash-and-burn agriculturalists and charcoal producers who seem to care little for losses to global heritage, biodiversity and impact on global climate, persuade many people to be concerned about the environment (Forsyth 2003). Many authors (Richards 1952, Myers 1984, Mather 1992, UNCED 1992, Bradley and Dewees 1993, GRZ 1998, Mather and Needle 2000, Brown 2001) have outright condemned deforestation and associated it with massive loss of fauna, flora and some high productive forest ecosystems. Such commentaries assume a direct relation between area of forest lost and the species lost (Forsyth 2003). The mindset created by this paradigm links the loss of forests with degradation of the environment. This mindset has led to the formulation of a variety of policies that seek to protect forests and their ecosystems against interference from the local communities for charcoal production and slash-and-burn agriculture. Such policies have condemned these two practices as forms of forest utilization in preference for single tree selection harvesting which is perceived to result in minimal negative impact on forests and woodlands. By contrast, later research has shown that this direct relationship between the area of forest lost and species lost overestimates the reality on the ground (Wu and Loucks 1995) and many species tend to survive in the remaining clumps of forests. Many studies in other parts of the world (Fairhead and Leach 1998, Schmidt-Vogt 1998, Sillitoe 1998, Fox *et al.* 2000) have shown the occurrence of a wide range of species over areas previously deforested. Perhaps what is most important is to classify the disturbances based on their associated impacts at both stand and population levels for a particular woodland. This approach helps to understand the implication of each disturbance and also how such a disturbance may be incorporated into sustainable forest management. A disturbance can either be a non-event or incorporated or a disaster or catastrophe relative to the scale at which it occurs, such as individual, population, community and landscape (Hansen and Walker 1985). A specific disturbance is a non-event if it does not alter the functional environment of an entity or may do so with a frequency too minor to elicit a response. It is an incorporated disturbance if it elicits dynamics of a scale to which the entity is adapted and thus necessary to maintain the entity in its present states. It is a disaster or catastrophe if it forces the entity into a new state.

This paper reports on a study which attempted to develop a new understanding of the regeneration and recovery potential of miombo woodland and the selected key miombo woodland species when exposed to single tree selection harvesting (STSH) for timber, slash-and-burn agriculture (SBA) and charcoal production (CP). These disturbances vary in intensity and in effects on the systems. STSH involves the removal of some trees, some opening of the canopy, and some soil disturbance. SBA removes most or all of the trees, burns the tree debris over the site, and cultivates the soil to various degrees which may continue intermittently over several years. CP removes most of the canopy and includes some soil turnover and fire in specific localities. The Copperbelt miombo woodland study of vegetation recovery after human disturbance was done at three sites in Zambia (Kaloko, Mwaitwa and Katanino/Kashitu), each containing areas under disturbance categories of STSH, SBA and CP in the past in close proximity to each other. In each study area, study sites with vegetation recovery ages of 2-3, 5-6, 10-12 and 15+ years after termination of land use activities were selected from within each disturbance category. Additionally, undisturbed miombo woodlands (UMW) was selected in each study area to act as a control. The selected practices bring into context the classification of the land use disturbances in miombo woodland based on their impacts at both population (species) and stand (ecosystem) level. This paper assesses how the results from the individual studies (Syampungani 2008) answered the research questions posed to achieve the specific and overall objectives posed for the study. It reviews and synthesizes the information on the regeneration characteristics and characteristic development stages of miombo woodland that has been under STSH, SBA and CP. In conclusion, the new understanding of regeneration and recovery potentials is assessed with a view to effectively integrate these disturbances into sustainable forest management.

Evaluation of methodological issues developed for the study

Five specific studies were conducted to examine different parts of this overall study with most requiring development of different methods (Syampungani 2008):

(i) miombo woodland utilization; management and conflict resolution among stakeholders: Semi-structured and key informant interviews were selected to generate the data. Assistants in data collection were familiar with and well-known within the communities to minimize discrepancies rising from such errors as fear, ignorance, hope of benefits by the respondents, etc. (see Chamber, 1983). In group meetings community members were divided into user groups to discuss issues relating to woodland utilization and management. This paper does not include the results from this component of the study.

(ii) use of species-stem curves in sampling the development of miombo woodland species in charcoal and slash-and-burn regrowth stands over time; The recovery stages over time of post-utilization stands are highly variable in both plant stocking and species composition (Strang 1974, Stromgaard 1985). STSH does not clear the woodland and stem density does not change from pre-harvested stands. Regrowth of cleared current woodland for SBA and CP results in dense stands of small stems which gradually grow taller over time with reduction of stem density through natural thinning, and increase in stem diameters. Traditional methods of fixed plot sizes, such as 0.4 ha (Lees 1962), 20 x 20 m (Lawton 1978) and 40 x 40 m (Scholes 1990), may be too large and time consuming (impractical) for young, dense regrowth stands (Mark and Esler 1970). The species-stem curve technique developed here uses a fixed number of plants in data collection, derived from the species-stem curves, to compare species responses to different land uses. The technique has significant implications for sampling regrowth stands in terms of time and number of species captured in the different regrowth stands. It avoids measuring too many plants in one plant age category with too few in other age categories, or to adjust sample size from one type of stand (land use x age) to another.

(iii) impact of human disturbance on the floristic composition of miombo woodland (using fixed number of stems obtained from species-stem curve approach);
(iv) regeneration and recruitment potentials of key species of miombo woodland species after disturbance and recovery of the woodland and species population structure;
(v) age and growth rate determination using selected dominant miombo woodland species within stands of different land use and recovery period: Stem discs were cut at 10 to 20 cm from the ground level, or stump in case of a shoot.

Resource use and perceptions on Miombo woodland recovery

The resources of miombo woodlands are central to the well-being and livelihood systems of millions of rural and urban people (Grundy 1990, Tuite and Gardiner 1990, Dewees 1994, Campbell *et al.* 1996, Syampungani, 2008), particularly charcoal and firewood as wood fuel, building material (timber and poles) and slash-and-burn agriculture. The most important products in the region are charcoal and firewood for the urban areas (Campbell *et al.* 1996), and ash for fertilizing the cultivation of crops for the rural population, which are also the most controversial uses in terms of their impacts.

Charcoal production and slash-and-burn agriculture

CP along roads in the Zambian Copperbelt Province to satisfy the increased demand for both industrial and household wood fuel in urban centers, has had a perceived negative impact on the woody vegetation of both forest reserves and open areas (Chidumayo 1987, GRZ 1998, Katsvanga *et al.* 2008). Deforestation arising from SBA has been reported to be high in Zambia (Syampungani 2008). Deforestation arising from both CP and SBA happens also in other parts of the miombo ecoregion. In Tanzania the estimated decrease in forest cover due to CP ranged from 300,000 – 400,000 ha/year (Ahlback 1988), with impacts including soil erosion and biodiversity loss (Monela *et al.* 1993). In Mozambique CP and SBA has been associated with loss of both forest cover and biodiversity (Mlay *et al.* 2003). In general, these practices are blamed as the principal causes of deforestation and its associated negative environmental impacts in tropical Africa (Myers 1989, Jepma 1995, GRZ 1998). This perception may be attributed to inadequate information on the recovery of the woodland once these disturbances cease. Some of the available information seems to suggest that woodland recovery for the southern African woodland is not possible (Walker 1981, Stromgaard 1986). Additionally, some of the available information on the growth rate of miombo woodland seedling shoots (Lees 1962, Chidumayo 1992) suggests very low growth rates and therefore may support the perception that CP or SBA does not result in woodland recovery once these are terminated over an area.

The response of miombo woodland to clearing for either CP or SBA is reflected in the development of regrowth stands once these disturbance factors are terminated over an area. On the Zimbabwean highveld system *Brachystegia spiciformis* and *Julbernadia globiflora* remained the characteristic and dominant species throughout the developmental stages of miombo succession after land clearing (Strang 1974). *Pterocarpus angolensis* occurred and performed well in miombo areas in Tanzania previously under SBA (Boaler and Sciwale 1966), and also in Zambezian Undifferentiated Woodland in northern Namibia (Graz 1996). In Zambia, the development of regrowth stands have been reported in various studies (Chidumayo 1988, 1993a, 1993b, 2004) although the studies did not deal with individual species development over time after termination of the disturbance, nor did they compare woodland response to different disturbances. Fanshawe (1971) noted that Zambian miombo woodland regrows virtually unchanged following clearing. Stromgaard (1986) reported that although the initial stages of the regrowth stand development of a previously cultivated area is a composition of fire resistant and some key miombo species, the development of miombo regrowth does not revert back to the original miombo.

Single tree selection harvesting

STSH for timber, poles or wood carving has been perceived to have no serious negative impact on the woodland ecosystem as a whole. For example, STSH for timber in Tanzanian miombo woodland did not show any significant change in species richness and stocking (Schwartz and Caro 2003). However, other studies reported the negative implication of STSH in many parts of Tanzania (Hall and Rodgers 1986, Nduwamungu and Malimbwi 1997, Mbwambo 2000, Luoga *et al.* 2002). Both Nduwamungu and Malimbwi (1997) and Luoga *et al.* (2002) observed very low levels of mature *Pterocarpus angolensis* due to past harvesting of this species for window frames and doors. Such a situation is referred to as an economic extinction of the species (Schwartz *et al.* 2002), which allows such species to persist at low densities which make their exploitation costly. The impact of STSH on species richness has also been reported in other parts of the Miombo ecoregion: Malawi (Konstant 1999, Makungwa and Kayambazinthu 1999); Mozambique (Grundy and Cruz 2001); Zimbabwe (Grundy *et al.* 1993, Mudekwe 2006). These studies showed that the commonly harvested species for either timber or pole production, namely *P. angolensis*, *Erythrophleum africanum, Brachystegia boehmii, Brachystegia spiciformis, Brachystegia bussei, Brachystegia utilis, Pericopsis angolensis, Khaya anthotheca* and *Afzelia quanzensis* exhibit unstable population structures with reduction in absolute densities and also species richness. Similarly, *Brachystegia floribunda, Pterocarpus angolensis* and *Albizia antunesiana* had unstable population structures and low densities in mature miombo woodland stands in which these species were under single tree harvesting.

Results from Copperbelt Miombo woodland study of vegetation recovery after human disturbance

Species and diversity over time

The occurrence and diversity of species tend to differ from one disturbance type to another and also with stand age within the same disturbance type. CP tends to yield the highest number of species compared to either SBA or STSH or UMW. SBA regrowth stands tend to result in more species than either the post STSH stands or the UMW stands. This suggests that opening up of miombo woodland enhances species richness of the area. Many miombo woodland species require high light intensities to regenerate and establish (Lees 1962). Under the canopy the growth and abundance of understory vegetation of miombo, as in many other vegetation types (Bassaz and Wayne 1994), are strongly limited by heavy shade and root competition for moisture with canopy species. Increased light, soil moisture and nutrient availability and creation of microsites for colonization associated with canopy disturbance promote succession dependent on the intensity of disturbance (Reader and Bricker 1995). Rapid development of miombo regrowth in abandoned cleared plots in certain parts of the Miombo Ecoregion, such as in Tanzania (Boaler and Sciwale 1966), Zambia (Chidumayo 1988, 2004) and Zimbabwe (Strang 1974) supports the significance of light intensity and reduced competition for nutrients and water in promoting regeneration. Some new species gained in 2-3 year old regrowth stands after SBA and CP are those of ubiquitous and chipya ecological groups (Kikula 1986) such as *Dalbergiella nyasae, Garcinia huillensis, Hexalobus monopetalus* and *Ozoroa reticulata*, all typical miombo sub-canopy and understory species (Fanshawe 1971, Storrs 1995). Some species were typical of only one disturbance type. For example, *Protea* spp, *Rhus longipes*, *Bridelia macrantha* and *Burkea africana* were typical of the CP regrowth stands. However, some species were lost during the development of CP and SBA regrowth stands, with the greatest loss over time in CP stands. A mixture of Mateshi, Chipya and Ubiquitous ecological group species were gained through CP, such as *Bridelia macrantha, Diospyros* spp., *Cassia singueana, Afzelia quanzensis*, etc while some, such as the *Uapaca* ecological group, were lost over time. The entrance of a mixture of species of different ecological groups in the early stages may suggest a variation in environmental conditions such as fire intensities within the same land use disturbance type. The abundance of some *Uapaca* spp. decrease due to natural mortality as the canopy of the regrowth stands begin to close (Kikula 1986). Species of the Chipya and *Uapaca* ecological groups can only grow well under light canopies (Lawton 1978). This explains why even though the members of the miombo group regenerate under the protection of the *Uapaca* and Chipya groups, these groups get eliminated later when the canopy of the miombo group gets dense (Kikula 1986). Clayton (1962) made a similar observation on the reduction in prevalence of *Uapaca togoensis* as regrowth stands advance in the Nigerian wooded savanna.

Mechanisms and management of miombo woodland recovery

The mechanism of regeneration for individual miombo species is mostly dependent on the disturbance mechanism. For example, in STSH and SBA stands, *Parinari curatellifolia* mostly develop by root suckering while *Albizia antunesiana, Brachystegia floribunda, Brachystegia longifolia, Brachystegia spiciformis, Isoberlinia angolensis, Julbernadia paniculata, Pericopsis angolensis, Pseudolachnostylis maprouneifolia* and *Pterocarpus angolensis* from seed. This observation offers a potential approach for managing individual forest crops based on their mode of regeneration. For example, the establishment and development of *Parinari curatellifolia* could be enhanced by disturbing its root system to produce root suckers. However, the management of *Albizia antunesiana, Brachystegia floribunda, Brachystegia longifolia, Brachystegia spiciformis, Isoberlinia angolensis, Julbernadia paniculata, Pericopsis angolensis, Pseudolachnostylis maprouneifolia* and *Pterocarpus angolensis* in STSH and SBA stands requires enhancing seedling establishment and growth, as shown by the Syampungani (2008) study. If these light-demanding species remain under the canopy cover, they may either die or remain suppressed in a stunted form (Werren *et al.* 1995), during which period they remain susceptible to fires, water stress, insectivory and herbivory (Savory 1963, Chidumayo 1997). Most of the photosynthetic products during seedling development are allocated to root growth while shoot growth may be further hampered by recurrent annual die-back caused by drought or fires (Chidumayo 1989, 1991, 1992). Management of young regrowth stands arising from SBA should include protection of seedlings against either fire or drought. Weeding around seedlings would reduce fire risks during their tender age, and reduced stocking may reduce water stress. However, in CP regrowth stands, coppicing is common in *Albizia antunesiana, Brachystegia floribunda, Isoberlinia angolensis, Julbernadia paniculata* and *Pseudolachnostylis maprouneifolia*. Management of such species in CP regrowth stands should focus on coppice enhancement and development. Stumps of almost all miombo tree species produce coppices once cut (Banda 1988). Management of coppicing species should protect the cut stump against desiccation, and then protect the coppicing stumps against fires and herbivory to increase their survival rate. Increased stump heights during felling in CP sites can enhance the survival of stumps and coppicing. Grundy (1990) observed a reduction in coppices in lower stumps (<5 cm) compared to higher stumps (>1.3 m) for *Brachystegia spiciformis*. Additionally, adhering to optimum diameters within which particular species coppice optimally can enhance coppice regrowth of such species. *Brachystegia longifolia, Brachystegia spiciformis* and *Isoberlinia angolensis* have high coppicing ability in trees of 15 to 36 cm DBH (Handavu 2008). Thinning of developing coppice shoots could be done to reduce competition for moisture and nutrients between the multiple many shoots developing from one stump (Banda 1988, Chidumayo 1989).

Structural changes over time under different disturbance categories

The size class profile, such as a stem diameter class distribution, at the community (stand) or population (species) level can explain the response of the stand or population to specific stand conditions resulting from particular disturbance regimes (Peter 2005). For example, the bell-shaped stem diameter profile characterizes both the UMW and STSH stands which suggest that the miombo woodland ecosystem is composed of populations which experience sporadic or irregular seedling establishment and requires large gaps to become established (DWAF 2005, Peter 2005). The observed fluctuations in stem density between diameter classes close to each other may be attributed to differences in regeneration intensity from time to time which result in notable peaks or ‘valleys’ in the stem diameter distribution. The irregularity of regeneration may be attributed to the effect of periodic extreme fires occurring in miombo woodland (Trapnell 1959). However, the similarity in stem diameter profiles between UMW and STSH stands implies that STSH as a disturbance in miombo woodlands is a non-event as it does not alter the functional environment of the miombo woodland or if it does then its impact is too minor to elicit a response of the miombo ecosystem as a whole.

The inverse J-shaped stem diameter profile that characterizes both SBA and CP regrowth stands up to about 10-12 years shows that these stands have adequate regeneration. In short, the opening up of the woodland through SBA and CP enhances regeneration which is present in the form of root suckers and recruitment of old stunted seedlings existing under the forest canopy (Chidumayo and Frost 1996, Geldenhuys 2005). However, the 15+ year old CP regrowth stands show the bell-shaped stem diameter profile and casual observation indicated that the canopy of this age group began to close. Canopy closure in CP regrowth stands happens faster than in SBA regrowth stands because stems of <3.2 cm diameter are left behind during charcoal production (Chidumayo 1990), and these trees may grow faster due to reduced competition for nutrients and sunlight. The bell-shaped stem diameter distribution in CP regrowth stands may develop over time because of the differential growth of stems of generally similar age and with almost no recruitment of young stems into such a dense stand. A similar stem diameter distribution profile would develop in SBA regrowth stands with time. The slower development of this profile in SBA regrowth stands over time could also be because CP regrowth stands develop mostly from coppices from already established root stocks whereas SBA regrowth stands develop from seedlings. In coppice regrowth most of the biomass is allocated to stem development, but in seedlings most of the biomass is allocated to root growth in the seedling phase (Chidumayo 1991).

At the population level of individual species, *Brachystegia floribunda, Pterocarpus angolensis* and *Albizia antunesiana* exhibit a static stem diameter distribution profile and low densities in mature miombo woodland stands from which these species are harvested within STSH. These species develop the inverse J–shaped stem diameter disributio profile up to 10-12 years in CP regrowth stands and up to 15+ years in SBA regrowth stands. Despite ample regeneration, seedling establishment and development for these species under the canopy are limited because of their requirement for high light intensities to develop and grow (Lees 1962), and for reduced competition for nutrients and moisture. This explains why saplings of dominant miombo species occur in larger numbers in SBA and CP regrowth stands as compared to UMW and STSH stands. The key miombo woodland species tend to be present throughout the different age class categories for each disturbance during woodland recovery contrary to the perception of non recovery of miombo (Walker 1981) or non existence of dominant miombo species in the early development stages of stand regrowth (Boaler and Sciwale 1966). This suggests that miombo woodland species are adapted to the kind of disturbances associated with either SBA or CP, i.e. the miombo woodland ecosystem is capable of incorporating the disturbances arising from these two land uses.

The static stem diameter distribution profile (low stem numbers throughout) exhibited by species under STSH shows the negative impact of species preference and single tree selection harvesting on the overall population of such species, and confirm observations in other parts of the miombo ecoregion: Tanzania (Hall and Rodgers 1986, Nduwamungu and Malimbwi 1997, Mbwambo 2000, Luoga *et al.* 2002); Malawi (Konstant 1999, Makungwa and Kayambazinthu 1999); Mozambique (Grundy and Cruz 2001); Zimbabwe (Grundy *et al.* 1993). Very low levels of the profile were observed for such species under the STSH, emphasizing their economic extinction (Schwartz and Cor 2003), which can result in limited availability of such light-demanding commercial species, even if they appear to have ample regeneration. This situation has the potential to result in decrease of the likelihood of conspecific replacement and increasing the risk of collapse of the natural successional pathway (McKenzie 1988). Even though many authors have outright condemned deforestation and associated it with massive loss of fauna, flora and some high productive forest ecosystems (Richards 1952, Myers 1984, 1989, Mather 1992, UNCED 1992, Bradley and Dewees 1993, Jepma 1995, GRZ 1998, Mather and Needle 2000, Brown 2001), this study has shown that STSH has a negative effect on species richness and population status of harvested stands. It can therefore be concluded that STSH can be a disaster at population level for some species (many commercial species) although it is non event at stand level.

Growth rates of selected miombo woodland species

The growth rates of miombo woodland seedlings and shoots have been said to be very low (Lees 1962, Chidumayo 1992). Some miombo woodland species showed very slow growth rates in other woodland types. For example, *Pterocarpus angolensis* showed mean annual diameter growth of 4.5 mm and 0.3 -2.8 mm respectively in the studies of Groome *et al.* (1957) and Shackleton (2002) in South African savannas. This information may support the perception that miombo woodland may not recover from SBA or CP clearing. However, this study showed mean annual ring width ranging from 4.4 to 5.6 mm or diameter growth of 0.9 to 1.1 cm/year in *Julbernadia paniculata, Brachystegia floribunda* and *Isoberlinia angolensis* in both SBA and CP regrowth stands. Geldenhuys (2005) considered mean diameter growth of 1 cm/year in miombo woodland in Zambezia Province in Mozambique as very productive miombo regrowth. The relatively high productivity of miombo woodland is supported by the higher mean annual diameter growth in this study, compared to those observed by Chidumayo (1988) in his long term study of diameter growth of miombo canopy species. It can therefore be concluded that the SBA and CP regrowth stands are very productive. The growth rate information generated from this study give a different perspective on the productivity of miombo woodland, and provided a means of collecting growth data relatively easy which could be used in yield regulation and carbon sequestration. This data could be supplemented with other growth data for trees of known age or long-term growth plots.

Integrating different land use disturbance into sustainable management of Miombo woodland

The realization of the importance of miombo woodlands to the livelihood security of rural people is a key to integrating livelihood needs and environmental security. The national planning sectors in Zambia have not adequately integrated timber harvesting by concessionaires, land use practices of rural communities, miombo woodland conservation and environmental security in general. Rural economics is mainly based on the premises of CP, SBA and to some extent STSH. These activities are on the increase and the result has been accelerated deforestation from SBA and CP. Currently, the deforestation rate in Zambia is estimated to range from 250,000 to 300,000 ha/year (MENR 2002). SBA and CP activities have increased in Zambia like in many other parts of the miombo ecoregion which was attributed to the slow growth in per capita income of 0.1 % between 1990 and 1999 (Kaimowitz 2003). SBA and CP do change the stand structure of mature miombo woodland over large areas, and the rate at which this takes place, is too fast and uncontrolled. However, this study has shown that both SBA and CP may be incorporated disturbances as clearing of up to 3.5 ± 0.4 ha for SBA and 1.9 ± 0.9 ha for CP can still support woodland recovery (Syampungani 2008). But when large tracts of woodland are cleared for these two land uses, this tend to be a disaster for the miombo woodland. Hence sustainable management of miombo woodland and its ecosystems need to find a way to integrate STSH with controlled SBA and CP to provide for adequate regeneration of harvested species, and integrated resource management in contrast to the current segregated agriculture, forestry and conservation activities.

Zonation of forest resource area into management classes

The integration of STSH, SBA and CP into miombo woodland management should involve zoning the forest resource area into management classes, such as for timber, poles, charcoal, wild fruit, crop cultivation, grazing, and protection. Each management class would require specific resource use management systems, which could be integrated on the same area, depending on the woodland type and condition of each mapping unit (Geldenhuys 2005). .

Fruit production

The collection of wild fruit by local communities is an important activity throughout the miombo ecoregion in Democratic Republic of Congo, Tanzania (Mbwambo 2000) and Malawi (Akinnifesi *et al.* 2006). Income generation from the sale of wild fruit was recorded for Zambia (Chidumayo and Siwela 1988) and other parts of the ecoregion (Campbell 1987, Olsen *et al.* 1999). Such sales help to meet specific cash needs, and provide a contingency in case of crop failure (Brigham *et al.* 1996). Important wild fruit species *Uapaca kirkiana* and *Anisophyllea boehmii* are among the dominant species in the early stages (2- 6 years) of woodland recovery from CP. Integration of fruit production into forest management can enhance financial security among local community members and may help to reduced undesired woodland destruction. CP regrowth stands can be managed to yield wild fruit of the light-demanding *U. kirkiana* and *A. boehmii* through control of dominance of the miombo ecological species such as *Isoberlinia angolensis* and *Julbernadia paniculata,* to prevent stand canopy closure.

Timber and pole production

Both SBA and CP result in enhanced seedling and vegetative regrowth with fast growth of a range of timber species when the disturbance impacts are terminated over an area (Geldenhuys 2005, Syampungani 2008). SBA farmers and charcoal producers can manage such regrowth through pruning and thinning of selected trees to facilitate different commercial timber species to grow into good-sized trees with potentially high quality logs which could be sold to timber concessionaires. The thinned stems can be used as poles for construction. Such integrated management of SBA and CP regrowth could produce additional income to the local farmer or other entrepreneur (see Geldenhuys, 2005) and could change the rate of woodland clearing.

Conclusions and recommendations

This Copperbelt Miombo Woodland study has shown that mature miombo woodland (both timber harvested and undisturbed stands) are dominated by species whose regeneration require large canopy gaps to become established. There is ample regeneration but in a stunted form. By contrast, and contrary to general perception, regrowth stands after abandonment of fields after slash-and-burn agriculture and charcoal production, have most of the canopy species and also other species of the mature woodland recovering at a relative fast and productive rate. The results suggest that single tree selection harvesting as disturbance event of the woodland stands is a non-event but does not stimulate the regeneration of the harvested and specifically the commercial timber species (a disaster at population level of the specific light-demanding species). The study concludes that the characteristics of the dominant miombo woodland species are adapted to recover more effectively and productively from charcoal production and slash-and-burn agriculture. It is acknowledged that the drivers of deforestation such as unemployment and poverty are prominent in the region. It is therefore concluded that deforestation will continue unless slash-and-burn agriculture and charcoal production are not incorporated into forest management systems to control the rate of deforestation and to provide incentives to local farmers to benefit financially from managing timber trees on their farms. The study recommends that miombo woodland management should incorporate and integrate charcoal production and slash-and-burn agriculture as they are necessary components of the miombo woodland to which the system and the majority of species are adapted. These disturbance-recovery systems also provide an opportunity for managing the miombo woodland for fruit production by manipulating species composition of the charcoal regrowth stands in the early stages of woodland recovery.

The study also recommends the need to carry out further research to determine:

- the optimum size of the cleared area for either charcoal production and slash-and-burn agriculture to guide the best response/recovery of miombo woodland;
- growth rates of miombo woodland species (both other canopy species and understory species) to enhance understanding of the system dynamics in different areas.

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IMPACTS OF UTILIZATION ON THE COMPOSITION AND DIVERSITY OF MOPANE WOODLANDS IN NORTHERN NAMIBIA

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Abstract

Impacts of woodland utilization on plant species composition, richness and diversity were investigated in mopane woodlands of Omusati Region, northern Namibia. A protected game park, a densely-populated (central) area and a sparsely-populated (western) area were compared. Utilization levels, species composition and stump densities were quantified in 58 plots. A X^2-test showed that utilization levels differed significantly among sites, with up to 34% of the central area under heavy utilization. Species richness and diversity were significantly lower in the central area as a direct consequence of heavy disturbance. Dead stump densities in the western area were significantly higher than at other sites because of less population pressure compared to the central area, where they are continuously harvested for firewood. Live stump densities were significantly higher in the central area, indicating continual heavy cutting of remaining trees in that area. Hierarchical Cluster Analysis showed significant changes in species composition due to woodland utilization, the heavily disturbed central area having become more uniform due to loss of less resilient species and the preponderance of just a few tolerant dominants. Detrended Correspondence Analysis further demonstrated a gradient of vegetation change mediated by local-level utilization, which significantly contributed to the 64.8% variation in species data along the first axis, as shown by Monte Carlo Permutation tests. From these findings, it is evident that heavy woodland utilization is a significant disturbance factor which may lead to undesirable changes in woodland composition and diversity. Community-based management interventions should, therefore, be put in place to ensure sustainable woodland utilization without causing further woodland degradation in central Omusati.

Introduction

The need for sustainable use of natural resources has been placed high on the priorities for most countries as the world faces an ever-increasing human population which puts pressure on the resources. The problem is more acute in Africa where the majority of people live in abject poverty and thus rely directly on natural resources, including woodlands, for their survival. In addition to playing important roles in local cultures and economies of many societies (Fotso 1998) woodlands provide many goods and services for local communities (Grundy *et al.* 1993, Campbell and Marsh 2000, Mafuta and Mukwekwerere 2000). It is therefore, generally recognized that woodland resources are critical for meeting human needs and for improving and maintaining the quality of human life, especially in communal areas (Mazambani 1992).

Sustainable management of woodland resources, as well as their protection, have been inherent in the practices of many rural communities. But increasing population pressure and poor management practices have led to their degradation in many parts of the world, especially those under open access tenure regimes. Such resources need to be properly managed to ensure that they continue to provide for household needs in the future (Geldenhuys 1996, Lynam *et al.* 1998).

Southern Africa is endowed with woodland resources that sustain millions of people, particularly rural peasants. One such woodland type is that dominated by *Colophospermum mopane*. Mopane is native to hot, tropical climates and occurs in various physiognomic types. The ecology and importance of mopane have been reviewed by various authors (Mapaure 1994, Timberlake 1996). Due to increasing awareness of the importance of mopane, many initiatives have commenced within southern Africa to provide a greater degree of support to the local people whose livelihoods depend on its sustainable management.

In Namibia, mopane woodlands occur mostly in the northern parts of the country, which are home to at least 60% of the rural human population of the country. Concern has been expressed about the dwindling woodland resources due to human pressure. In Omusati Region in particular, the Directorate of Forestry cautioned that woodland use was apparently unsustainable (Selänniemi *et al.* 2000). It was in view of this concern that this study was carried out in Omusati Region in northern Namibia to do an inventory and assess the state of mopane woodlands and investigate the impact of woodland utilization on the species composition and diversity in the area.

Methods

Study area

The study was carried out in Omusati Region, northern Namibia (Figure 1). Omusati is one of the 13 political regions of Namibia and covers 26,573 km^2. It is bounded by Kunene Region in the west and south, Oshana and Ohangwena Regions in the east and Angola in the north. Omusati has a human population of 228,842, and has a high mean population density of 8.6 persons/km^2 (NPC 2007), ranging between 1.8 and 54.6 persons/km^2 (Figure 1). Two communal sites were selected for study on the basis of the differences in the living styles and population densities of the respective ethnic groups: one in western Omusati (predominantly OvaHimba tribe) and one in central Omusati (Owambo tribe). The Ogongo game park, a protected area since 1996, was selected as the third site.

Topography is characterised by flat plains which form part of the Etosha depression. In the western part, the land rises gently to the foothills of the Kaokoland. Annual rainfall ranges between 450-500 mm in the north east and 250-300 mm in the south west (NPC 2007). Mean maximum and mean minimum temperatures range between 32-34^{o}C and 6-8^{o}C, respectively. The vegetation is classified into four broad types (Selänniemi *et al.* 2000): palm savanna, bush Mopane savanna, seasonally flooded grasslands with patches of Mopane and Acacia, and open shrub savanna of Mopane and Acacia.

Field assessments

Fifty-eight plots were demarcated in total, 21 in central Omusati, 18 in western Omusati and 19 in the game park. Trees and stumps were assessed in 20 m x 20 m plots while 5 m x 5 m subplots nested within the 20 m x 20 m plots were used for shrub and sapling assessments. Grasses and forbs were inventoried in 1 m x 1 m subplots nested within the 5 m x 5 m subplots. Woody plants with basal circumferences ≥15 cm were regarded as trees while shrubs and saplings were <15 cm (Anderson and Walker 1974). All plants in the respective plots were identified, while stumps were further categorized as dead or alive. The number of coppice shoots on each live stump was recorded. In each 20 m x 20 m plot, human utilization levels were assessed and scored on a scale adopted and modified from those generally used for wild herbivore 'damage' to vegetation (Anderson and Walker 1974, Ben Shahar 1996, Mapaure 2001). The utilization scale comprised five levels of percentage of the woody plants showing evidence of utilization: 0 = no use, 1 = light use (<10%), 2 = moderate use (10-25%), 3 = heavy use (25-50%) and 4 = very heavy use (>50%).

Data analyses

Utilization levels were calculated as the numbers of plots falling in each utilization category at each site, and differences among sites were tested using a X^2-test. Stump densities were calculated and differences among sites were tested using One-way ANOVA, with Tukey's *post hoc* analyses. At each site, comparisons between dead and live stumps were done using a t-test. Differences in Shannon diversity index and species richness were tested by a Kruskal-Wallis test. Hierarchical Cluster Analysis (HCA) (van Tongeren 1995) was used to test for differences in species composition among sites. Species presence/absence data and the average linkage cluster method were used in HCA. Detrended Correspondence Analysis (DCA) (ter Braak 1986, 1995, ter Braak and Smilauer 2002) was performed on species binary data to elucidate relationships amongst the various plant associations and hypothesize on any utilization or other environmental gradients. The significance of the contribution of utilization to variation in species data was tested by Monte Carlo Permutation tests.

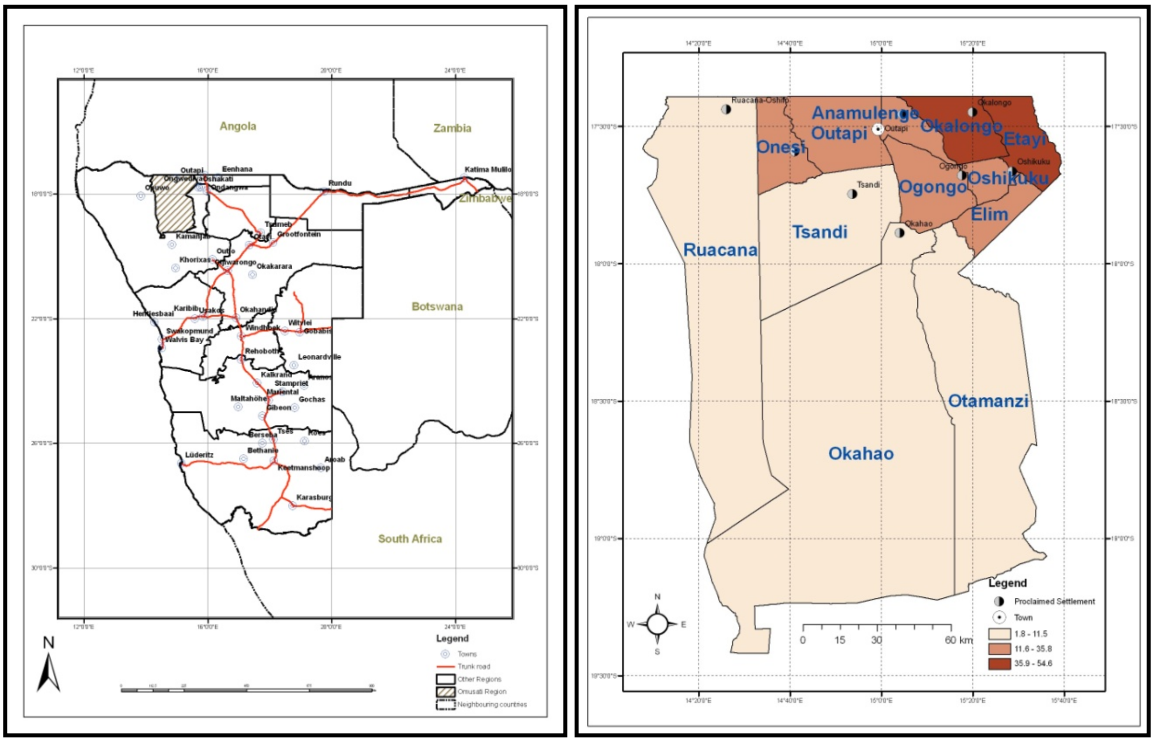

Figure 1: Location of Omusati Region in northern Namibia (left) with indication of population densities of various areas within Omusati Region (right) (NPC 2007)

Results

Fifty plant species (34 woody, 16 herbaceous) were recorded during the inventories. Of all woody plants encountered, 87.2% were *Colophospermum mopane*. More trees were recorded in the western area and game park than the central area while more live stumps were recorded in the central area than the other two sites (Table 1).

Table 1: Numbers of trees, shrubs and stumps recorded in central area, western area and the game park in Omusati Region in northern Namibia.

	Site			
Life form	**Central**	**Western**	**Game park**	**TOTAL**
Trees	85	335	332	752
Shrubs	123	58	102	283
Stumps - Live	547	100	52	699
Stumps - Dead	71	81	26	178

Levels of woodland utilization differed significantly among sites ($\chi^2 = 129.50$, $p < 0.001$). As expected, a large proportion (51%) of the plots in the game park showed no utilization (level 0), but only 41% and 22% showed no utilization in the western and central areas, respectively (Figure 2).Only 2% of the plots were heavily utilised (level 4) in the game park and 6% in the western area compared to 34% in the central area. There was a much higher than expected heavy to very heavy utilization level (levels 4 and 5) in the central area. Most stumps recorded (98.6%) were *Colophospermum mopane*, with the rest being *Combretum apiculatum, Combretum collinum, Kirkia acuminata, Terminalia prunioides* and *Acacia nilotica*. Dead stump densities differed significantly among sites ($F = 4.48$, $p < 0.05$), with higher densities in the western area than the game park ($p < 0.05$) (Figure 3). All other comparisons were not significant. Densities of live stumps also differed significantly among sites ($F = 13.70$, $p < 0.001$) (Figure 3), with significantly higher densities in the central area than at the other two sites ($p < 0.001$). There was no significant difference in live stump densities between the western area and the game park. There were significantly higher densities of live than dead stumps in the central area ($t = 2.02$, $p < 0.001$) (Figure 3) but no significant differences were detected at the other two sites.

All the live *Colophospermum mopane* stumps recorded in the study were coppicing, with an average of 5.3 (range 1 to 27) coppice shoots per stump.

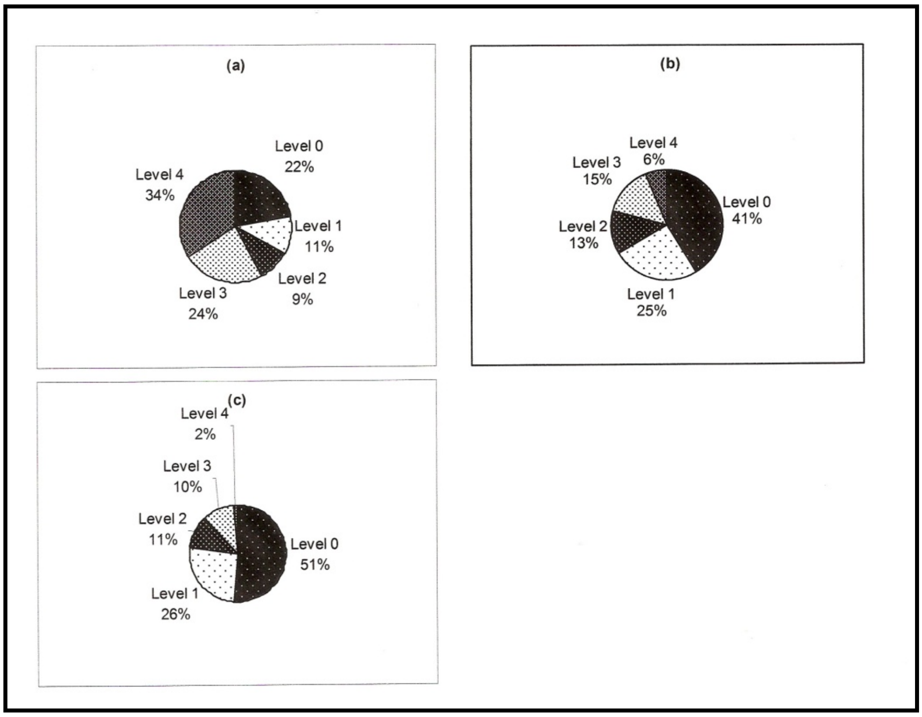

Figure 2: Variations in woodland utilization levels in central area (a), western area (b) and game park (c) in Omusati Region, northern Namibia (Levels are 0 = no use, 1 = light use , 2 = moderate use, 3 = heavy use, 4 = very heavy use)

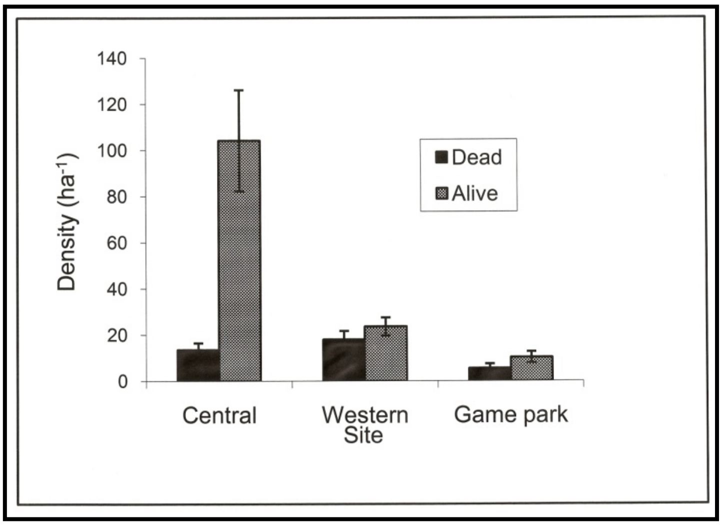

Figure 3: Differences in the densities of dead and live stumps in mopane woodlands at three sites in Omusati Region, northern Namibia

Species richness in the central area was significantly lower than the western area (H = 12.59, p <0.01), other comparisons were not significant. Species diversity also differed significantly among the sites (H = 12.59, p <0.01) (Table 2), with significantly lower diversity in the central area than at the other two sites. There was no significant difference in species diversity between the western area and the game park.

Table 2: Differences in plant species diversity and richness in mopane woodlands at three sites in Omusati Region, northern Namibia (different subscripts for each variable indicate significant differences)

SITE	Shannon Diversity Index		Species richness	
	Mean	**SE**	**Mean**	**SE**
Central	1.0377a	0.0724	3.0p	1.30
Western	1.4887b	0.1099	4.9q	2.71
Game park	1.3629b	0.0913	4.2q	1.69

Hierarchical Cluster Analysis separated the plots into three major clusters, largely conforming to the three sites, indicating clear differences in species composition among the sites (Figure 4). The central area had a more uniform composition compared to the western area. Much of the differences manifested themselves in the herbaceous and shrub composition. However, the western area had more woody species than the other two sites, resulting in this separation. Notable additional species in that area include *Terminalia prunioides, Commiphora glandulosa, Acacia nilotica* and *Combretum apiculatum*.

Ordination results indicate that 64.8% of the variation in species data was accounted for along DCA Axis 1, with the level of disturbance (human utilization) decreasing from left to right along this axis. The second, third and fourth axes accounted for 56.5%, 40.3% and 33.3% of the variation, respectively. Monte Carlo permutation tests showed that the influence of utilization on the variation in species data was significant ($F = 3.346$, $p < 0.001$). The plots were generally grouped according to the three sites (Figure 5), supporting the HCA classification. The gradient associated with the second axis is not clear but possibilities are discussed below.

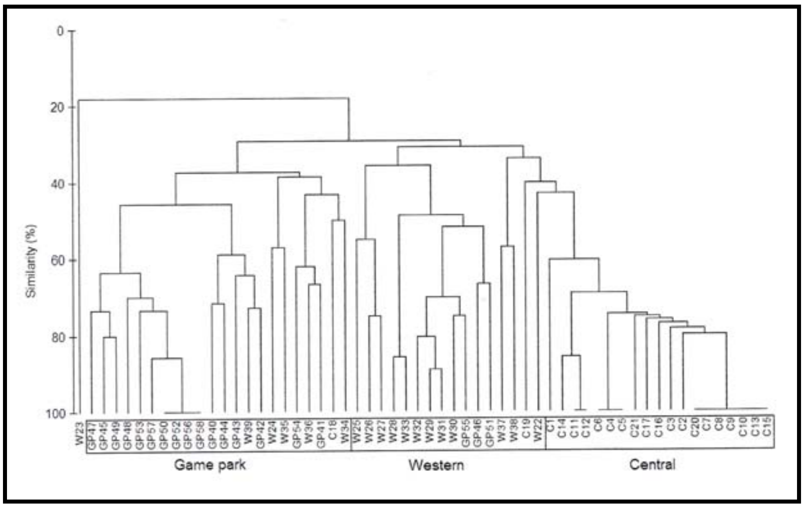

Figure 4: A Hierarchical Cluster Analysis (HCA) dendrogram of species presence/absence data of plots inventoried at three sites in Omusati Region, northern Namibia.

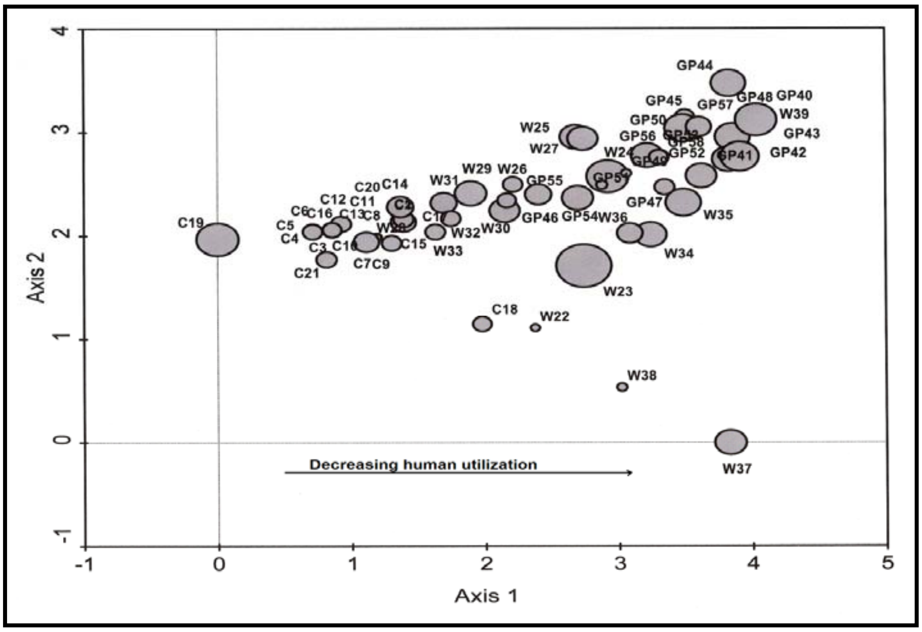

Figure 5: A Detrended Correspondence Analysis (DCA) ordination diagram of the species presence/absence data of plots from three sites in Omusati Region, northern Namibia. Larger circles indicate higher species diversity while smaller circles indicate lower species diversity (C = central area, W = western area, GP = Game park)

Discussion

This study has clearly demonstrated that utilization pressure has significantly impacted on mopane woodlands in northern Namibia, in central Omusati in particular. This trend is not unexpected in communal areas with high population densities and where property regimes are open access in nature. Subsistence harvesting of woody plants by local communities in southern Africa has been shown to result in significant changes in woodland structure and functioning. Local Owambo people in northern Namibia use the largest quantity of wood for homestead construction than any other tribe in southern Africa (Erkkilä 2001). Although western Omusati is generally less populated, the OvaHimba people traditionally use less wood for construction. They engage mainly in livestock husbandry than crop farming, hence they keep woodlands for their livestock. Cunningham (1993) emphasized that patterns of woodland use and depletion vary according to settlement patterns, abundance and patchiness of favoured plant species and their sizes.

Demand for woodland resources depends on human population densities and replacement times of construction timber. The extent to which the woodlands have been degraded in central Omusati should be a cause for concern. In central Omusati, the pattern is indicative of a woodland dominated by smaller trees, disproportionately fewer individuals in the middle-size classes and much higher than expected numbers of large trees (Mapaure 2006). The fact that 58% of the sites in central Omusati show heavy utilization levels (compared to 21% and 12% in western Omusati and the Game Park, respectively) is clear testimony of high pressure on the resources. Higher densities of live stumps (between 342% - 910% more than western area and game park) bears more evidence for this. Dead stumps are subsequently harvested for firewood, hence the lower densities recorded in central Omusati.

Species composition has significantly changed due to woodland utilization in the area. The mixture of plots from the game park with those from western Omusati in Fig 4 indicates more similarities between the two sites. The game park is geographically in central Omusati, and one would therefore expect it to be more similar to central than western Omusati. It can, therefore, be concluded with certainty that human pressure in central Omusati contributed to the observed differences in species diversity and composition between these two sites. According to the intermediate disturbance hypothesis (Schwilk *et al.* 1997, Skowno *et al.* 1999), it would be expected that areas with moderate disturbances such as the game park and western Omusati would have higher diversity than heavily disturbed areas such as central Omusati. Further support for this is provided by the DCA ordination which shows up to a 50% species turnover between the game park and central Omusati, and woodland utilization contributed significantly to the observed variation in species data. However, some of the variation is attributable to other factors (associated with DCA axis 2) such as variations in soils and geology, landscape type and grazing pressure.

It is evident that woodlands in central Omusati have been significantly degraded with increased scarcity of woodland resources in this area. People from this area travel to western Omusati to obtain wood and other resources such as mopane caterpillars (Mapaure 2006).

Such activities were already evident more than a decade ago (Erkillä and Siiskonen 1992) but the incidences have intensified in the last few years. All these are indications of a non-sustainable situation. The assertion by Selänniemi *et al.* (2000) that woodland use in Omusati Region appeared to be non-sustainable is confirmed. From this study, however, it is not possible to calculate a sustainable harvesting rate that would encourage woodlands in central Omusati to recover.

Mopane coppices readily (Gelens 1996, Timberlake 2000, Mlambo and Mapaure 2006), a property supported by the fact that all live stumps encountered in this study were coppicing. This indicates that mopane is a very resilient species, which can recover if properly managed. Unless local communities in central Omusati start to sustainably manage these woodlands in the manner suggested by Musvoto *et al.* (2006), the situation is bound to worsen. In order to achieve this, enforcement of existing natural resource policies should be effectively carried out. More awareness is required to sensitise local communities on sustainable management practices. The concept of Community Forests promoted by the Forest Policy of Namibia should be implemented in more areas, provided financial and other challenges are addressed.

Conclusions

Heavy woodland utilization in central Omusati has resulted in declines in species diversity and species richness. This has also led to undesirable changes in species composition to more homogenous vegetation. Whilst human pressure on the woodlands can account for some of these changes, part of the observed differences are not due to utilization but other factors may play a role. Such factors include livestock grazing, landscape type, topography, variations in edaphic factors and small-scale variability in rainfall. It is evident that mopane woodlands in the game park have not fully recovered from past use, and regular illegal harvesting in the park is slowing down the recovery process. *Colophospermum mopane* regeneration from coppicing is prolific. Therefore, proper coppice management and pollarding of remaining mopane woodlands in central Omusati is essential if the situation is to be reversed. Woodland utilization in central Omusati is therefore unsustainable, as evidenced by the scarcity of woodland resources in the area. The concept of Community Forests should be expanded to such areas in order to promote sustainable utilization of woodland resources.

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ANALYSIS OF THE DEGRADATION OF THE FOREST ECOSYSTEM OF MBIYE ISLAND (KISANGANI, D.R. CONGO)

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Abstract

Mbiye Island is located upstream of the Wagenia falls on the Congo River and covers about 56 km^2. The forest ecosystems of this island are under severe human pressure. Once covered by a dense tropical forest, it became the target of surrounding populations as a refuge, a place to practice shifting cultivation and harvest forest resources. The present study aimed to quantify the deforestation dynamics between 1990 and 2005 in order to raise awareness for the design and implementation of a conservation strategy adapted to this fragile insular environment. Landscape ecology approaches combined with GIS have shown that in 15 years, the area of original forests decreased by 20% while secondary forests increased by 5%. Areas of anthropogenic activity increased from 5.3% to 20.2% during the same period. The most affected areas are the periphery of the island and the side facing the city of Kisangani. If nothing is done for conservation of natural resource areas and to raise population awareness, then in a few years this island of great biodiversity interest, will disappear to only remain a souvenir in memory.

Introduction

Deforestation is a problem of world-wide concern because of its impacts on the ecosystems, biodiversity and the climate. Between 2000 and 2005 the annual forest loss was 13 million ha (FAO 2007), mainly in South America, Southeast Asia and the Congo Basin. During 1990 to 2005 (15 years) Africa lost more than 9% of its forest surface. The main reasons are the expanding slash-and-burn agriculture, the increasing population and the socio-political instability.

The Congo Basin contains about 20% of the world tropical moist forests and is the second largest tropical moist forest area of the world, after the Amazon and ahead of Southeast Asia. Its location around the equator makes it of specific interest in terms of conservation of biodiversity. The annual deforestation rate in the Congo Basin is estimated as 0.6% (FAO 2007). The DR Congo has about 65% of this forest cover, and these forests are threatened more and more to lose some of its faunal richness as well as numerous plant species of high commercial value through the processes of forest degradation and deforestation, with negative impacts on the ecosystems, the life styles of the local populations, and on the entire humanity because of the global climate change (MMFT 2002).

The islands along the Congo River are particularly sensitive to these forest changes, and more specific Mbiye island on the south-eastern periphery of Kisangani. It once was covered by intact, very dense forest, but now has decreasing forest cover based on satellite images. Except for floristic and phytosociological studies that had been done by the University of Kisangani on this island (Nshimba 2005, 2008), no studies were done of forest structure to gain understanding of forest dynamics. It was considered important to complete these studies with a landscape approach to relate the habitat (soil types) with forest content (biodiversity). The objective of this paper is to quantify the rate of deforestation on the island between 1990 and 2005 as basis for a conservation strategy for this very fragile insular island ecosystem.

Methods

Study area

Mbiye Island is situated in the Oriental Province, in the centre of the Democratic Republic of Congo. It is located to the southeast of the capital city of Kisangani, between 0°31' North and 25°11' East (Figure 1).

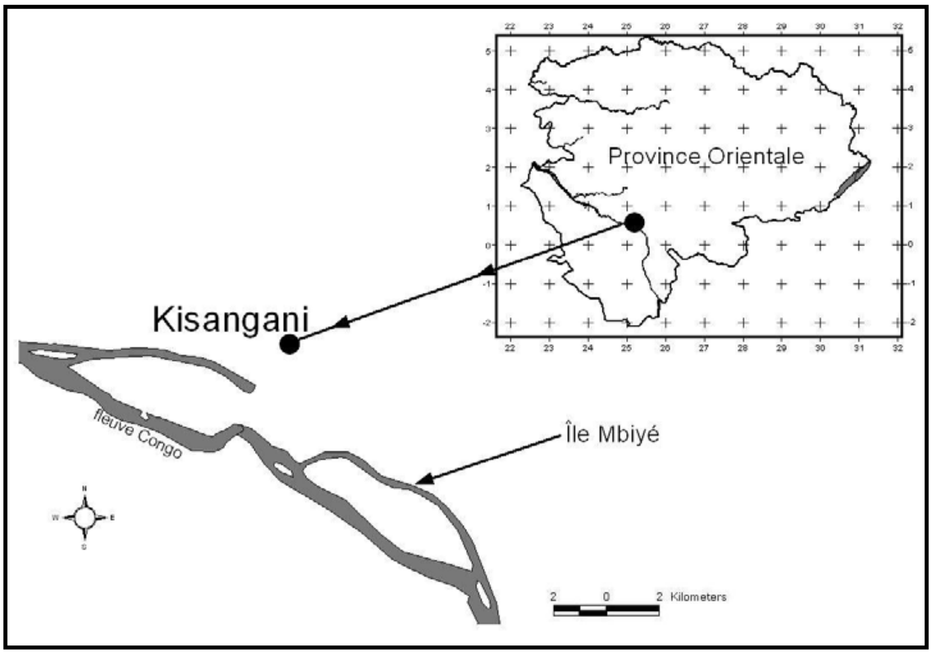

Figure 1: Location of Mbiye Island in the Oriental Province of the DR Congo.

The island within the Congo River may have an own microclimate, but no specific weather data are available for the island. The description here is based on weather data for the city of Kisangani for which the climate is classified as Köppen type Af (tropical wet). The all-year rainfall of 1,728.4 mm (range 1,417.5 mm to 1,915.4 mm) includes two short dry seasons during December-February and June-August (Nyakabwa 1982). The mean temperature oscillate between 23.5°C and 25.3°C. Two primary forest formations are recognized: rain forest on well-drained sites and swamp forest on hydromorphic soils.

During the last three decades the island experienced a major increase in people escaping from the wars and rebellions, also in the city of Kisangani (Nshimba 2008). They used the forest biodiversity for their food and medicinal needs.

Mapping

Two land-cover images for the FRM Kisangani area for 1990 and 2005 were used. The mapping was done using Arcview 3.3 and ArcGis 9.2 software. The two images were georeferenced. Three land-cover types were identified based on the objectives of the study and field experience: dense forest, secondary forest, and 'other', representing human activities (fallows, fields and bare soil). The maps were digitized based on the stains in vector format (group of pixels with a similar vector represented by a specific colour). The perimeter and area for each of the polygons were obtained from the digitization to determine the spatial configuration of the different land-cover classes of the island.

Matrix of transition

The transition matrix between two states (t_0 and t_1) is obtained from the values obtained from the GIS software and treated in Excel, i.e. a square matrix describing in condensed format the state changes of the elements of the system over the study period presented by the data (Bamba *et al.* 2008). The cells of the matrix contained the value of a variable having passed from class *i* (initial) to class *j* (final) during the active period of t_0 to t_1. The values of the columns and rows represent proportions of the areas occupied by every class of land cover for the specific period.

Areal distribution of the land-cover classes

The cumulated frequency distribution of stains representing the three land-cover types over the map area was used to compare the changes in the three land-cover types. This method avoids the use of stain classes with no information. Many classes of stains have low frequencies and use was made of where a class approaches 100% and the levelling of the curve (Bamba 2006).

Indications of spatial change were determined from the number of stains belonging to a land-cover class *j* (n_j). This indicated the fragmentation of a cover class between two periods. The increase in the number of stains of a class can be due to the degree of fragmentation of this class (Davidson 1998).

The **total area** (a_{tj}) occupied by the *j-th* class (in km²) has been calculated according to the equation (1) indicating the area of the *i-th* stain of the *j-th* class:

$$a_{tj} = \sum_{i=1}^{nj} a_{ij} \,. \qquad (1)$$

The **mean area** $\overline{a_j}$ (the mean value of the area of the stain of the *j-th* class) has been calculated according to the following formula:

$$\overline{a_j} = \frac{a_{tj}}{n_j} \qquad (2)$$

The **maximal area** $a_{\max j}$ (in km²) is the largest area given by the stains of the *j-th* class. This was calculated to show the difference between the largest and smallest areas.

The **dominance** $D_j(a)$ indicates the proportion of area occupied by the dominant stain in the *j-th* class, i.e. it shows the part occupied in the total area (a_{tj}) by the largest stain frequency of the *j-th* class noted as $a_{\max j}$ (McGarigal and Mark 1995):

$$D_j(a) = \frac{a_{\max j}}{a_{tj}} \times 100 \qquad (3)$$

$0 < D_j(a) \leq 100$: The higher the stain frequency of a class, the less the class is fragmented.
The variety or diversity of the areas of the stains of the *j-th* class, noted as $H_j(a)$, was calculated by Shannon Diversity Index (Bogaert and Mahamane 2005), given by formula (4) where *ln* represents the natural logarithm:

$$H_j(a) = \sum_{i=1}^{nj} -\left(\frac{a_{ij}}{a_{tj}} In \frac{a_{ij}}{a_{tj}} \right) \qquad (4)$$

This index measures the relative diversity of the stains relative to the level of the class. The value of $H_j(a)$ depends on the number of stains present (n_j), their relative proportions ($\frac{a_{ij}}{a_{tj}}$) and the basis of the logarithm. It is equal to 0 when the class is constituted of only one stain and its value increases with the number of stains and with the equitability between the areas covered by the stains of a class (McGarigal and Mark 1995). The index of equitability of Pielou of the areas of the stains $E_j(a)$ is calculated from the formula:

$$E_j(a) = \frac{H_j(a)}{In\ n_j} \qquad (5)$$

Where $In\ n_j$ is the potential maximum diversity (or H_{max}). The values obtained from the calculation of the diversity index H_j permit the calculation of the index of equitability or regularity (*E* or *R*). It varies between 0 (very little equitable) and 1 (good equitability between the stain classes).

Results

Mapping

The maps produced from the different analyses show the changes in the land-cover types over the 15 years between 1990 and 2005 (Figure 2). The cover types show different patterns of change in different parts of the island. There is a strong decrease in the area of closed forest and an increase in area of secondary forest and human-occupied land ('Other'). The cover type 'Other' (fallows, fields and bare soil) shows a strong expansion in the northern part of the island, closer to Kisangani, and also along the boundary of the island.

Matrix of transition

Between 1990 and 2005 land cover of the island changed with a loss of dense forest and increase in the cover of secondary forest and human-occupied (other) land (fallow, fields and bare soil) (Table 1, Figure 3). Dense forest cover decreased from 67.0% to 46.5% (net loss of -20.5%), with 17% going to secondary forest and 6.1% to 'Other', but also a 2.2% gain from secondary forest and 0.4% from 'Other', but 43.9% remained intact (undamaged). Secondary forest cover increased from 27.7% to 33.3% (+5.6%). Human-occupied land ('other') increased from 5.3% to 20.2%, with 12.1% gain (i.e. destroyed) from secondary forest and 6.1% from dense forest.

Cumulative frequency distribution of the size of individual stands by land classes

The development of the cumulative frequency curves shows that most of the stains for dense forest and secondary forest represent small areas (Figure 4), i.e. for both dense and secondary forest almost 90% of the stains represent areas smaller than 1 km² and more small stains exist in the classes of 1990 that in those of 2005 (the curves for 2005 occur below the curves for 2005). Even if the number of stains is few, they are particularly small.

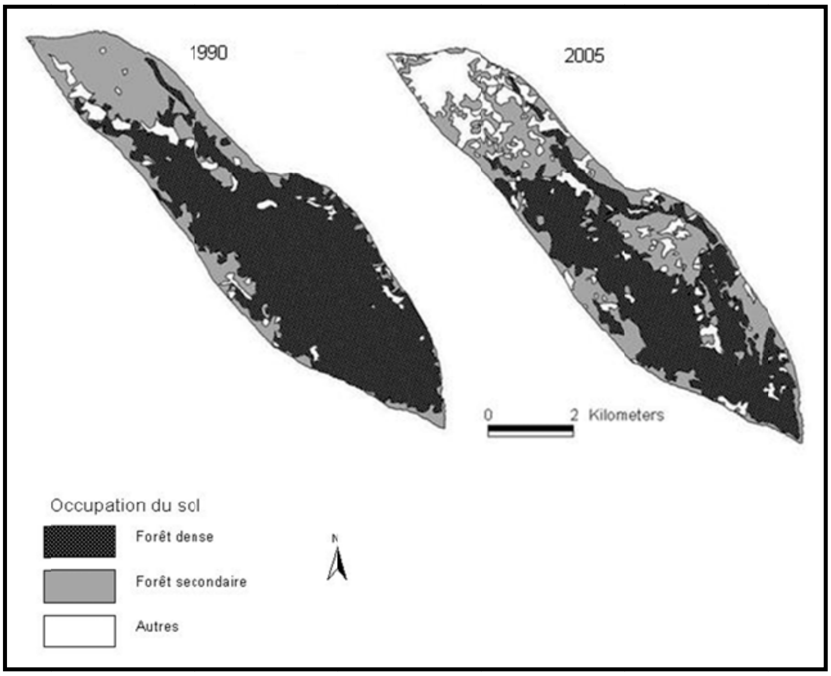

Figure 2: Maps of the three land-cover types (Occupation du sol) of closed forest (foret dense), secondary forest (foret secondaire) and human-occupied land (autres) of the Mbiye Island in 1990 and 2005.

Table 1: Matrix of transition of the land-cover types (in %) between 1990 and 2005.

	1990 cover changed to or remained as in 2005			Total 1990
	Dense forest	**Secondary forest**	**Other**	
Dense forest	43.9	17.0	6.1	67.0
Secondary forest	2.2	13.4	12.1	27.7
Other	0.4	2.9	2.0	5.3
Total 2005	46.5	33.3	20.2	100.0

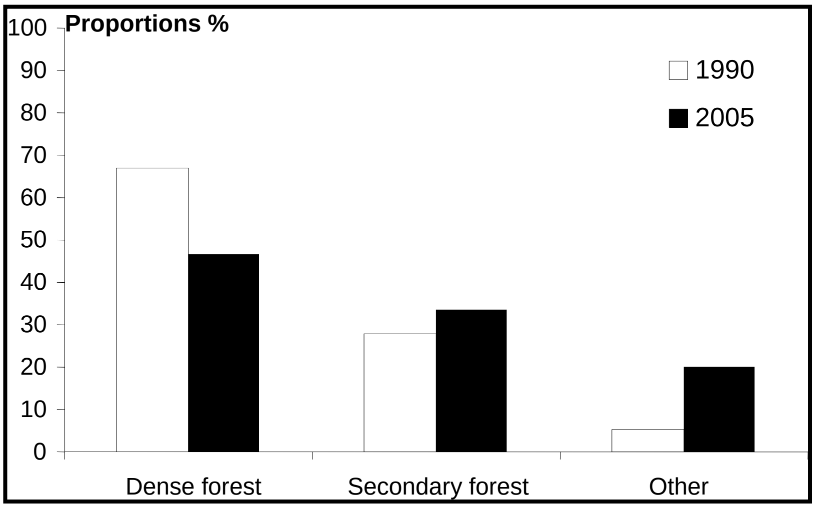

Figure 3: Proportions of the land-cover classes (dense forest, secondary forest, other as human-occupied land) of Mbiye island in 1990 and 2005.

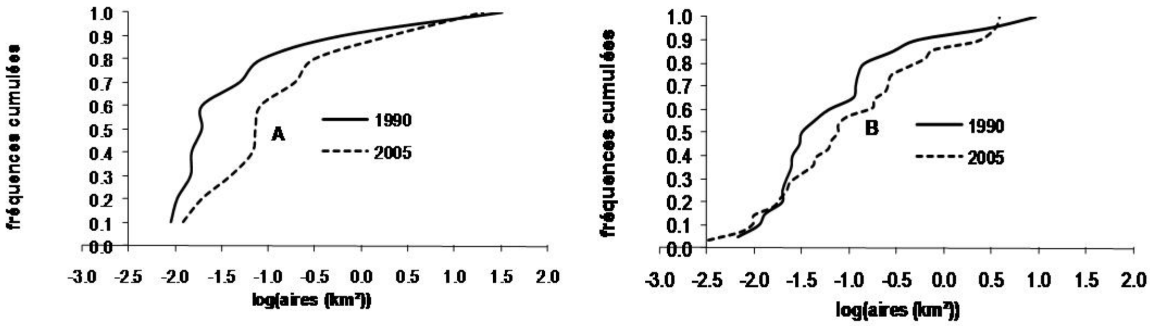

Figure 4: Curves of the accumulated frequencies of the areas of the pixels representing the cover classes of forest: A: Dense forest; B: Secondary forest.

Index of spatial structures

The indices calculated for the changes in spatial configuration and structure of the three land-cover classes on Mbiye island between 1990 and 2005 showed the spatial transformation of the forest (Table 2). For dense forest the number of stains (10 stains) remained the same over the 15 years, but the total area, mean area, the area of the largest stain and its dominance decreased, and diversity and equitability increased. In secondary forest the number of stains and total area increased, but the mean area, the area of the largest stain and its dominance in the landscape decreased, and the diversity and equitability of the areas of the stains increased. In human-occupied land (Other) the number of stains, total area, mean area, maximum area and dominance increased, but diversity and equitability decreased.

Table 2: Summary statistics for the indices of spatial structure calculated for each of the land-cover classes on Mbiye island between 1990 and 2005.

Variable	Dense forest		Secondary forest		Others	
	1990	2005	1990	2005	1990	2005
Number of stains	10	10	20	28	34	79
Total area, km^2	39.956	22.867	13.622	16.387	2.593	9.921
Mean area. km^2	3.295	2.286	0.681	0.585	0.076	0.125
Maximum area, km^2	32.115	20.017	9.178	3.879	0.463	4.116
Dominance	97.000	87.530	67.400	23.670	17.800	41.500
Diversity	0.145	0.509	1.107	2.131	2.949	2.916
Equitability	0.063	0.221	0.369	0.640	0.836	0.667

Discussion

The extent of deforestation is clearly visible on the map of the island of 2005. The northern zone, closer to the Kisangani metropole is the most affected, but also the accessible edges of the whole island. All 2005 zones of receding forest are zones that were small points of villages, fields or fallows in 1990. There is an undesirable intensification of human activities in and impact on the forests of the Mbiye island. Around the developed zones are secondary forests between the human activities and the primary forests, forming a landscape mosaic on the island similar to the landscape sequence model of Forman (1995) with the anthropogenic activities forming the core. The danger of this model is that if the diffusion of the core continues for too long, with shorter fallow periods, then the degradation will affect the remaining primary forest. In Africa, 75% of farmers take advantage of the openings to reclaim the primary forest (Gasana 2002).

In general, the forest constitutes an important economic and social value to the people in the area. Degradation of Mbiye Island is one of the main concerns for the entire population of Kisangani. It provides natural resources and food to the population but also constitutes an important economic and social capital for the future, i.e. sources of energy through biomass, traditional medicines, and a sanctuary. Deterioration of the forests through human activities is the main reason for forest loss, particularly from rural communities from different remote areas. This results directly into a deterioration of their livelihoods and endanger their life styles (Anonymous 2007). From this context, it is important to sensitize the people on the importance of maintaining the forests and its biodiversity.

Matrix of transition

The cycle of normal vegetation change in the study area constitutes in part a loss of forest towards more degraded systems, with a small component of forest recovery through forest succession (Figure 5; based on Table 1 values).

Figure 5: The reality of the cyclic change in land cover on Mbiye island near Kisangani

There is a major loss of primary forest becoming secondary forest through degradation (17%), and similarly a loss from degraded forest becoming human-occupied land (12%), following the general trend observed with slash-and-burn agriculture (Anonymous 2005). However, there is also a reverse trend, although small, of cultivated land developing through fallow land towards secondary forest, and from secondary forest developing towards more mature forest. The zones that are least affected are the swampy forests. The focus should therefore be to reverse the trend of forest degradation towards more forest recovering via secondary forest towards mature regrowth forest, and a decrease in clearing mature forest. If long fallow periods can be maintained then the development of more secondary could be expected (Locatelli 2000).

Distribution of the areas of the stains in the forest classes

The reason why the cumulative frequency curves of 1990 lie above those of 2005 (Figure 4) is that there were more small stains in 1990 that in 2005. In 1990 this may have been due to the few and small sites of human-occupied land, and the forests were presented by very few discontinuous stains. In 2005, although the numbers of stains of the two forest classes were relatively low (10 for primary forest and 28 for secondary forest; Table 2), their concentrations were dislocated in part (Figure 2). This supports the increase in equitability in these two forest classes. The people focused their activities in areas where there had been some fragmentation of the larger blocks of intact forest. This caused the decrease in area of the large stains. This situation causes a severe threat to the preservation of the biodiversity of the island because it is well-known that fragmentation of the habitat can be a source of biodiversity loss (Henry *et al.* 2007).

Indices of spatial structures

The indices of spatial configuration and structure indicated a process of spatial transformation and fragmentation of the primary forest (Bogaert and Mahamane 2005). It confirms the spatial change observed in the map for 2005 which shows the incursion of human activity into the forest. The change in total surface of secondary forest between 1990 and 2005 and the increased number of stains show that secondary forest are in a process of being created. The structure of the stains showed a decrease in the size of the largest stain which also suggests degradation in secondary forest. The increase in equitability and reduced dominance of the area occupied by the largest stain indicate a partition of the stains of these forest classes. A similar observation was made in Bas-Congo (Bamba *et al.* 2008) where the larger forests have been fragmented with parts developing into savannas, fallows and fields.

Conclusion

This study allowed a presentation of evidence, through the methods of landscape ecology and mapping of spatial change, of the degradation of the landscape of the Mbiye island between 1990 and 2005. The matrix of the vegetation of the island was dominated by primary forest (67% of the landscape in 1990) but currently large parts had been changed through human activity. This is particularly evident in the northern part, near Kisangani, and also along the edge of the island.

The transition matrix indicated that between 1990 and 2005, the primary forest receded by 20% but also gained 5% from secondary forest. Human-occupied land which covered only 5.3% of the landscape in 1990 increased fourfold to 20.2% in 2005. The landscape evolved towards a nuclear mosaic with the villages and zones of human activity occupying the central position in the process of degradation. The two forest classes (primary and secondary) of the dominant stains are characterized by large coverage (areas). Small sizes (areas) of <0.5 km² represent close to 80% of the stains, and the equitability between the stains of these classes increased. The process of spatial transformation operating in this insular landscape over 15 years caused a severe perforation and fragmentation of the primary forests. At the same time secondary forests developed both in the degradation process and through recovery. Human-occupied land expanded.

The reasons for this change are multiple, including the demographic pressure with associated livelihood needs and the different armed conflicts that raged in the region over recent years. This situation threatens the biodiversity of the island and if conservation measures are not implemented, then major losses of biodiversity could be expected. The effort of Rotary Belgium since 2000 in collaboration with the Faculty of Sciences of the University of Kisangani to create a reserve is very beneficial and merit to be sustained. But if this cannot be achieved, then the current rate of conversion of the forests on the island will in a few years cause this forest and its animal and plant biodiversity will only be a memory with severe consequences to the surrounding populations.

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WILD FAUNA MANAGEMENT IN D.R. CONGO: BATS, BIRDS AND ELEPHANT SHREWS IN YOKO FOREST RESERVE

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Abstract

Bats, elephant shrew and birds are considered important in the maintenance of the forest and therefore should form part of the management planning actions in lowland forests. This study used mist-nets to capture bats and birds and traditional traps to capture elephant shrew in primary forest, secondary forest, fallow land and cultivated land in the Yoko Forest Reserve (00°16’40.2’’ N; 25°18’90.6’’E; 435 m) near Kisangani in the Democratic Republic of Congo. A total of 213 bats, 59 elephant shrew (*Petrodromus tetradactylus*) and 76 birds were captured. The bats belong to 2 orders (Megachiroptera and Microchiroptera), 5 families and 16 species with *Epomops franqueti* the most abundant species (49.3%), followed by *Megaloglossus woermanni* (17.4%), *Rousettus aegyptiacus* (10.8%) and *Myonycteris torquata* (8.0%). Yoko forest presents an important diversity (H=2.47) and a high probability to capture different species (D=0.71). Fallow land has a high species diversity (12 of the 16 species, with 112 of the 213 individuals captured in the study). Elephant shrew prefers old fallow land as habitat. The preliminary results show that the birds observed or captured include the Blue blackbird (*Lamprotornis splendidus*), Hornbills (*Bycanistes* sp), Pigeons (*Treron australis, Streptopelia smitorquata, Turtur afer*) and bulbuls (*Andropardus* sp). The majority of forest birds observed eat the fruit and/or seed of vegetable food, but also of several tree species. The bats, birds and elephant shrew form an integral part of the main functional components of these forests and contribute to the forest ecological processes and balances.

Introduction

The reduction of lowland rainforest area through human activities is often perceived to threaten the forest animals and their habitats. The numbers of forest animals are decreasing due to habitat loss through forest degradation and deforestation, and the increase in hunting in the region. Deforestation, hunting and lack of information pose a serious problem of unsustainable forest management. Yet forest management is considered a tool of rational and sustainable use of this natural heritage and to overcome the difficulties linked to the management and maintenance of its components (flora and fauna) and the biochemical processes. Most reserves in lowland rainforest are surrounded by logging concessions. It is important that the fauna be considered in all management plans for long-term sustainable management and harvesting of the natural forest resources.

Wild animals in the Kisangani area contribute greatly to the food security of the people living around the forests. For example, studies in the central market of Kisangani showed the market importance of game animals (Belembo *et al.* 2003) and diversity of edible caterpillars (Okangola 2007); both groups are obtained from the forests.

Several processes (biological, physical, etc) maintain the rich fauna and flora diversity of the Congo Basin humid forests. Unfortunately, these natural processes are not well studied. Bats, birds, elephant shrews and caterpillars (lepidoptera) are important in forest dynamics and biodiversity maintenance, and could be useful bio-indicators. Okangola (2007) counted 12 edible caterpillar species that eat 23 plant species of which 91% are used in traditional medicine, 61% in commercial timber species, 35% in local construction and 13% as wild edible plants. The fruit-eating animals such as bats, birds and elephant shrews play a major role in pollination and seed dispersal in forests (Bonaccorso and Humphrey 1984, Ifuta 1993, Upoki 2001). They are responsible for the propagation of plants and forest regeneration. Zoochorie helps to maintain the ecological balance in forests. Charles-Dominique *et al.* (1981) claims that 75% of the plant species of tropical forests depend on fruit-eating animals (Old world fruit bats and birds) to maintain them in the forests.

Yoko Forest in the Democratic Republic of Congo (DR Congo) is a good example of humid rainforest which is protected as reserve since 1959. The lack of enforcement and protection are visible in the field. Political instability in DR Congo is a major reason for neglecting protected area management by the government. There is a lack of recent scientific studies in the Yoko area. In Yoko Forest Reserve the key animals in forest dynamics and maintenance are bats, birds and elephant shrews. Their conservation is important to maintain the forests and forest biodiversity in the sensitive ecological area around Kisangani.

The present study focuses on the bats, birds, and Elephant shrews of the Yoko Forest Reserve and aims to demonstrate the importance of the wild fauna in maintaining ecological balance of lowland rainforest .The results could be used to raise awareness of the need for sustainable management of the humid lowland forests, and could indicate the impact of forest interventions on the fauna. The local extinction or the moving of fauna could compromise the life of our forests and the local populations.

Methodology

Study area

Yoko Forest Reserve (00°16’40.2’’ N and 25° 18’90.6’’ E; 435 m) (Lomba, 2007) is located in the Kisangani ecological region between kilometer points 21 and 38 on the road between Kisangani and Ubundu (DR Congo). The reserve covers 6,979 ha. Kisangani region is characterized by an equatorial climate, high rainfall, and a constant temperature fluctuating around 25°C. The vegetation is Guineo-Congolian lowland rain forest,

Methods

Observations focused on areas of high activity levels of elephant shrew, and feeding places of bats and birds. Biological material were collected of bats (213 species in area), birds (76 species in area), and elephant shrews (59 species in area).

Vegetation transects were sampled in all habitats (primary and secondary forest, old and young fallow land, cultivated area). Traps were placed along these transects to determine the relative abundance of faunal groups in each habitat. Mist-netting was used for trapping bats and birds. For bats 20 nets were opened at sunset (18:00) and closed at sunrise (05:00) (Richter and Cumming 2006). The opposite approach was used for birds where the same nets were opened in the morning (8:00 h) and closed in the evening (17:00 h). Elephant shrews were collected with 40 traditional traps placed along particular transect lines and their holes were counted (Cobert and Neal 1965, Rathbun 1979).

Collected animals received a preliminary identification in accordance with available keys (Bergmans 1989, 1990). The morphological characters of individuals (coat or plumage color, size, morphometric data) were useful for the first stage of species determination.

Statistical data analysis included the following:

1. The relative abundance expressed in percentage: % = 100*n/N; with *n* is the observed number of individuals of a species in a sample and N the total number of individuals of all species.
2. Shannon – Wiener diversity index (H'): $H' = -\sum (pi) \log2 (pi)$; where pi is equivalent to the probability or the relative frequency of i species in relation to the total number of the species captured.
3. Simpson diversity index (D): $D = 1 - \sum (pi)^2$

Results and discussion

Bats

The bats are distributed over 2 Orders, 5 Families and 16 species. *Epomops franqueti* with 105 specimens (49.3%) is the most abundant species, followed by Megaloglossus *woermanni* (17.4%), *Rousettus aegyptiacus* (10.8%) and *Myonycteris torquata* (8.0%) (Table 1). The Yoko Forest Reserve presents an important biodiversity of bats (H= 2.47), and the probability to capture different species is great (D = 0.71).

Table 1: Systematic inventory and frequency of bats

Species	Sex		Total	%
	Female	**Male**		
Suborder: Megachiroptera				
Family: Pteropodidae; Subfamily: Pteropodinae				
1. *Casinycteris argynnis* Thomas, 1910	5	3	8	3.76
2. *Eidolon helvum* (Kerr, 1792)	0	4	4	1.88
3. *Epomophorus anurus* (Heuglin, 1864)	1	1	2	0.94
4. *Epomops franqueti* (Tomes, 1860)	56	49	105	49.28
5. *Hypsignathus monstrosus* Allen, 1861	2	2	4	1.88
6. *Myonycteris torquata* (Dobson, 1878)	6	11	17	7.98
7. *Rousettus aegyptiacus* (Geoffroy, 1810)	6	17	23	10.80
8. *Scotonycteris zenkeri* Matschie, 1894	1	0	1	0.47
Family: Pteropodidae; Subfamily: Macroglossinae				
9. *Megaloglossus woermanni* Pagenstecher, 1885	12	25	37	17.37
Suborder: Microchiroptera				
Family: Nycteridae				
10. *Nycteris arge* Thomas, 1903	1	1	2	0.94
11. *Nycteris nana* Andersen, 1912	0	1	1	0.47
Family; Molossidae				
12. *Myopterus whitleyi* (Scharff, 1900)	2	0	2	0.94
Family: Rhinolophidae				
13. *Hipposideros commersoni* (Geoffroy, 1813)	1	1	2	0.94
Family: Vespertilionidae				
14. *Mimetillus moloneyi* (Thomas, 1891)	0	1	1	0.47
15. *Neoromicia tenuipinnis* Raffinesque, 1820	3	0	3	1.41
16. *Glauconycteris beatrix* Thomas, 1901	0	1	1	0.47
TOTAL	96	117	213	100.00
S (Number of species)	16			
H (Shannon-Wiener index)	2.47			
D (Simpson index)	0.7061			

Bats were most diverse and abundant in fallow land (12 of the 16 species; 112 of the 213 individuals), followed by dwellings and cultivations (10, 90) and least in primary forest (Table 2). *Epomops franqueti* is captured in all habitats and *Casinycteris argynnis, Megaloglossus woermanni* and *Myonycteris torquata* in 3 habitats (except primary forest). Bats exploit different strata of the net according to species and types of habitats. For examples, *Eidolon helvum*, *Epomophorus anurus* and *Hypsignathus monstrosus* are among the species that fly higher and they are captured in the interval of 3 to 6 m.

The numeric dominance of bats in fallow land, cultivated land and dwellings can be explained by the variety of fruit trees that attract the bats and the ease of flight. The entanglement of the lianas in the lower forest strata restrict their flight paths and increase the probability of being captured. The open areas within the forest environment, with fruit trees, form zones of attraction and intense movement for the bats. Dudu (1991) also observed a numeric importance in small mammals at Masako. Our studies confirm the high biodiversity in the Kisangani region. The small Vertebrates and Invertebrates are not directly affected by the initial modifications of the forest habitats.

Table 2: Ecological distribution of bats captured in area of Yoko Forest

Species	**Habitats of capture**				**Capture height (m)**
	Primary forest	**Secondary forest**	**Fallow land**	**Dwellings and cultivated land**	
Casinycteris argynnis	0	1	5	2	2-5
Eidolon helvum	0	0	4	0	3-5
Epomophorus anurus	1	0	1	0	5-6
Epomops franqueti	1	2	59	43	1-6
Megaloglossus woermanni	0	2	5	30	1-6
Hypsignathus monstrosus	0	0	2	2	3-7
Myonycteris torquata	0	1	12	4	1-6
Rousettus aegyptiacus	0	0	18	5	1-5
Scotonycteris zenkeri	0	1	0	0	2
Glauconycteris beatrix	0	0	0	1	7
Hipposideros commersoni	0	2	0	0	4-5
Mimetillus moloneyi	0	0	1	0	1
Myopterus whitleyi	0	0	2	0	3-4
Neoromicia tenuipinnis	0	0	1	3	2-4
Nycteris arge	0	0	2	2	2
Nycteris nana	0	0	0	1	5
Number of species	2	6	12	10	
Total number of individuals	2	9	112	90	

Elephant shrew

Elephant shrew (*Petrodromus tetradactylus*) prefers old fallow land, where they appear to be attracted by understory plant cover of Marantaceae, Zingiberaceae and Arecaceae (Table 3). The sprouting leaves and fruits of these plants constitute essential food, and the leaves are used to decorate their holes.

Birds

Preliminary observations of the birds showed that the majority of forest species feed on the fruits and/or seeds. The blue Blackbird (*Lamprotornis splendidus*), the Hornbills (*Bycanistes* sp), Pigeons (*Treron australis, Streptopelia smitorquata, Turtur afer*) and bulbuls (*Andropardus* sp) eat the fruit/seed of vegetable foods, but fruit-eating birds were observed to use *Alchornea cordifolia*, *Xanthophyllum gillettii* (Rutaceae), *Laccosperma* sp and *Eremospatha* sp (Arecaceae), *Musanga cercopioides* (Moraceae) and *Rauwolfia vomitoria* (Apocynaceae). The group of nectar-eating birds feeds on nectar of the flowers of several tree species.

Table 3: Number of elephant shrew (*Petrodromus tetradactylus)* captured in different forest habitats in the Yoko Forest area

Habitats	**Number**	**%**
Primary forest	1	3,5
Secondary forest	3	10,3
Old fallow land	25	86,2
Total	29	100

Conclusion

Lowland rainforests provide a habitat for a variety of animal species in Yoko forest. Animals feed, reproduce and find shelter in the forest. The animals studied are an integral part of the main functional components of the rainforests. They contribute to their ecological balances by dissemination of plant species, reduction of some destructives insects and fertilization of the forest soils. The higher frequency of occurrence of all bat species in areas of fallow land, cultivated land and human dwellings indicate that such areas contribute an import part of the faunal diversity. The elephant shrew is also more abundant in old fallow land. It is possible that some of these animals could be used as bio–indicators of forest condition and their assessment will be important in forest management activities to ensure the sustainable management of the functional renewable natural forest resources, involving all its components.

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RESILIENCE OF SUDANIAN SAVANNA-WOODLANDS IN BURKINA FASO

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Abstract

The savanna-woodlands of West Africa have been subject to disturbance by fire, grazing and tree cutting for centuries. Often the disturbance is severe, for instance when a thick patch of 4 m tall perennial grass catches fire late in the dry season or man decides to clear-cut an area. Fortunately Mother Nature is very forgiving and the woodlands show remarkable resilience.

Research plots were established in the Laba and Tiogo State forests in Burkina Faso in 1992. The plots have been monitored by research institutions from Burkina Faso and Sweden ever since. The results show great inter-annual variation in grass species richness, abundance and diversity at both sites. The combined effects of fire, grazing and tree cutting were limited and varied between life forms. Grazing tended to favor diversity of perennial grasses and fire affected the richness of annual grasses. The herbaceous biomass was reduced by the presence of livestock but the effect was not statistically significant for early fire or selective tree cutting. Fire had a homogenizing effect at the species level with increased biomass of the most abundant annual grass *Loudetia togoensis* and decreased biomass of the most abundant perennial grass *Andropogon gayanus*. Fire, grazing and selective tree cutting acted independently on the population dynamics of tree saplings. Many responses are site or species specific which accentuates the importance of landscape-level approaches to understand the impacts of disturbance on structure and function of the savanna ecosystems. The lack of treatment results at some levels clearly show how resilient the woodlands are to disturbance.

Introduction

Savanna vegetation varies considerably in structure and is characterized by mixtures of scattered trees or scattered clumps of trees and an herbaceous layer (Bourliere and Hadley 1983, Cole 1986, Frost *et al.* 1986, Scholes and Walker 1993). Savanna ecosystems are often subjected to multiple disturbances, such as grazing, fire and tree cutting (Breman and Kessler 1995). These are major factors that shape productivity, diversity and community organization (McNaughton 1983, van Langevelde *et al.* 2003).

Disturbance is known as any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resource pools, substrate availability, or the biophysical environment (White and Pickett 1985). It may be natural or anthropogenic in origin (Turner *et al.* 2003) and may lead to sudden or gradual, dramatic or subtle changes in ecosystems (White and Jentsch 2001). Disturbances are ubiquitous, inherent and unavoidable and affect all levels of biological organization from individual to ecosystem and landscape with consequences and mechanisms differing at each hierarchical level (Rykiel 1985). They are the primary causes of patchiness and heterogeneity in ecosystems (Turner *et al.* 2003) and are evolutionary forces causing adaptation in the biota exposed to them (Darwin 1859, McNaughton 1983, van Langevelde *et al.* 2003). The effects of disturbances are often contingent on the frequency, intensity and timing of their interactions, on the past and present states of the system and their interaction with future events (Frost *et al.* 1986).

Generally, after disturbance some species may increase or invade while other decrease or retreat (Gibson and Brown 1991). Such functional adaptations underlie two mechanisms of ecosystem response to disturbance; i.e. complementarity and redundancy (Walker 1992) that contribute to ecosystem stability and resilience (Holling 1973). Ecosystem stability is known as the probability of all species persisting and is enhanced if each important functional group of organisms (important for maintaining function and structure) comprises several ecologically equivalent species, each with different responses to environmental factors (Walker 1995). Resilience is defined as "the capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks" (Walker *et al.* 2004). It represents the property of an ecosystem that enables it to resist displacements in structure or function when subjected to a disturbing force and is often referred to as inertia (Gunderson 2000, Westman 1978). A regime shift, then, initially represents a loss of resilience, in that former function, structures, feedbacks, and therefore identities (Folke *et al.* 2004) give way to new versions. Feedbacks between processes stabilize phases and make reversals in the vegetation phase unlikely (hysteresis) (Westman 1978). Walker *et al.* (2004) explores four aspects of resilience where the first three can apply both to a whole system or the sub-systems that make it up: latitude, resistance, precariousness and panarchy. Latitude is the maximum a system can be changed before loosing its ability to recover. Resistance is how difficult it is to change the system; precariousness is how close the current state of the system is to a threshold; and panarchy cross-scale interactions and influences from states and dynamics at scales above and below, for instance policies, market shifts or climate change. An ecosystem can adapt or transform post-disturbance.

There are two opposing views on disturbance dynamics in savanna ecosystems: the equilibrium and non-equilibrium paradigms (Tainton *et al.* 1996). Certain savannas have been considered to be stable ecosystems, whose dynamics consist of fluctuations around one or more steady states or points of equilibrium (Walker and Noy-Meir 1982, Lamprey 1983), to which they return after disturbance. Other savanna ecosystems, however, particularly in arid and semi-arid environments, follow non-equilibrium dynamics in that a steady state is never achieved (Skarpe 1992). In these systems, abiotic factors (notably rainfall distribution, amount and intensity) seem to have an overriding influence on vegetation dynamics than do disturbance agents per se. Dynamics in disequilibrium systems are characterized by periods of rapid change resulting from the coincidence of various factors (e.g. intense grazing following a drought) followed by periods when the system is relatively insensitive to manipulation. The mainstream or orthodox view adheres to the equilibrium theory, which postulates that once disturbance in a system (e.g. vegetation community) occurs, the system's state either returns to its former equilibrium or equilibrates within a new "domain of attraction" (Tainton *et al.* 1996).

Ecosystem resilience is an integral part of sustainable development for numerous economic, social and cultural reasons (Adger 2000). For instance in Burkina Faso in West Africa, the natural forest currently cover approximately 26% of the country's land area (274 200 km^2). The remaining woodlands and dry forests are preserved in 86 State Forest Reserves, which were established for wood production and biodiversity conservation (Bellefontaine *et al.* 2000). Therefore, it is crucial to understand the resilience of the ecosystem to unavoidable disturbance (fire, grazing and wood cutting) in order to forecast future changes, facilitate ecologically informed management decisions and to balance ecosystem conservation and societal consumption needs (Turner *et al.* 2003). Although assessing resilience and stability is clearly important, it is also difficult. Some authors suggest using a wide variety of stressors and disturbances (Mooney *et al.* 1991). However such in-depth analyses are expensive and often not feasible, especially from a management standpoint. A solution is to assess resilience using experimental disturbances, an approach that has been used by a number of authors in various ecosystems (Cole 1995, Walker *et al.* 1997, Lavorel 1999, Savadogo *et al.* 2007a, Slocum and Mendelsshohn 2008).

In this study, we present the results from 16 years of data (1992-2007) on the resilience of a Sudanian savanna-woodland ecosystem to experimental disturbances (e.g. grazing, prescribed early fire, selective tree cutting and their interactions). We argue that the resilience of dry savanna woodlands to disturbances covering a range of frequency and intensities is a reason why we have not been able to show statistical significance for some treatments or treatment combinations on the structural and functional components of the savanna-woodland ecosystem. Also the resilience is a result of the diversity of recovery strategies coexisting in the communities and stochastic environmental variability, such as rainfall.

Material and methods

Study area

The experimental sites are located on flat areas in Laba (11°40' N, 2°50' W) and Tiogo (12°13' N, 2°42' W) State forests (forêts classées), both at an altitude of 300 m a.s.l in Burkina Faso, West Africa (Figure 1). The Laba and Tiogo State forests were delimited by the colonial French administration in 1936 and 1940 and cover 17 000 ha and 30 000 ha, respectively. Both forests are located along the only permanent river (Mouhoun, formerly known as Black Volta) in the country. The unimodal rainy season lasts for about six months, from May to October. Based on data collected from an in situ mini-weather station at each site, the mean annual rainfall during the period 1994-2003 was 883 ± 147 mm for Laba and 856 ± 209 mm for Tiogo, and the number of rainy days per annum was 75 ± 16 for Laba and 70 ± 9 for Tiogo (Figure 2). Mean daily minimum and maximum temperatures ranged from 16°C to 32°C in January (the coldest month) and from 26°C to 40°C in April (the hottest month). Most frequently encountered soils are Lixisols (Driessen *et al.* 2001), and the soil at Laba is shallow (<45 cm depth) silty-sand while it is mainly deep (>75 cm) silty-clay at Tiogo. These soils are representative of large tracts of the Sudanian Zone in Burkina Faso (Pallo 1998).

Phyto-geographically, the study sites are situated in the Sudanian Regional Centre of Endemism in the transition from the north to south Sudanian Zone (Fontes and Guinko 1995). The vegetation type at both sites is a tree/bush savanna with a grass layer dominated by the annual grasses *Andropogon pseudapricus* Stapf. and *Loudetia togoensis* (Pilger) C.E. Hubbard as well as the perennial grasses *Andropogon gayanus* Kunth. (dominant in Tiogo) and *Andropogon ascinodis* C.B.Cl. (dominant in Laba). The main forb species are *Cochlospermum planchonii* Hook. F., *Borreria stachydea* (DC.) Hutch. and Dalz., *Borreria radiata* DC. and *Wissadula amplissima* Linn. Species of the families Mimosaceae and Combretaceae dominate the woody vegetation component at both sites. In terms of basal area, the main woody species are *Detarium microcarpum* Guill. & Perr., *Combretum nigricans* Lepr. ex Guill. & Perr., *Acacia macrostachya* Reichenb. ex Benth., *Entada africana* Guill. & Perr., *Lannea acida* A. Rich., *Anogeissus leiocarpus* (DC.) Guill. & Perr. and *Vitellaria paradoxa* C.F. Gaertn. Prior to the start of the experiments, the mean basal area of woody species at Laba was 10.7 m^2 ha^{-1} and 6.3 m^2 ha^{-1} at stump level (20 cm) and at breast height (130 cm), respectively, with the stand density of 582 individuals ha^{-1} having at least one stem >10 cm GBH (girth at breast height). At Tiogo, the equivalent figures were 10.9 m^2 ha^{-1} at stump level, 6.1 m^2 ha^{-1} at breast height and 542 individuals ha^{-1}. Both sites were frequently grazed by livestock and wild animals and burnt almost every year during the dry season (November to May) since long before the start of the experiment. The presence of livestock in the two State forests varies spatially and temporally, occurring mainly during the rainy season (June to October) when the grass is green and the surrounding areas are cultivated. During the dry season, they graze on straws in the bush clumps that have escaped the fire as well as the young shoots of perennial grass species and young woody foliage induced by the fire.

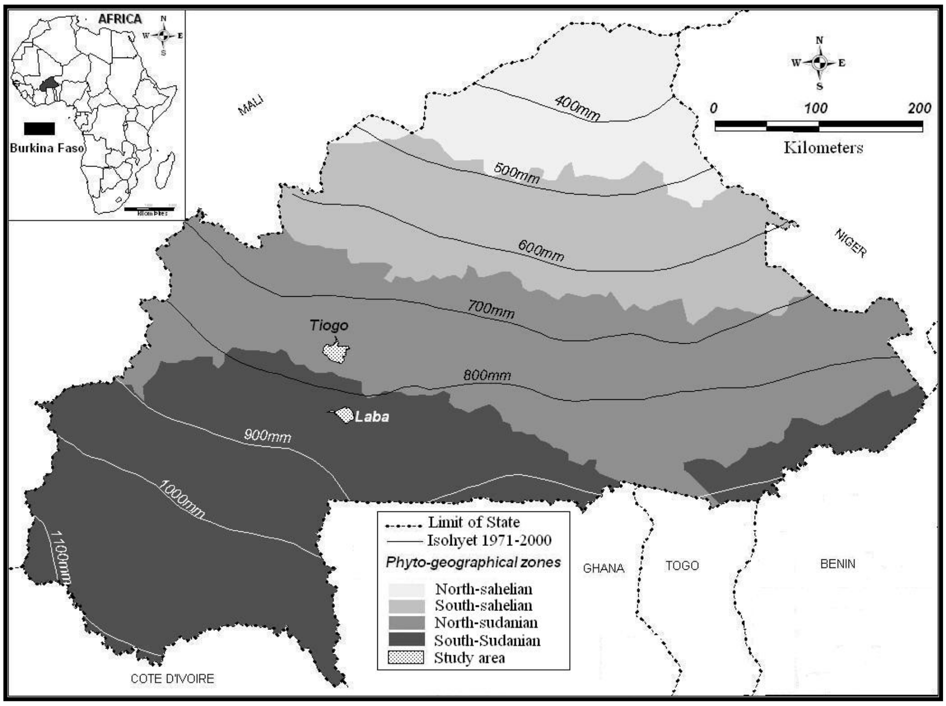

Figure 1: Vegetation map of Burkina Faso with isohyets and location of the two study sites (Readapted April 2007 by CTIG/INERA/Burkina Faso after Fontes and Guinko (1995) and Direction of the National Meteorology)

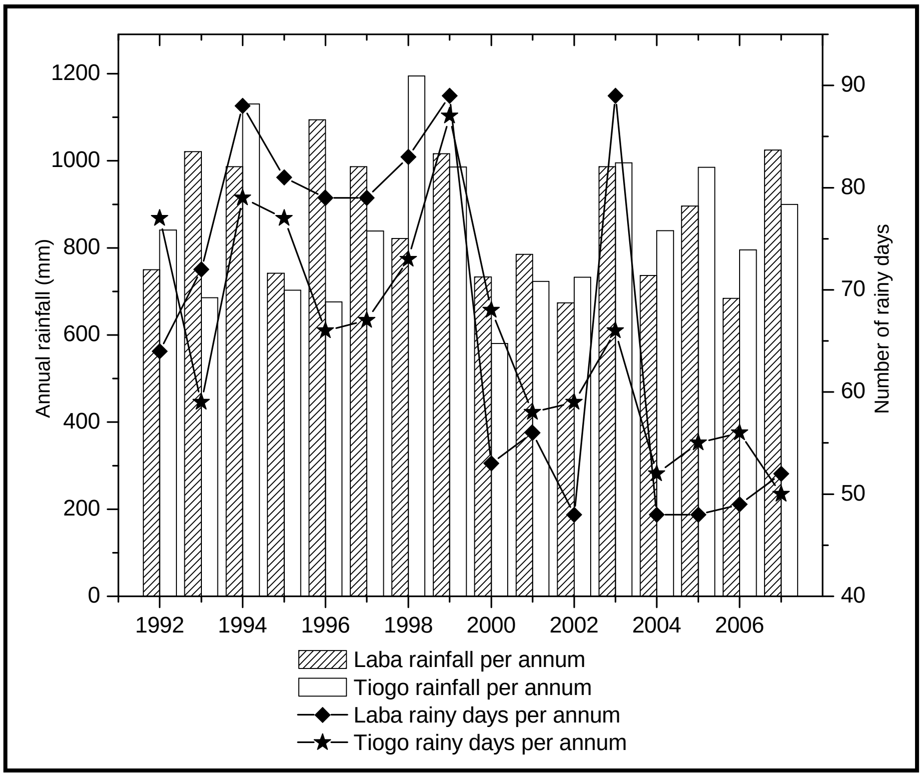

Figure 2: Annual rainfall and number of rainy days for Tiogo and Laba across the study period.

Experimental design

A factorial experiment was established in one experimental site in each of the two State forests to examine stability and resilience of the savanna-woodland ecosystem to experimental disturbances (e.g. grazing, prescribed early fire, selective tree cutting and their interaction). Each experimental site (18 ha) was divided into eight blocks (2.25 ha each); four of which were fenced to exclude livestock (hereafter referred to as non-grazed plots) and the other four were open for grazing (hereafter referred to as grazed plots). Each block was further divided into four plots of 0.25 ha (50 × 50 m), separated from each other by 20 – 30 m fire-breaks (Figure 3). The following treatments were randomly assigned to the four plots within each block: no cutting – no fire, no cutting – early fire, cutting – no fire, and cutting – early fire. The selective cutting was done in December 1993 at Tiogo and a month later in January 1994 at Laba by removing 50% of the merchantable standing volume. Prior to cutting, all species were categorized according to their local uses as protected species, timber, poles and fuel wood, and others (Hagberg *et al.* 1996, Sawadogo 1996). Except protected species, individuals of other categories were cut according to the following size criteria: >30 cm butt diameter for timber species, >14 cm diameter at stump level for poles and fuel wood species and >8 cm diameter at stump level for others (Sawadogo *et al.* 2002). The prescribed early fire was applied at the end of the rainy season (October – November) each year beginning 1993 when the grass layer humidity was approximately 40%. The grazing plots at both study sites were open for grazing by livestock (a mixed herd of cattle, sheep and goats). The livestock carrying capacity in Laba forest was 1.0 tropical livestock unit ha^{-1} (TLU ha^{-1}) and that of Tiogo was 1.4 TLU ha^{-1} (Sawadogo 1996) and the grazing pressure at both sites was about half of this capacity (Sawadogo *et al.* 2005).

Data collection

Herbaceous layer

Structural characteristics of the herbaceous layer at the two sites were assessed every year from 1992 onwards. The point-intercept sampling procedure (Levy and Madden 1933) was used to gather species-cover data annually at the end of the rainy season (September to October) when most of the species are flowering and fruiting, thus facilitating species identification. The presence of species was recorded along a 20 m permanent line laid in each plot. At every 0.20 m a pin of 6 mm diameter, taller than the maximum height of the vegetation was lowered from above; and a species was considered as present if the pin hit any of its live parts. Identification of species and families of plants followed Hutchinson *et al.* (1954). Abundance, species richness and diversity were computed for each replicate in each treatment, for each life form (annual grasses, perennial grasses and forbs) and for some selected species (*Andropogon ascinodis* and *Diheteropogon hagerupii* at Laba and *Andropogon gayanus* and *Loudetia togoensis* at Tiogo).

The functional characteristics examined included phytomass and nutrient concentration of four grass species (Savadogo *et al.* 2005, 2008a). The herbaceous phytomass was annually collected from six quadrats (1 x 1 m) in each burned and protected plot from 1992 onwards. The location of these quadrats was chosen systematically to avoid selecting the same location in consecutive years. Plants were harvested manually by cutting at the base (Fournier 1987), approximately 10 cm above-ground each year at the beginning of the dry season. The samples were sorted by species, bagged, air-dried until constant mass and weighed to determine dry matter content. In each plot, plant litter was also collected, and its weight determined. Fire treatment effect on nutrient concentration was restricted to two annual (*Chasmopodium caudatum* Stapf. and *Rottboellia exaltata* Linn.) and two tufted perennial grasses (*Andropogon gayanus* Kunth and *Diheteropogon amplectens* W.D. Clayton) due to budget constraints. The chosen species are sources of quality forage and conserved fodder for livestock production in the study area. Further functional studies included the effects of grazing intensity at four levels (light grazing, moderate grazing, heavy grazing and very heavy grazing) and fire at two levels (early burning or long-term fire protection) on above-ground phytomass and soil physical and hydrological properties (Savadogo *et al.* 2007a).

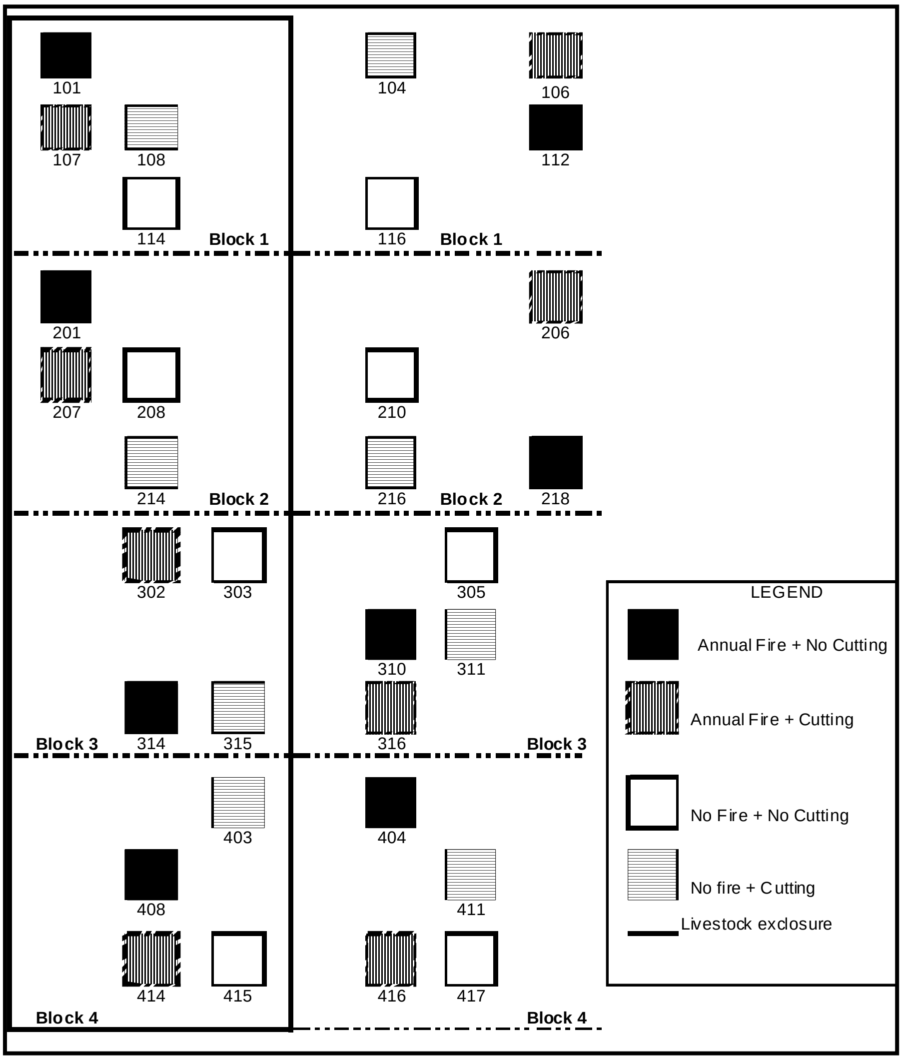

Figure 3: Lay-out of the factorial experimental design employed.

<u>Tree layer</u>

The study plots were assessed during the dry season January to May in 1992 (Laba and Tiogo), 1996 (Tiogo), 1997 (Laba), 2002 (Laba and Tiogo) and 2007 (Laba and Tiogo). The following parameters were recorded in each 50 × 50 m plot: species name, number of stems per individual, stem height, girth at 20 cm and at 130 cm (girth at breast height or GBH) along the stem (for stems ≥10 cm girth). Total stem length was measured for all stems including those that did not reach the 10 cm girth limit using a height-measuring pole (for stem ≤6 m) or a clinometer (for stem ≥6 m). Species were identified according to Hutchinson *et al.* (1954). The following structural and functional characteristics were calculated: tree basal area for each tree, stocking rate (stems/ha), standing total tree basal area and mean annual increment.

At both experimental sites, the sapling populations were inventoried in 1992 (before applying the treatments) then ten years later in 2002. The seedlings were assessed in 1992, 1997 and 2002 at Laba. The following parameters were recorded in each 50 × 50 m subplot: species name, number of stems per individual, stem height, girth for stems ≥10 cm girth at stump level; GBH for stems ≥10 cm GBH. Changes in species richness and population density were calculated for both sapling and seedling populations. Height class distribution and growth attributes were also investigated.

Stumps from cut trees were surveyed annually at the end of the dry season (May). The following parameters were recorded: stump mortality (stumps have not sprouted or the shoots have died), height (or length along the stem if the shoot is leaning) of stems, girth at stump height and at breast height (stems >10 cm GBH). We assumed a stem >10 cm GBH, which corresponds to a height of about 2 meters, could withstand browsing and fire. This threshold value is based on the assumption that self-thinning takes place among stems <10 cm GBH and therefore girth and basal area has not been measured for these stems. In analogy with seedlings and saplings in sexual reproduction the number of stems below this threshold value (<10 cm GBH), represents the recruitment of "future stems" per stool. Stump mortality for each year was calculated as number of stools recorded dead divided by number of stumps at the start in 1993. Girth for stems >10 cm GBH was measured in centimeters with a tailor-tape and the basal area was calculated per stool. Stem height was measured with a graded pole.

Data analyses

Data in these studies on herbaceous and woody vegetation were subjected to analysis of variance (ANOVA) using the SPSS software package (Copyright SPSS for Windows, Chicago: SPSS Inc.). The general linear model (GLM) univariate or repeated measures was chosen as deemed applicable. The dataset was checked for normality before analysis. Means that showed significant differences at $p < 0.05$ were compared using Tukey's pair-wise comparison procedures. Linear regression analyses, where total annual rainfall (mm/yr) and number of rainy days were used as predictor variables, and vegetation attributes as responses, were performed to examine the inter-annual variability. A series of multivariate ordinations techniques, namely Principal Component Analyses (PCA) using Simca-P software (Copyright: Umetrics AB, Sweden, 2000) and Principal Response Curves (PRC) analysis using the software package CANOCO 4.5 (ter Braak and Smilauer 2003), were performed to explore the response of herbaceous and seedling populations to experimental disturbances over time at the individual species level. In all analyses, if disturbance had no significant effect on the measured structural or functional parameter in any period of assessment, we assumed that the ecosystem is resistant to the disturbance.

Results

Effect of livestock grazing

The main effects of moderate livestock grazing on total species richness, abundance and diversity of herbaceous flora were not significant at either of the experimental sites, except total abundance of the herbaceous flora, which tended to be higher on ungrazed than grazed plots at Tiogo (Savadogo *et al.* 2008b). Among life forms, perennial grasses tended to be more abundant on ungrazed than grazed plots at Laba while they tended to be more diverse on grazed than ungrazed plots at Tiogo (Savadogo *et al.* 2008c). The main effect of grazing on abundance was generally positive for the herbaceous vegetation community throughout the study period; particularly these treatments favored species such as *Loudetia togoensis*, *Andropogon fastigiatus*, and *Andropogon pseudapricus* (Savadogo *et al.* 2008c).

There was large inter-annual variation of above ground biomass during the study period (Savadogo *et al.* 2005, 2007a, 2008a). Also an inverse relation was seen between species richness and above ground phytomass; highest pasture yield was measured during a season with average rainfall. The quantity of plant litter on the ground varied depending on the intensity of grazing (Savadogo *et al.* 2007a). There was a significant reduction of mean total herbaceous biomass which reduces the risk of fire and fire severity (Sawadogo *et al.* 2005). But there was a statistically significant effect on some herbaceous species and growth forms. Grazing reduced the biomass of forbs at the two sites, annual grasses at Tiogo and perennial grasses at Laba. The species specific response was site specific and grazing increased the biomass of the perennial grass *Andropogon ascinodis* at Tiogo and decreased the biomass of the perennial grass *Andropogon gayanus* at Laba (Sawadogo *et al.* 2005).

Moderate livestock grazing did not have a significant effect on all species and size classes confounded basal area at neither Laba nor Tiogo. The treatment had significant increasing effect, however, on fuel wood species in Tiogo (p=0.004). Livestock had significant increasing effect (p=0.021) on the total basal area growth at Tiogo, but not at Laba. Livestock did not have any significant impact on the basal area growth of small trees (≤10 cm girth at stump level ≤40cm) at neither Laba nor Tiogo (unpublished data). Total seedling population density tended to be lower on grazed than on ungrazed plots (Zida *et al.* 2008). Sapling species richness increased on both grazed and ungrazed plots from 1992 to 2002 at the two sites. However, the total sapling density at Tiogo was not affected by grazing, but the density of single-stemmed individuals increased significantly over the study period on ungrazed compared to grazed subplots while the density of multi-stemmed individuals tended to increase on grazed compared to ungrazed subplots. At Laba, grazing did not affect the rates of change in total density and the density of multi-stemmed or single-stemmed individuals (Zida *et al.* 2007). The presence of livestock had several effects on coppices (Sawadogo *et al.* 2002): stool mortality was 7–8 points lower every year; basal area per stool was larger after the fourth year; height of stems >10 cm GBH were slightly shorter; number of stems >10 cm GBH per stool was higher starting from the fourth year.

Prescribed early fire

The main effects of fire on total species richness, abundance and diversity of herbaceous vegetation were not significant at neither Laba nor Tiogo; however fire tended to influence the richness of annual grasses at Tiogo, and abundance and diversity of perennial grasses at Laba (Savadogo *et al.* 2008b). The effect of prescribed fire was not significant for the mean total biomass at either site. At the growth form level, however, the treatment had a tendency to increase the biomass of annual grasses and to decrease the biomass of perennial grasses at both sites. The forb biomass increased only in Tiogo (Sawadogo *et al.* 2005). At the species level, early fire significantly reduced above-ground phytomass of *Andropogon gayanus* (Savadogo *et al.* 2005, 2008a). The opposite effect was found for *Loudetia togoensis* at both sites. Early fire significantly reduced mean palatable species crude protein, neutral detergent insoluble crude protein and concentrations of Ca, Fe, and Mn (Savadogo *et al.* 2008a).

There was no effect of fire on the total basal area growth. Prescribed fire had, however, significant impact on the total basal area growth of small trees at both Laba and Tiogo ($p=0.001$ and $p=0.020$ respectively). Significant impact on the growth of fuel wood species was only found at the Laba site ($p=0.02$) where fire protection led to an almost four-fold increase in the basal area growth of both the fuel wood species and the total basal area (unpublished data).

For seedlings, fire significantly influenced the relative change in species richness of single-stemmed individuals, which also showed an inter-annual variation (Zida *et al.* 2008). Also, single-stemmed species richness was higher on unburnt than on burnt plots, and they were more numerous during the first half of the study period (1997) than the remainder of the study period (Zida *et al.* 2008). Fire did not have a significant effect on temporal variation in total density of seedlings. The main effect of fire on sapling species richness was significant at both study sites. After 10 years of annual early fire, the proportional increase in sapling species richness was at least three times higher in the unburnt than burnt subplots at both Laba and Tiogo (Zida *et al.* 2007).

With regard to coppice growth: there was no statistically significant difference in the stool mortality and basal area per stool between the fire regimes. However, there was a trend to decreasing mortality for early fire compared to 2-year initial fire protection. Overall coppice stems were significantly more numerous for no fire than for fire regimes in 1996 and 1998–99. There was no difference between fire regime treatments but a tendency towards more stems >10 cm and fewer stems <10 cm GBH per stool with no fire than for the prescribed fire treatments (Sawadogo *et al.* 2002).

Selective tree cutting

Selective tree cutting affected neither the total species richness nor abundance or diversity of herbaceous flora at both experimental sites. Further, selective cutting had no effect neither on species richness, abundance nor diversity of different life forms (Savadogo *et al.* 2008b).

Mean total biomass during the study period was not significantly influenced by selective cutting (Sawadogo *et al.* 2005). However, the different herbaceous growth forms (annual grasses, perennial grasses and forbs) reacted differently to the treatment. Annual grass biomass increased at Tiogo, while there was a tendency towards reduction for the perennial grasses. Selective tree cutting did not affect woody recruitment (Zida *et al.* 2007). Also sapling species richness did not vary significantly between cut and uncut subplots at both study sites (Zida *et al.* 2007).

Combined effects of treatments

For herbaceous structural characteristics, none of the treatment combinations had significant effects at both experimental sites, except fire and cutting treatment that tended to influence the total species richness and abundance of herbaceous flora at Laba (Savadogo *et al.* 2008b). At life form level, the combined treatment of fire and grazing tended to reduce the richness of forbs at Tiogo while it tended to increase their diversity more than either grazing or fire. With regards to phytomass production, treatment combination effect was site, species and life form specific (Sawadogo *et al.* 2005).

At both sites the combination of fire and livestock grazing had a significant effect on all species and size classes confounded (p=0.039). This effect was not found on fuel wood species. In Tiogo the combined effect of these two treatments was significant for the smallest size class both in 1996 and 2002 (p=0.000). In 2002 there was also an effect on the next size class (p=0.013) (unpublished data).

None of the treatment combinations had a significant effect on seedling density. The relative change in density of multi-stemmed individuals also remained the same during the study period on all plots but it tended to be higher on plots subjected to fire-grazing treatment than on grazed plots (Zida *et al.* 2008). The interactive effects of grazing, fire and selective cutting had no significant effect on the sapling attributes (Zida *et al.* 2007).

Discussion

Results from the present experiment show that savanna-woodland ecosystems resist experimental disturbances or recover from it; in other cases the ecosystem appears to shift to an alternative state. For instance grazing had no effect on total species richness and diversity of herbaceous vegetation at either of the experimental sites. This could be explained by the grazing intensity on the site which was half the carrying capacity. This intermediate level of grazing disturbance could have enhanced species survival allowing succession to proceed (Olff and Ritchie 1998). Also the experimental sites have been subjected to various disturbances, such as bush fire and grazing by domestic and wild animals for many years prior to the establishment of the experiment, thus the species might be adapted to herbivory. Further, high resilience to grazing observed in species-rich herbaceous and woody layers presumably resulted from the efficient regeneration strategies (with abundant seed production and a soil seed bank) as well as from intra-population diversity in these strategies. Similar findings have been reported for other types of ecosystems (Lavorel 1999, Pagnotta *et al.* 1997).

The effects of grazing on vegetation structure and function were often site, life form or species specific and characterized by a great inter-annual variation at both sites. This is in agreement with the fact that resilience indicators or measures are often site and species specific (Lugo *et al.* 2006). It also indicated that in the studied ecosystem some components may be more resilient than others as generally established for various ecosystems (Westman 1978). For example, grazing tended to reduce the abundance of herbaceous flora, particularly the abundance of perennial grasses at Laba while favoring the performance or establishment of individual species (abundance of *Loudetia togoensis*, *Andropogon fastigiatus* and *Andropogon pseudapricus*, and increased biomass of the perennial grass *Andropogon ascinodis*). This could be related to trampling effect (Hiernaux 1998), which in turn is related to the species ability to resist trampling-induced changes, their tolerance to a cycle of disturbances and their resilience following cessation of trampling (Cole 1995). This is particularly true for those resilience attributes that are species specific such as the ability to resprout or the nutrient-use efficiency. The inter-annual variation found at the experimental sites could be related to species-specific responses to climatic change (mainly amount and distribution of the rainfall) or species' flexibility and resilience to drought.

The lack of marked change in overall abundance, richness and composition emphasizes the resilience to fire of the savanna-woodland system to long-term fire exclusion and prescribed burning. The time and frequency of burning strongly influence the effects of fire on savanna productivity (Jensen and Friis 2001). Generally, burning occurring at the end of the dry season is more destructive (Trollope and Tainton 1986); thus it may disrupt the "savanna equilibrium". Fire burning early in the dry season tends to be of low intensity as the predominantly herbaceous fuel still holds moisture from the wet season (Liedloff *et al.* 2001). Given that fire is a prominent feature of most savanna ecosystems in the Sudanian zone (Menaut *et al.* 1991), it is not surprising that there was no effect of the fires on the herbaceous layer richness since species might be adapted. For instance some species may have adopted resistance or adaptation strategies to fire related cues for germination (Dayamba *et al.* 2008). Further, the high resilience to different fire regimes was most likely related to the wide diversity of regeneration strategies which ranged from vegetative resprouting to germination from soil-stored seed banks (Whelan 1995).

The results indicated that the overall main effect of selective cutting of trees was not significant for herbaceous structural and functional characteristics as well as woody recruitment. The lack of significant effect could be related to the extent of cutting disturbance. It should be noted that the selective cutting treatment was applied once by extracting 50% of the basal area of all trees; therefore, the competition for light, water and nutrients might be determined by initial density of trees. For instance, if tree density was high before cutting, selective cutting of trees might reduce the competition for resources among herbaceous species and thus have a clear effect (Savadogo *et al.* 2008b). Vegetation resilience in such a case depend on how the species interacts with other species, for competition for nutrients, light and water (Peterson *et al.* 1998) when the woody canopy is open after selective tree cutting.

Some of the combined effects of annual early fire, grazing and selective tree cutting found were life form and site specific, which indicated that some components of the ecosystem may be more resilient than others as generally established for various ecosystems (Westman 1978). Furthermore, additive effects involving grazing, fire and selective cutting combinations were often detected for species individually. Such limited additive effects of grazing and fire have been observed in other semi-arid plant communities (Belsky 1992, Valone 2003, Valone and Kelt 1999). For example, the combined effects of fire and grazing on vegetation attributes (Savadogo *et al.* 2005, 2008b, 2008c, Zida *et al.* 2007, 2008) could have resulted from different sets of species responding positively or negatively to each disturbance or from the fact that fire simply duplicated the effect of grazing by reducing above ground biomass. Herbivory at the site reduce fuel load by herbage removal and trampling and therefore lower intensity of fires (Savadogo *et al.* 2007b). It should be noted that treatment combinations also tended to show significant inter-annual variation, suggesting temporal variability in grazing and fire intensities, as well as stochastic factors in nature such as the correlation of rainfall with vegetation attributes.

Conclusions

It seems that the Sudanian savanna-woodlands, in the experimental areas, follows the non-equilibrium dynamics as evidenced from the highly significant inter-annual variation in herbaceous flora while the effects of fire, grazing and selective cutting were limited and minimal. Based on the data from these experiments, the following conclusions could be drawn:

- Prescribed early fire is a good compromise between the utopian total fire exclusion idea and devastating late fire, but the treatment should be applied with due caution regarding timing of burning, weather conditions and other factors that may increase fire severity.
- Moderate levels of livestock grazing could be considered as a tool for forest management as limited livestock grazing has positive effects on tree regeneration and growth and also provides another source of income (second most important export earnings for the country)
- More research is needed on controlling the timing and type of livestock to be considered as well as testing different cutting criteria (intensity, species, size) in order to achieve optimum results.

Although experimental disturbances as resilience “probes” provide important information on the savanna-woodland dynamics, they should not be used as the sole evaluation of stress or ecosystem health because ecosystem health is also dependent on other processes. Furthermore, use of experimental disturbances as resilience probes of savanna should address the effect of disturbance intensity, severity, and scale on a variety of structural attributes and functional processes. This may require examination over a longer period of study.

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HISTORICAL CHANGES IN THE EXTENT, STRUCTURE AND COMPOSITION OF THE FOREST PATCHES ON THE KWA-NIBELA PENINSULA, ST LUCIA IN SOUTH AFRICA

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Abstract

The KwaNibela Peninsula is situated at the northern-most part of Lake St Lucia in KwaZulu-Natal, South Africa and is covered by patches of forest, which are utilised rather heavily by the inhabitants of this area. The aims of this study were to map the current and historical extent of the forest patches and quantify the changes, using structural and compositional data gathered in the field. The reasons for doing so were to determine whether the forest patches have increased or decreased in extent, whether the changes can be attributed to both natural and anthropogenic factors, whether intervention is necessary to promote sustainable harvesting practices, and to develop a basis for developing a conservation management plan for KwaNibela. The forested area in KwaNibela is classified as either Sand Forest or Maputaland Coastal Forest. The compositional data was used to verify or refute these classifications and determine whether Sand Forest exists in KwaNibela. Seven series of aerial photos from 1937, 1960, 1969, 1979, 1990, 2002 and 2008 were used to track the changes in cover type. The photos were digitized, georeferenced, image-processed and mosaiced in TNTMips 7.0. Filters were run in ArcView 9.2 to classify the cover types into core forest, transitional thicket, woodland/grassland and disturbed areas. The percentages of each cover type were compared, for each year, to determine the overall changes in vegetation. Structural and compositional data were collected from sample plots along nine transects, to represent different stages of forest succession. The data were analysed, using TWINSPAN and CANOCO, to quantify the floristic and structural changes in the vegetation.

Introduction

Deforestation is a trend of global significance as the reduction in forest-based carbon-sink is considered to have a detrimental impact on climate change. Burgeoning human populations in forested areas have led to increased pressure on timber and non-timber forest products and in many cases, wide-scale degradation and depletion of previously forested areas.

At a local level, the destruction of forests and woodlands has often resulted in the formation of reserves to protect habitats for rare and endangered species and to exclude resource use by neighbouring communities (Gaugris and Van Rooyen 2007). The ecological effects of exclusion vs. full protection are, to a large extent, still unknown and are often a balancing act, in which a balance should be sought (Sinclair 1998). Each ecosystem responds differently to disturbance (West 1999) and a thorough understanding of this is imperative when formulating a site-specific management plan for an area (Goodman 2003). According to Egan and Howell (2001), knowledge of historical conditions is of immense importance in setting goals for conservation as it allows scientists to evaluate the changes that have taken place in the landscape (Swetnam *et al.* 1999). Effective restoration of degraded ecosystems requires a reference condition in order to avoid subjectivity when planning conservation strategies. If grassland was originally the dominant land cover type, surely we should not encourage woodland regeneration by actively excluding fire regimes? Disturbance and diversity are often linked and the question to ask is: where is the threshold between too little disturbance and too much? This can be likened to a scale (Figure 1) onto which all ecosystems fit at different levels. A paradigm shift in traditional ecological thinking is necessary to effectively manage the human-environment interface (Hobbs and Huenneke 1992, Everard *et al.* 1994).

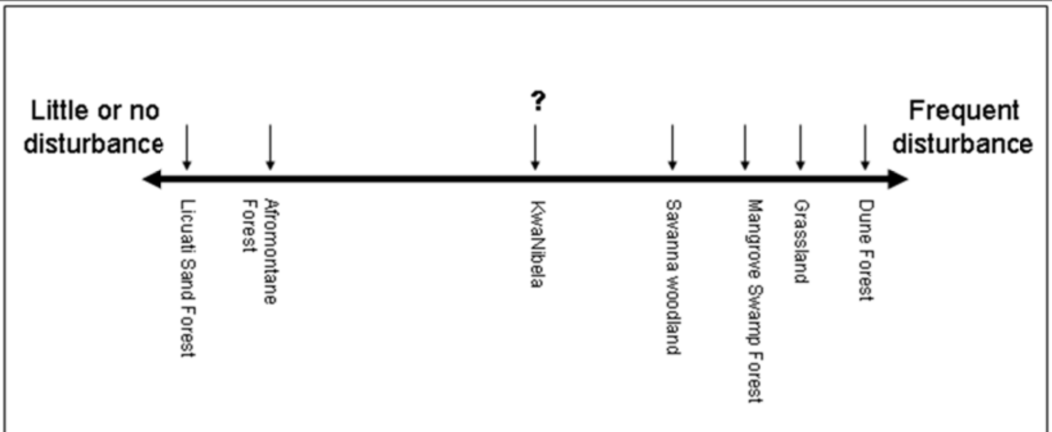

Figure 1: **The relative affinities of various ecosystems to disturbance events**. The results from this study attempt to place KwaNibela at some relative point along this scale

The Maputaland Centre of Endemism is renowned for high levels of endemic fauna and flora as well as a wide variety of diverse vegetation types. KwaNibela is situated in southern Maputaland, at the northern reaches of the Greater St Lucia World Heritage Site at 27° 56' 10.9" S and 32° 26' 35.9" E. The peninsula extends into Lake St Lucia and is bordered by False Bay National Park to the west and Eastern Shores Nature Reserve to the east. The southern portion of KwaNibela is thought to include patches of Licuati Sand Forest (Von Maltitz *et al.* 2003) and was classified by Mucina and Rutherford (2006) as Maputaland Coastal Forest and by Acocks (1953) as KwaZulu-Natal Coastal Forest. KwaNibela is not under formal protection by the state or any other Non-Governmental Organisation (NGO) and the inhabitants of the area utilise the forest, in particular, for raw materials, food, medicines, and building and handcraft materials. This resource use is currently unmonitored and unmanaged and the sustainability thereof is questionable.

This study determined the spatial changes of the land cover types on the peninsula over the last 71 years to give an indication of the reference conditions of the area as other historical data, such as fixed point photography, previous fauna and flora surveys or historical records, was not available for KwaNibela. The spatial data also specify the nature of the change, which can be attributed to natural oscillations and/or anthropogenic influences. The vegetation structure of the different cover types was determined to assess regeneration potential of the forest patches as old-growth forest patches (core forest) are more likely to remain stable, whereas the re-growth forest (transitional thicket) is the more dynamic buffer zone in which regeneration and bush encroachment occur. The open areas (grassland/woodland and disturbed patches) are only briefly discussed. Species composition for each land cover type was determined to assess species diversity and abundances as well as to assess the current classification of the forest patches on KwaNibela as Licuati Sand Forest (Von Maltitz *et al.* 2003). Ultimately, this study will contribute towards informing a participatory management plan for the KwaNibela Peninsula, in which the interests of the KwaNibela inhabitants are melded with the conservation of this valuable resource.

Methodology

Past and present distribution of forest patches

8-bit Greyscale aerial photographs of varying scales and resolutions were obtained from the Chief Surveyor General (Mowbray, RSA) and were used to map the spatial-temporal changes in forest cover of the KwaNibela Peninsula. A series of six years, spaced approximately 10 years apart, was available: 1937, 1960, 1969, 1979, 1990 and 2002 and a 2008 Google Earth image was studied to represent the most current state of forest cover on the peninsula (Google Corporation 2008).

The aerial photographs were digitized, geo-referenced to a topographical map and mosaiced in TNTMips 7.0 to create spatially-accurate single images for each year. The images were then processed in Corel PHOTO-PAINT to reduce the disparities at join lines and imported into ArcView 9.2. Each image was adjusted with a majority filter to reduce the effect of light reflectivity variation. A low pass filter was then run on each image to further reduce resolution and classify the image into three classes, based on the greyscale variation. The number of pixels per class was used to calculate the percentage each class occupies on the peninsula and the size of each pixel was used to calculate area, in hectares. The Landscape Shape Index (LSI), as described by Limpitlaw and Woldai (2004), was used to measure the fragmentation of the core forest patches and the open areas. Fragmentation of the landscape can be related to human presence, such as homesteads, croplands, roads, etc. and the LSI provides a measure of disturbance in KwaNibela.

Vegetation structure and species composition of the forest patches

The areas of core forest were identified by comparing the earliest aerial photograph of the peninsula (1937) with the most recent Google Earth (2008) image. Vegetation was sampled according to Mucina and Geldenhuys (2006). Transects were then extended from core forest to the forest margin and 33 circular 400 m^2 plots were sampled at different stages of succession along each transect. The following information was recorded on each plot: diameter at breast height (DBH) measurements of all trees 5-9 cm DBH within a 200 m^2 subplot and all trees ≥10 cm DBH within the 400 m^2 plot, by species; height of the canopy; Braun Blanquet cover-abundance values for each species in each layer to determine dominance. This information was collected to quantify changes in the structure of the forest patches, in diversity and dominance between core forest, transitional thicket and open areas, and to assess the current classification of KwaNibela as Licuati Sand Forest (Von Maltitz *et al.* 2003, Matthews 2005).

A two-way hierarchical analysis was performed in TWINSPAN (Hill 1979), using stem-count per species per plot to distinguish community types and provide descriptions and indicator species for each type. CANOCO (Ter Braak and Similauer 2003) was used to relate the differences in species composition to environmental variables, such as multi-stemness, total basal area, number of species per plot and canopy height.

Results and discussion

Past and present distribution of forest patches

The earliest aerial photograph image of the KwaNibela Peninsula shows a wide expanse of open area in the centre of the peninsula and relatively intact areas of core forest. The absence of small geometrical gaps in the forest and thicket is apparent, when comparing the 1937 image to the 2002 image (Figures 2 and 3). These small geometrical gaps are likely to be human-induced as the inhabitants cleared small areas for homesteads, croplands, etc. The 2002 image also shows quite extensive bush encroachment as former open areas are now covered by core forest or transitional thicket (Figures 2a and 2b).

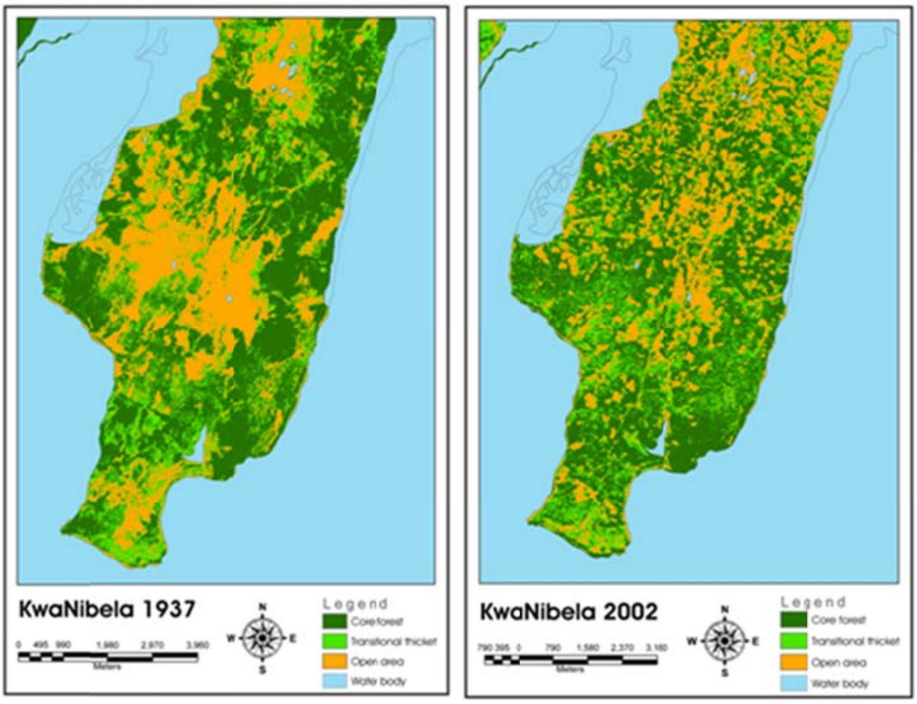

Figure 2a and 2b: The changes in the extent and distribution of the forest patches on the KwaNibela Peninsula are apparent between 1937 and 2002. The distribution of the forest patches has increased but the sizes of the patches have decreased. Patch fragmentation of the core forest and the open areas is quite evident in 2002.

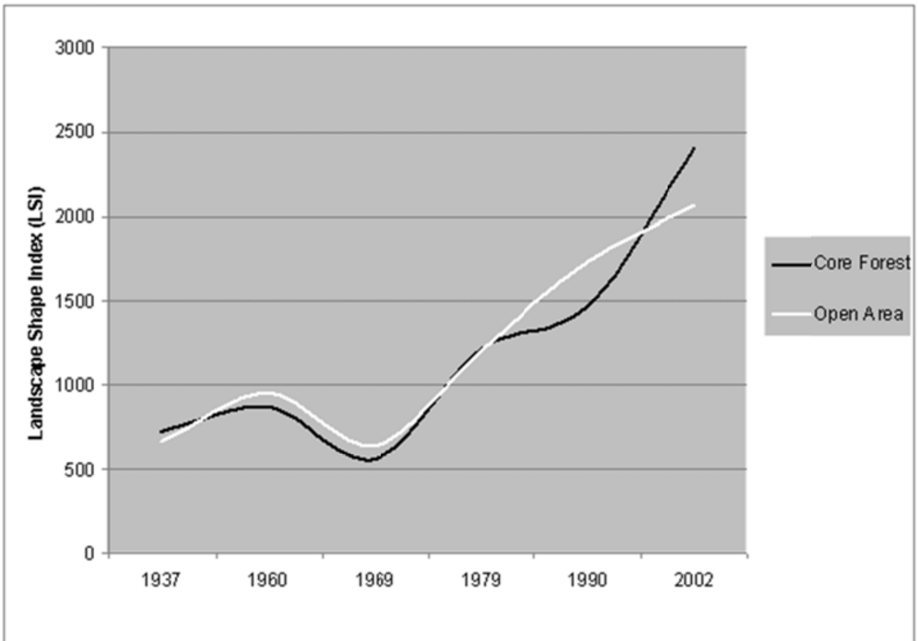

Figure 3: Landscape Shape Index values from 1937 to 2002. the fragmentation reached its lowest level in 1969; however, both core forest and open areas have become more fragmented overall.

The LSI results (Figure 3) show that the degree of fragmentation of the core forest patches and open areas both increased slightly from 1937 to 1960. In 1969 the peninsula woody vegetation showed the least degree of fragmentation. From 1969 to 2002, the LSI increased consistently and reached its highest in 2002.

Vegetation structure and species composition of the forest patches

The TWINSPAN hierarchical classification analysis (Figure 4) grouped the plots into three communities, with 2 outliers. The ordination results (Figure 5) show that canopy height is negatively correlated with the marginal vegetation; there are a greater number of species per plot in the old-growth forest and there are more areas of old-growth forest in the southern part of the peninsula.

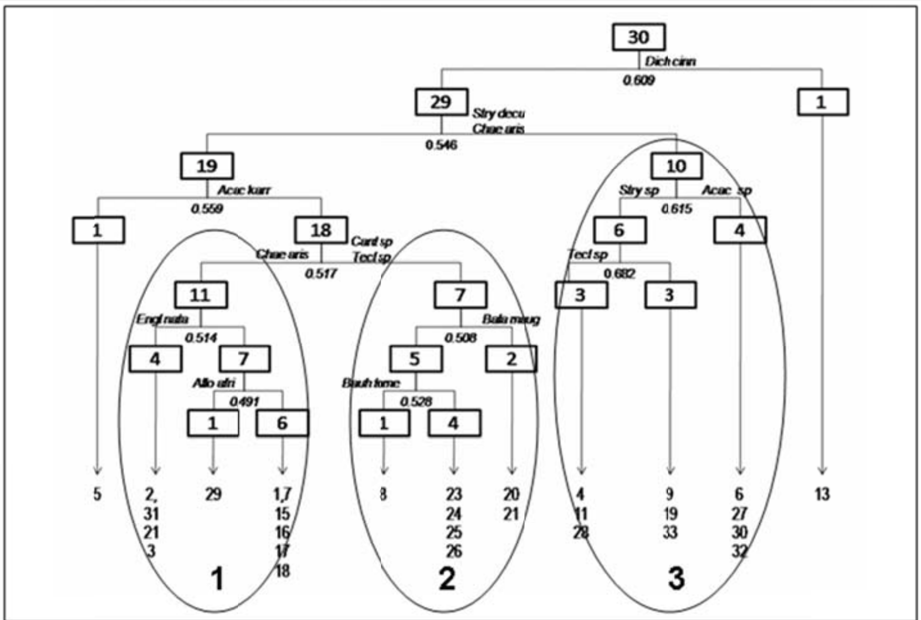

Figure 4: **The TWINSPAN classification results** show that 30 vegetation plots can be grouped into three community types, with two outliers.

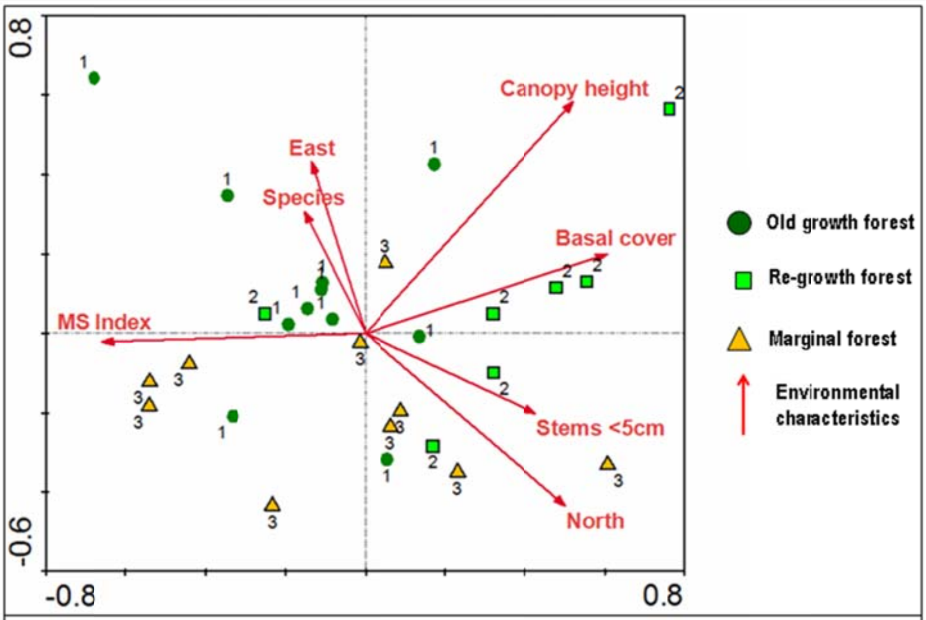

Figure 5: **CANOCO RDA Ordination diagram**, showing the relationships between the communities and environmental characteristics.

A greater incidence of invader species, such as *Chromolaena odorata, Solanum elaeagntifolium, Ricinus communis, Ipomoea purpurea, Asimina triloba* and *Lantana camara,* were observed in the northern part of the peninsula (pers. obs.), which coincides with the increased human settlement in the north.

The northern forest patches have also became more fragmented between 1937 and 2008 and a full transect was, therefore, not possible. In some cases, it was only possible to sample the "core forest" plot as there was no gradient from core forest to transitional thicket to open area.

It is evident, from the maps and Landscape Shape Index results that the historical conditions on the peninsula consisted of a few relatively intact patches of core forest with large expanses of open areas, which were probably covered by grassland/woodland. In the last 71 years, the forest patches have expanded to cover 55% of the peninsula, as opposed to 48% in 1937; however the fragmentation of the patches increased considerably. The increase in forest cover as well as the increase in fragmentation may well be due to veld management practices, employed by the inhabitants of the peninsula, where the exclusion of fire and the introduction of domestic grazers may have contributed to the propagation of forest species over the grassland species and the clearing of numerous areas of forest for homesteads, croplands, etc. (Bürgi *et al.* 2000, West *et al.* 2000)

The species composition as well as the resilience of the forest on the KwaNibela Peninsula suggests that the forest type, in general, is not typical Licuati Sand Forest, as described by Von Maltitz *et al.* (2003) and Matthews (2005). The forest type may be a transitional precursor to Sand Forest or it may be more closely related to KwaZulu-Natal Coastal Forest (Mucina and Rutherford 2006).

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LITTERFALL AND NUTRIENT INPUT IN AFRICAN TROPICAL SECONDARY FORESTS, WITH SPECIAL REFERENCES TO OKOUME (*Aucoumea klaineana*) FORESTS OF CONGO

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Abstract

Litter, the intermediate between vegetation and soil, ensures the transfer of nutrients and organic matter between these two ecosystem components, and many other forest functions. It must be taken into account in practical forest management. Litter production and nutrient return were assessed in natural moist tropical secondary forests in Southwest Congo where Okoume (*Aucoumea klaineana*) has an important presence. Okoume is the main commercial timber species of southern Congo with a high economic value, and it is important to manage a sustainable productivity of forests where this species is present. The functioning of Okoume stands in Congo was assessed through litter studies carried out on four plots at two sites:

- Chaillu forest growing on clay soil: Malanga stand (an old secondary forest) and CCAF stand (a young secondary forest);
- Coastal forest growing on sandy soil: Bitsifa forest stand (monodominant Okoume forest) and Yangala stand (Okoume-Dichostemma forest).

Annual litter production was 5.8 and 10.7 t/ha respectively for the Malanga and CCAF stands in Chaillu forest; and >11 t/ha for both stands in the coastal forest. The lower productivity in Chaillu forests may be due to intensive forest exploitation over a longer time, and low Okoume tree density. Bio-element return of N, P, K, Ca and Mg through the leaves (the main litter component in Congolese forests) was assessed. Total N is higher compared to other bio-elements and varies from 6 (Bitsifa stand) to 16 $g/m^2/yr$ (CCAF stand). Inputs of all bio-elements were highest in the CCAF stand. Litter production and nutrient inputs showed wide variations between forest types, the interior of stands and with species. The litterfall data from the Congolese forests are within the range for the African tropical forests but slightly lower for most of the nutrients. The variability in litterfall and nutrient inputs observed in secondary forests need to be taken up in forest management guidelines.

Introduction

The extent of secondary forests is increasing globally. A participatory and adaptive management and research approach is needed to increase the ecological and technological knowledge base for secondary forest management. Improved management of secondary forests requires better inventories and better access to and dissemination of information (FAO 2003, 2004). However, in Africa the scientific knowledge concerning the flora and fauna in these ecosystems seems to be limited.

All forests are dependent on recycling of plant nutrients to meet nutrient requirements for growth. For most elements, biogeochemical nutrient cycling is dominated by litter production and decomposition. Litter dynamics is a process that replenishes the nutrient pool in forest ecosystems. Litter on the forest floor acts as an input-output system for nutrients. Leaf litter serves as both a source and a sink for nutrients in forest ecosystems (Herbohn and Congdon 1993, Lisenawork and Michelsen 1994, Jamaludheen and Mohan Kumar 1999).

Factors influencing litter decomposition have important implications for long-term productivity of forest ecosystems. Environmental factors, floristic composition, stand age, tree management and stocking levels cause variations in quality and quantity of the litter. The return of plant nutrients to the soil and subsequently recycling through plant uptake can be influenced by choice of species or dominant species during plant succession or settlement (Herbohn and Congdon 1993, Jamaludheen and Mohan Kumar 1999, Bernhard-Reversat and Loumeto 2001).

Many authors studied and reviewed litterfall and nutrient return, also in tropical forest (Herbohn and Congdon 1993, Lisenawork and Michelsen 1994, Jamaludheen and Mohan Kumar 1999). However, the generalizations on the functioning of secondary forest are based on few studies (Lugo *et al.* 1999). It is known that the tropical forest can return higher levels of nutrients to the forest floor, behave as nutrient sinks and function at lower nutrient use efficiency, and increase the nutrient pool in the litter and topsoil of damaged sites recovering from forest use (Lugo *et al.* 1999). Little information is available on tropical secondary forest of Africa. Therefore, the review made by Fournier and Sasson (1983) on African tropical forest ecosystems need to be actualized.

Secondary forests dominated by Okoume (*Aucoumea klaineana*) occur in southwestern Congo (Hecketsweiler and Mokoko Ikonga 1991, Doumenge 1992, Loumeto 2002, Pangou *et al.* 2003, Kimpouni *et al.* 2008). Okoume, a pioneer species, is the main commercial timber species of southern Congo forests, has a high economic value (Loumeto 1997, 2003) and an important resource for plywood. Okoume forests are often disturbed by logging or agricultural activities which create secondary forest (Nasi 1997, Fuhr *et al.* 1998, 2001). Limited data are available on the functioning of Okoume forests (Loumeto 2002, 2003, Loumeto and Kaya 2005). Therefore, information is needed to understand how forest stands with Okoume should be managed to sustain productivity (Loumeto 1997).

The working hypotheses are:

- The fast growth and the gregarious behavior of many typical species of secondary forest (eg. Okoume), influence the litter production and the nutrient recycling.
- The functioning of secondary forest depends on its age, floristic composition, and disturbances.
- Environment factors (soil, climate, etc) and tree management influence variations of the litter quality and quantity, and nutrient inputs.

This study aimed:

- To improve data on litter production and nutrient inputs of Okoume forests in southwestern Congo.
- To assess the influence of the development stage of secondary forest on litter production and nutrient return.
- To quantify the variability of litterfall and nutrient inputs in African secondary forests.

Material and methods

Study area

Field work was done in two sites in southwest Congo: Chaillu forest in the Ngouha 2 area; Coastal forest in the Youbi area (Table 1). The climate in both sites is characterized by an alternation between a rainy season (September – May) and a dry season (June – August). The vegetation at Chaillu forest (Ngouha 2) is a transition between Okoume and Limba (*Terminalia superba*). It is moist evergreen forest and the flora is dominated by species of Caesalpiniaceae, Irvingiaceae, Meliaceae and Burseraceae. Pangou *et al.* (2003) recorded 91 plant families and indicated that in the undergrowth, the dominant species belong to Agavaceae, Commelinaceae, Costaceae and Zingiberaceae. This zone is disturbed by traditional agricultural activities and timber logging (Loumeto 2003, Pangou *et al.* 2003). The vegetation of the Coastal forest (Youbi area) is a relictual forest characterized by the abundance of a few species, including Okoume as the main species (Loumeto 2002), followed by *Trichilia heudelotii, Carapa procera* and *Sacoglottis gabonensis* (Kimpouni *et al.* 2008).

Table 1: Geographic parameters of the study sites in southwest Congo.

Forest	Chaillu	Coastal
Area	Ngouha 2	Youbi
Geographic position	2°58”S, 12°25’’E	4°00’’-4°30’’S, 11°30’’-12°00’’E
Annual rainfall (mm/yr)	1,644 (1981-1996)	1,236 (1982-2001)
Temperature	25°C	25°C

Sampling design

Two stands were selected for study in each site. In Chaillu forest, two stands were selected: Malanga, an old secondary forest; CCAF, a young secondary forest. On the basis of woody species with trees >30 cm stem diameter at breast height (DBH), Okoume density is higher in Malanga stand (29 stems/ha) than in CCAF. In Coastal forest, two stands were selected: Bitsifa, a monodominant Okoume forest with 384 stems/ha >10 cm DBH of Okoume; (Kimpouni *et al.* 2008); Yangala, dominated by Okoume and *Dichostemma glaucescens*, with 95 stems/ha of Okoume stems >5 cm DBH (Loumeto 2002).

The soils of the study sites highly desaturated ferrallitic soils (French classification). In the FAO/UNESCO classification, the soils are Ferralic Arenosols and are sandy in texture, and particularly poor in nutrients (Table 2).

Table 2: Soil parameters of the four stands selected at the two study sites

Forest	**Chaillu**		**Coastal**	
Stand	**Malanga**	**CCAF**	**Bitsifa**	**Yangala**
Clay (%)	28.0	15.4	6.3	8.6
Sand (%)	66.5	77.1	91.4	90.2
pH	3.39	3.27	4.3	4.4
C (%)	4.3	4.8	1.6	1.7
N (%)	0.31	0.29	0.10	0.10
P (%)	0.17	0.11	0.23	0.28
Exchangeable Cations (meq)	0.89	0.44	0.10	0.10

Litterfall

Litter was collected every two weeks over a one-year period from 10 traps in each stand. A trap was a constructed square wooden frame of 1 m x 1 m (= 1 m²) with a 2 mm mesh. The collected litter were separated into leaves, woody parts and plant reproductive parts, and were oven-dried at 65°C to constant weight.

Nutrients in litter

Leaf litter was gathered into one composite sample per month for chemical analysis. Woody parts were lumped together into a single sample for each stand. Plant reproductive parts (fruits, flowers, seeds, etc) were gathered by season. Chemical analysis was done at Pointe-Noire (Laboratory of IRD “Institut de Recherche pour le Développement”, Center of Congo) for N, P, K, Ca and Mg.

Results

Litter production

The annual litterfall was higher in Coastal forest (>11 t/ha/yr) than at Chaillu forest but the CCAF stand at Chaillu forest (9.9 t/ha/yr) was only slightly lower than at the Coastal forest (Table 3). Leaf litter is the dominant component of total litter: 72.1% at Malanga, 63.5% at CCAF, 71.0% at Bitsifa and 68.3% at Yangala. Okoume leaves contributed a higher percentage of total leaf litter in Coastal forest (68.6% in Bitsifa, 67.1% in Yangala) compared to Chaillu forest where other leaves formed most of the total leaf litter (95.0% in Malanga, 93.5% in CCAF).

Table 3: Annual litter production (g/m²) in the four study sites by litter components and as total

Forest	**Chaillu**		**Coastal**	
Stand	**Malanga**	**CCAF**	**Bitsifa**	**Yangala**
Okoume leaves	21.4	40.8	538.7	547.3
	± 6.3	±12.4	± 40.7	± 44.6
Other leaves	410.9	587.6	246.1	267.9
	± 50.4	± 57.4	± 29.5	± 50.0
Woody parts	146.6	296.7	277.7	305.6
	± 34.9	± 25.1	± 30.6	± 42.1
Flowers & fruits	21.0	64.1	42.7	72.3
	± 13.0	± 28.0	± 6.2	± 22.0
Total	**599.9**	**989.2**	**1105.3**	**1193.0**
	± 81.9	**± 96.2**	**± 48.5**	**± 83.8**

Annual nutrient input

In all stands, N is the most important bio-element contributed annually in the falling litter (Table 4). N input is higher in Chaillu forest, and specifically in the CCAF stand, but the main contribution is from leaves other than Okoume leaves. For most of the nutrient elements, the differences are slight between the three other study sites.

According to total amounts of N, stands can be ordered as follows:

CCAF > Malanga > Yangala > Bitsifa

This arrangement is different for the other nutrients:

- Ca and Mg: CCAF > Yangala > Malanga > Bitsifa
- K: CCAF > Malanga, Yangala, Bitsifa
- P: CCAF > Bitsifa, Yangala > Malanga.

Proportions of nutrient amounts related to Okoume leaves are higher for coastal forest for all bio-elements, corresponding to at least at 30% (Table 5).

Discussion

Litter production in Congo forests

Litter production is higher in the Coastal forest than in Chaillu forest, probably mainly due to the higher Okoume density in the Coastal forest (Loumeto 2002, Kimpouni *et al.* 2008). In secondary forests, pioneer species (such as Okoume) often form an important component part of the stand. They can boost litterfall but their litter tend to decompose more rapidly than the litter from other species (Fournier and Camacho-de-Castro 1973).

Table 4: Annual nutrient contribution (g/m²) through litterfall in different litter components at the different sites

Stands	Fractions	Biomass	N	P	K	Ca	Mg
Malanga	Okoume leaves	21.4	0.44	0.01	0.09	0.15	0.08
	Other leaves	410.9	8.37	0.22	1.37	2.29	1.76
	Woody parts	146.6	1.92	0.04	0.25	0.44	0.28
	Flowers & Fruits	21.0	0.53	0.002	0.10	0.13	0.09
	Total	599.9	11.26	0.27	1.81	3.01	2.21
CCAF	Okoume leaves	40.8	0.59	0.02	0.19	0.30	0.18
	Other leaves	587.6	11.10	0.29	2.52	4.63	3.02
	Woody parts	296.7	4.09	0.12	1.16	2.08	1.30
	Flowers & Fruits	64.1	1.15	0.01	0.44	0.47	0.31
	Total	989.2	16.93	0.44	4.31	7.48	4.81
Bitsifa	Okoume leaves	538.7	2.86	0.12	0.43	1.27	1.32
	Other leaves	246.1	1.56	0.07	0.22	0.43	0.51
	Woody parts	277.7	1.91	0.08	0.42	0.87	0.37
	Flowers & Fruits	42.7	0.49	0.04	0.20	0.11	0.14
	Total	1105.3	6.83	0.31	1.26	2.67	2.34
Yangala	Okoume leaves	547.3	2.82	0.12	0.43	1.32	1.28
	Other leaves	267.9	1.82	0.08	0.26	0.59	0.65
	Woody parts	305.6	2.14	0.11	0.54	1.34	1.18
	Flowers & Fruits	72.3	0.86	0.03	0.22	0.15	0.29
	Total	1193.0	7.64	0.34	1.45	3.40	3.40

Table 5: Annual contribution of nutrients through Okoume leaves as percentage of total nutrient contribution (% of total weight)

Forest	**Chaillu**		**Coastal**	
Stand	**Malanga**	**CCAF**	**Bitsifa**	**Yangala**
N	4	4	42	37
P	4	5	31	35
K	5	4	34	30
Ca	5	4	48	39
Mg	4	4	56	38

Higher concentrations of P (phosphorus) in coastal forest soils could also be responsible for this high litter production. The level of exchangeable P in the soil can influence litterfall (Silver 1994) and its availability of P can be a major constraint for productivity, particularly in acid soils (Northop *et al.* 1998), as is the case in the Congo forests.

Leaf litter is the main component of total annual litterfall (many authors quoted by Guo and Sims 1999) and it is known that litter production is higher in younger secondary forest than in older secondary forest. In Chaillu forest, litter production is higher in the younger CCAF stand of secondary forest with a higher tree density (671-686 stems/ha) than the Malanga stand (446-456 stems/ha), but the Okoume density is lower in CCAF.

In the Coastal forest, in spite of stand differences in terms of Okoume stem density and floristic composition, the amounts of litterfall was similar in both stands. Soil nutrient status seems to be more important here as stated by some authors (Spain 1984, Herbohn and Congdon 1993).

Apart from litter production, nutrient contribution is higher in Chaillu forest than in the Coastal forest, with the CCAF stand having the highest contribution for all nutrients. The two areas represent two systems of nutrient cycling based upon the nutrient status of the soils (Herbohn and Congdon 1993). The Coastal forest, growing on poorer soil, would correspond to an Oligotrophic system with the litterfall low in nutrients. By contrast, Chaillu forest on a richer soil would be a Eutrophic system with no problem for nutrient use efficiency.

African secondary forests

Litter production

Annual litter production, both leaf litter and total litter, in African tropical secondary forests shows much variability within the same country, or same ecological area, and between forest types (Table 6 for Democratic Republic of Congo; Table 7 for other countries). Young secondary forest (e.g. Ile Kongolo or Southern Bakundu) or a monodominant species forest (e.g. Okoume forest or *P. macrocarpus* forest) can have a higher litter production than the others. Litter production of this study in southwest Congo falls within the range for the African secondary forests.

Table 6: Annual litterfall (t/ha) in tropical secondary forests in Democratic Republic of Congo

Area	**Vegetation type**	**Leaf litter**	**Total litterfall**	**Authors**
Yanghambi	-	-	12.3 - 15.3	Bartholomey *et al.* (1953)
Ile Kongolo	Fallow forest	6.1	8.1	Mosango (1991)
	Young secondary forest	13.1	14.1	
	Old secondary forest	7.3	10.0	
	Primary forest	6.4	10.2	
Kinsangani	Forest of *Piptadeniastrum africanum & Celtis mildbraedii*	6.2	10.2	Mosango and Lejoly (1990)
	Forest of *Caloncoba subtomentosa*	3.6	-	Mosango and Lejoly (1987)
	Forest of *Petersianthus macrocarpus*	13.0	-	

Table 7: Annual litterfall (t/ha) of secondary forests in other African countries

Country	**Area**	**Leaf litter**	**Total litterfall**	**Authors**
Cote d'Ivoire	Banco	7.1-8.2	9.2-11.2	Bernhard-Reversat *et al.* (1979)
	Yapo	6.3	9.0	
Cameroon	Southern Bakundu	7.8	13.6	Songwe *et al.* (1988)
Ghana	Kade	-	10.5	Nye (1961)
Congo	Dimonika	-	5.0-5.7	Schwartz (1993)
	Bilala	5.4	-	Goma-Tchimbakala *et al.* (2005)
	Ngouha 2 (Monodominant Okoume forest)	7.8	10.2	Loumeto and Kaya (2005)
	Ngouha 2	4.3-6.3	5.8-10.7	This study
	Youbi	7.8-8.2	11.1-11.9	This study
Literature	Africa	3.7-8.5	8.0-15.0	Mosango (1991)

Annual nutrient contribution through the litter

Nutrient contribution through the litter varies widely in African secondary forests (Table 8 for DRC, Table 9 for other African countries). Nitrogen has the highest annual input in all forests, and Phosphorus the lowest.

Table 8: Annual nutrient contribution through the litter (kg/ha) in Democratic Republic of Congo

Area	Vegetation types	N	P	K	Ca	Mg	Authors
Yanghambi	Musanga forest	140.0	4.0	104.0	127.0	43.0	Mosango (1991)
	Mixed forest	224.0	7.0	48.0	105.0	53.0	Laudelout and Meyer (1954)
Ile Kongolo	Fallow forest	14.0	0.9	3.8	8.1	2.4	Mosango (1991)
	Young secondary Forest	22.5	2.0	10.8	27.7	4.3	
	Old secondary Forest	32.0	2.3	7.1	20.7	6.4	
	Primary forest	23.6	1.0	14.0	18.0	3.0	
Kinsangani	*Caloncoba subtomentosa* forest	99.9	9.4	66.2	66.9	22.4	Mosango and Lejoly (1987)

Table 9: Annual nutrient contribution through the litter (kg/ha) in secondary forests of other African countries

Country	Area	N	P	K	Ca	Mg	Authors
Cote d'Ivoire	Banco	158.0-170.0	8.0-14.0	28.0-81.0	61.0-81.0	35.0-51.0	Bernhard (1970)
Cameroon	Southern Bakundu (leaf litter)	123.5	11.6	90.9	181.8	39.2	Songwe *et al.* (1998)
Ghana	Kade	202.0	7.4	68.0	209.0	45.0	Nye (1961)
Congo	Ngouha 2 (Monodominant Okoume forest)	700.0	2.6	19.6	23.3	14.8	Loumeto and Kaya (2005)
	Ngouha 2	112.0-169.0	3.7-6.2	18.0-48.0	30.1-74.8	22.1-48.1	This study
	Youbi	68.0-76.0	3.1-3.4	12.6-14.5	26.7-34.0	23.4-34.0	
Literature	Africa	91.0-224.0	4.0-14.0	26.0-104.0	61.0-206.0	22.0-53.0	Mosango (1991)

Amounts of most nutrients returned through the litter in the Congolese forests are in the lower range or below the values of African secondary forests reported by Mosango (1991).

Environment factors, climate and mostly soil nutrient status could contribute to these differences.

Conclusion

Results obtained in this study complement the available data on litter systems of Congolese forests, and specifically for Okoume forest. Okoume density influences the litter production which is higher in Coastal forest than in Chaillu forest, illustrating the important contribution of pioneer species to litterfall. But nutrient contribution through the litter seems to be more related to soil nutrient status. Amounts are higher in the CCAF stand at Chaillu forest than in Coastal forest for all studied elements (N, P, K, Ca & Mg). However, for most nutrients, differences are low between the other studied stands. Therefore, forest management can strongly affect the nutrient cycling which influences the productivity and tropical forest sustainability. The studied stands in Chaillu forests have shown the influence of the forest development stage. The CCAF stand, a young secondary forest plot, has a higher litter production than the older Malanga stand. Litterfall production and nutrient contribution show much variation in the African secondary forests. The results from this study for litter production are within the range for other studies in the African tropical secondary forests. However, the values are in the lower ranges for nutrient contribution through litterfall. Such variability in litterfall and nutrient contribution needs to be incorporated into guidelines for sustainable management of the African secondary forests.

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Productivity and yield regulation systems for natural forests:

SYNTHESIS OF GROWTH AT STAND LEVEL IN 16 SOUTH AFRICAN EVERGREEN FOREST PLOTS AFTER 10 YEARS

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Abstract

Stand and tree growth rates are important components of timber yield regulation and calculation of the annual allowable cut in a timber concession. However, very few studies exist to provide growth data for the forests in Africa. A series of 16 long-term study sites in seven representative areas was established since 1987 to provide data on recruitment, growth and mortality for the South African natural evergreen forests. The selected areas cover a latitudinal gradient from the Cape Peninsula (34ºS) to the Soutpansberg (Limpopo Province) (23ºS). In each area one to four sites were selected to cover a local altitudinal gradient. All these sites were located in forest which had not been disturbed through timber harvesting for long periods. The general plot size was 80 m x 80 m, and each plot was sub-divided into 10 m x 10 m subplots. Stem diameter was measured at breast height (DBH) at 5-year intervals. A total of about 15,000 stems were measured covering 132 canopy (58) and sub-canopy (74) tree species. In general the trees grew very slowly, and growth rate was expressed in cm/10 years. The results show much variation in stand and tree growth, including negative growth. About 5 to 10% of the trees showed negative growth; 50 to 70% grew between 0 and 1.0 cm, and 10 to 15% grew more than 3 cm over the 10-year measurement period. Growth rate varied according to species, tree size and position of the crown of a tree within the general canopy of the stand. Crown position, i.e. how much direct light it receives, and whether it is a canopy tree or a sub-canopy tree, has a major impact on tree growth. In general, there is an increasing growth rate from trees in the understorey to trees in the canopy. Within a specific grouping the growth is almost constant with increasing stem size. The implications for yield regulation are discussed.

Background

Forest biodiversity and processes, and forest use, can be sustained if products and values are utilized in relation to the growth potential of the site and the essential ecological processes to which component species are adapted. Tree growth is part of the demographic processes that contribute to forest stand dynamics (recruitment, growth and mortality), biodiversity and recovery, and population status (size class structure) of tree species.

The production rate of a resource determines how much of the resource can be used, like the interest rate on invested capital. If the amount we use is more than the interest rate, the invested capital erodes and our future benefits decline. If we use less than the production rate, we may lose resources through excessive mortality during the felling cycle. Regular tree measurements (stem diameter, tree height or shoot elongation) provide information on production rates. We need the mean growth or production rates, the ranges in those rates, and an understanding of the causes of fluctuations in those rates. For most products from natural areas we have very little information on production rates.

Stand and tree growth rates are important components of sustainable resource use in forest management. Stem diameter growth, ingrowth from regeneration and mortality of trees are the basic components of species population dynamics and stand changes over time. They form the basic elements of timber yield regulation and calculation of the annual allowable cut for sustainable timber harvesting from timber concessions (Vanclay 1989a, 1989b, 1994, 1995, Alder 1995). There are a few studies on tree and stand growth in Africa but the information on and from such studies need to be made available for better management of the African forests and woodlands.

The natural evergreen forests in South Africa cover a small area (less than 500,000 ha) over a wide latitudinal gradient (Mucina and Geldenhuys 2006). They provide many products to satisfy a wide range of needs of people directly and indirectly dependent on the forests (McKenzie 1988). Timber for quality furniture, building and energy are only some of the needs. Tree harvesting affects forest dynamics and biodiversity. Many targeted forest tree species have the potential to be grown adjacent to the forest as alternative product sources, and as nurse stands in forest rehabilitation practices.

Sixteen growth study sites in eight representative areas of the South African natural evergreen forests were established since 1987. They were maintained to provide data on recruitment, growth and mortality as basis for sustainable resource use, to monitor timber harvesting impacts on forest biodiversity and productivity, and for selecting species for planting outside the forest. Van Daalen (1991, 1993a, 1993b, 1993c) made important contributions to the study of forest growth in Diepwalle forest in the Southern Cape. Interim reports on the individual plots five or 10 years after establishment are available. No synthesis was made of the growth, ingrowth and mortality of the plots for practical use.

This paper presents some initial synthesis of the stand composition of the 16 plots and their relationship with the national forest types, the changes in structural stand variables over 10 years, and variation in tree growth at stand level (not by individual species).

Study area

The 16 plots were selected to cover a latitudinal gradient from the Cape Peninsula (34ºS) to the Soutpansberg (23ºS) (Figure 1). In each area one to four sites were selected to cover a local altitudinal gradient. The plots occur from near sea level at 150 m to 300 m above mean sea level (amsl) (Orangekloof, Diepwalle, Witelsbos, Koomansbos and Manubi), at 580 m to 1,160 m asml in the Amathole mountains, 1,220 m to 1,280 m amsl in the Weza area, 1,100 m asml at Ngome, 1,350 m to 1,580 m amsl in the Magoebaskloof area, to 1,380 m asml in the Soutpansberg. The geology varies from quartzites (Diepwalle, Witelsbos and Matiwabos), shales (Koomansbos, Ngeli and Ngome), mudstone, shale and sandstone with dolorite intrusions (Amatole mountains), dolorite (Manubi and Ngeli), granite (Orangekloof) and grantite-gneiss (Magoebaskloof area).

All the plots were located in forest which had not been disturbed for long periods, but the sites represent different stand development histories. Orangekloof on the Cape Peninsula is in a regrowth phase after heavy timber utilization during the early days of European settlement (17th and 18th centuries). The Diepwalle plot is part of a large research site since about 1930. Timber was harvested from all the other sites (based on stumps of sawn trees and saw pits in the area) but the sites are under conservation management for at least 30 years before the plots were established.

The plots were established in Afrotemperate forest (Cape Peninsula and Southern Cape), Mistbelt forest (Amatole, Weza, Magoebaskloof, Soutpansberg) and Scarp forest (Manubi and Ngome) of the national forest types (Von Maltitz *et al.* 2003, Mucina and Geldenhuys 2006).

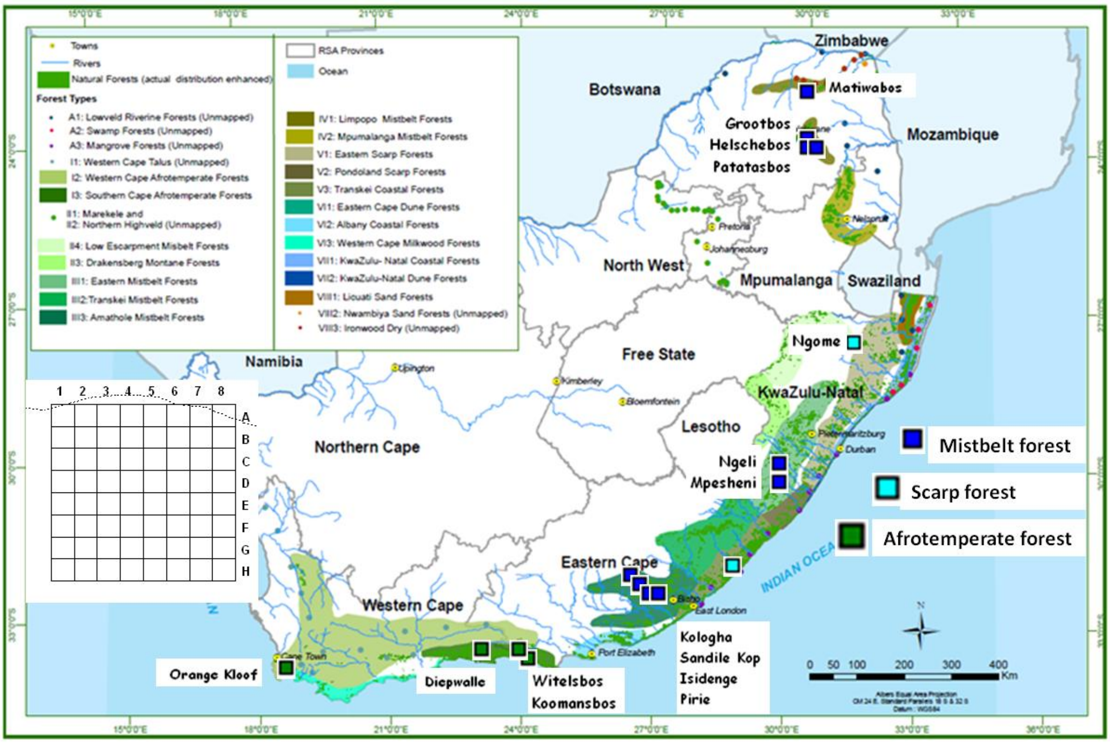


Figure 1: Location of 16 long-term plots throughout the natural mixed evergreen forests in South Africa. The insert shows the basic lay-out of an average plot.

Materials and Methods

Plots were established in February 1987 (Amathole mountains), May 1987 (Diepwalle), during 1988 (Witelsbos, Koomansbos, Manubi and Orangekloof) and 1989 (Magoebaskloof and Soutpansberg) (Geldenhuys 1997, 1998, 2000), and finally in October 1998 (Weza and Ngome) (Geldenhuys 1999). The principle was that a plot should be relatively uniform throughout, and be established on a relatively level terrain or at most a gentle slope on a generally southern aspect to control for local site variation. The basic plot size was 80 m x 80 m (0.64 ha) (Figure 1 insert), but this was not always possible because of specific site conditions. The Orangekloof (0.52 ha, in a triangle) and Sandile Kop (0.46 ha) plots were smaller, and the Koomansbos (0.65 ha) and Kologha (0.80 ha) plots were longer but narrower. The Diepwalle plot (2.86 ha) was initially used for competition studies (Van Daalen 1993a, 1993b) with growth data collected since 1974, but for this specific analysis a plot of 0.64 ha was used.

Each plot was divided into 10 m x 10 m subplots (Figure 1) to ease relocation of marked trees, and to enable the calculation of the standard errors for the mean stem density, basal area and diameter growth per plot.

Diameter at breast height (DBH, 1.3 m above ground level) was measured for all stems with a DBH ≥5 cm. A unique number was painted on each tree and the exact point of measurement was marked with a horizontal painted band. Sometimes a tree was marked and measured either above or below a swelling or a branch, or of a wound on the stem, or 50 cm above a buttress.

All the plots were remeasured twice, i.e. approximately 5 years and 10 years after establishment and initial measurement, except for the Weza/Ngome plots which were remeasured only once, after about 5 years. Measurements were done towards end of the dry season, but before the rain starts, to prevent measurement errors due to swelling of the bark during the rainy season.

During each subsequent remeasurement, all stems of ≥5 cm DBH which were not measured during the earlier measurements were numbered, measured and recorded (ingrowth). Also, trees not found (missing), or died or blew over or illegally harvested since the earlier measurements, were recorded as dead trees (mortality). During remeasurement, the crown position (CP) of each measured stem was assessed and recorded as follows (adapted from Van Daalen 1993c): CP1 = understorey, no direct light; CP2 = lower canopy, some overhead light; CP3 = canopy, full overhead light; and CP4 = emergent (including a small tree in a large gap), light from all sides. Observations that could affect reliability of the growth data, such as tree showing signs of dying, stem rot, lianas around the stem, etc. were noted.

The data (initial measurement and all subsequent remeasurements) were recorded for each individual stem per individual 10 m x 10 m subplots, i.e. subplot number, stem number, species code, DBH to nearest millimetre, crown position, and general comments. The data were entered into a separate LOTUS 123 file for each plot.

The following analyses were done:

- The data from four adjacent subplots (a square of 20 m x 20 m) were combined to obtain stem numbers by species for 0.04 ha plots, for a classification of the tree stands using TWINSPAN (Hill 1979) and an ordination using detrended correspondence analysis (DCA) of CANOCO (Ter Braak 1988).
- Importance value (IV) of a species in each of the plots was based on the data recorded with establishment of the plots. IV was calculated as follows:
  IV = (RF + RD + RBA)/3, where
  RF = relative frequency, calculated as the number (frequency) of subplots in a plot in which the species was present, expressed as the percentage of all frequencies of all species in the plot; RD = relative density, calculated as the number of stems (stem density) of a species in a plot, expressed as the percentage of all stems of all species in the plot; and RBA = relative basal area (relative dominance), calculated as the total basal area (i.e. the horizontal surface area of a stem at 1.3 m above ground level) of a species in a plot, expressed as a percentage of the total basal area of all species in the plot.

Changes in growing stock were assessed for mean stand DBH, stand density and basal area, and stand level stem diameter distributions, with all change values calculated per 10 years. Only trees that were alive and measured during both the first and last measurements were used in the analyses of growth.

Results and discussion

Species composition and importance values

A total of 134 tree species (59 canopy and 75 sub-canopy species; including *Acacia melanoxylon*, an alien canopy tree species) were recorded in the 16 long-term plots. Table 1 summarizes the species composition information for the 16 plots based on canopy tree species with IV ≥8 in at least one plot. The species information shows the links between the plots.

The DCA ordination based on all stems ≥5 cm DBH shows a clear separation of the plots in groups of plots (Figure 2). Axis 1 represents the latitudinal gradient between the Cape Peninsula, the Southern Cape, the Amatole, Manubi and Weza plots, and the Ngome and Limpopo plots. Axis 2 represents an altitudinal gradient within the Amathole plots and the Ngeli plot as one group, with the Manubi plot at the other extreme, and the Mpesheni plot in between. However, it is also possible that geology may play a role in their separation. Axis 3 (not shown, with eigenvalue = 0.474) further separated the groups but the reason is not clear.

In general the sub-plot groups within a plot clustered together. The TWINSPAN classification (not presented and discussed here) shows similar separated groupings of plots.

Table 1: Importance values for selected species (with IV ≥8 in at least one plot)

Growth plot*	**OK**	**DW**	**WB**	**KB**	**PR**	**ID**	**SK**	**KL**	**MN**	**MP**	**NL**	**NM**	**PB**	**HB**	**GB**	**MB**
Number of subplots	52	64	64	65	64	64	46	80	64	64	64	64	64	64	64	64
Number species per plot	16	27	25	32	43	37	38	36	46	24	39	38	28	28	27	32
Stems per plot	1372	1093	494	1040	1354	1081	638	1528	877	554	713	953	662	833	646	503
Basal area (m²) per plot	31.09	23.86	29.38	28.33	27.94	30.95	26.33	25.81	21.33	33.02	20.80	33.78	34.78	35.73	39.22	31.85
Generally canopy tree species																
Cassine peragua	41.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Olinia ventosa	20.1	0.8	0.2	1.5	-	-	-	-	-	-	-	-	-	-	-	-
Olea capensis capensis	8.1	1.7	2.5	5.5	-	-	-	-	-	-	-	0.1	-	-	-	-
Olea capensis macrocarpa	-	21.9	6.0	12.7	8.8	8.8	6.0	4.5	4.8	-	-	0.8	1.8	0.8	1.3	6.5
Podocarpus latifolius	1.7	15.8	8.9	10.8	0.7	2.8	12.5	5.1	1.7	-	-	0.4	0.9	0.9	2.4	-
Pterocelastrus tricuspidatus	-	5.3	4.8	8.9	-	-	-	-	-	-	-	-	-	-	-	-
Platylophus trifoliatus	-	-	18.9	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Ocotea bullata	-	1.0	11.5	1.8	-	-	-	-	-	22.1	-	-	-	-	-	-
Nuxia floribunda	-	2.2	4.1	0.2	9.4	0.1	-	-	-	-	-	-	1.7	2.6	0.3	1.5
Mimusops obovata	-	-	-	-	8.0	1.7	-	0.4	2.8	-	0.2	-	-	-	-	-
Xymalos monospora	-	-	-	-	-	17.1	23.0	6.3	3.3	1.9	15.2	10.8	13.7	11.8	23.2	24.7
Vepris lanceolata	-	-	-	-	3.0	6.8	3.5	11.6	4.7	-	7.6	-	-	-	-	-
Chionanthus peglerae	-	-	-	-	-	-	-	-	10.1	1.5	3.2	0.4	-	-	-	-
Podocarpus henkelii	-	-	-	-	-	-	-	-	-	35.2	2.4	-	-	-	-	-
Cryptocarya myrtifolia	-	-	-	-	-	-	-	-	-	-	8.1	1.2	-	-	-	-
Syzygium gerrardii	-	-	-	-	-	-	-	-	3.2	3.7	2.3	21.7	35.2	0.5	10.2	4.0
Cryptocarya transvaalensis	-	-	-	-	-	-	-	-	-	-	-	-	11.6	5.7	-	3.7
Nuxia congesta	-	-	-	-	-	-	-	-	-	-	-	-	1.2	5.0	8.5	-
Generally sub-canopy tree species																
Gonioma kamassi	-	11.7	15.5	5.4	-	-	-	-	-	-	-	-	-	-	-	-
Trichocladus ellipticus	-	-	-	-	23.5	23.3	5.6	19.1	-	-	24.2	-	-	-	-	-
Diospyros whyteana	3.7	3.0	0.5	0.5	2.2	3.6	6.5	13.9	-	-	1.4	-	-	-	-	-
Englerophytum natalense	-	-	-	-	-	-	-	-	20.4	-	-	0.1	-	-	-	-
Eugenia zuluensis	-	-	-	-	-	-	-	-	-	13.2	4.3	5.6	-	-	-	-
Psychotria capensis	-	-	-	-	-	0.1	0.2	-	0.2	-	-	13.1	-	-	-	-
Cassipourea malosana	-	-	-	-	-	-	-	-	-	-	0.3	1.0	9.1	7.6	10.4	8.6
Rinorea angustifolia	-	-	-	-	-	-	-	-	-	-	-	7.5	-	21.9	-	-
Oxyanthus speciosus	-	-	-	-	-	-	-	-	0.4	0.3	-	7.2	1.7	0.1	9.0	1.8
Rothmannia capensis	-	-	-	-	0.5	2.0	-	0.4	-	2.2	1.4	-	2.5	7.9	3.0	9.4

** OK = Orangekloof; DW = Diepwalle; WB = Witelsbos; KB = Koomansbos; PR = Pirie; ID = Isidenge; SK = Sandile Kop; KL = Kologha; MN = Manubi; MP = Mpesheni; NL = Ngeli; NM - Ngome; PB = Patatasbos; HB = Helschebos; GB = Grootbos; MB = Matiwabos.*

The grouping of the plots as indicated in the TWINSPAN output and the DCA ordination shows relative uniformity within a plot (except perhaps within the Orangekloof plot), and clear separation of the plots in groups that agree with the national forest types (Von Maltitz *et al.* 2003, Mucina and Geldenhuys 2006): Western and Southern Cape Afrotemperate forests;

Amathole and Eastern Mistbelt forests; Transkei Coastal and Eastern Scarp forests, and Limpopo Mistbelt forests.

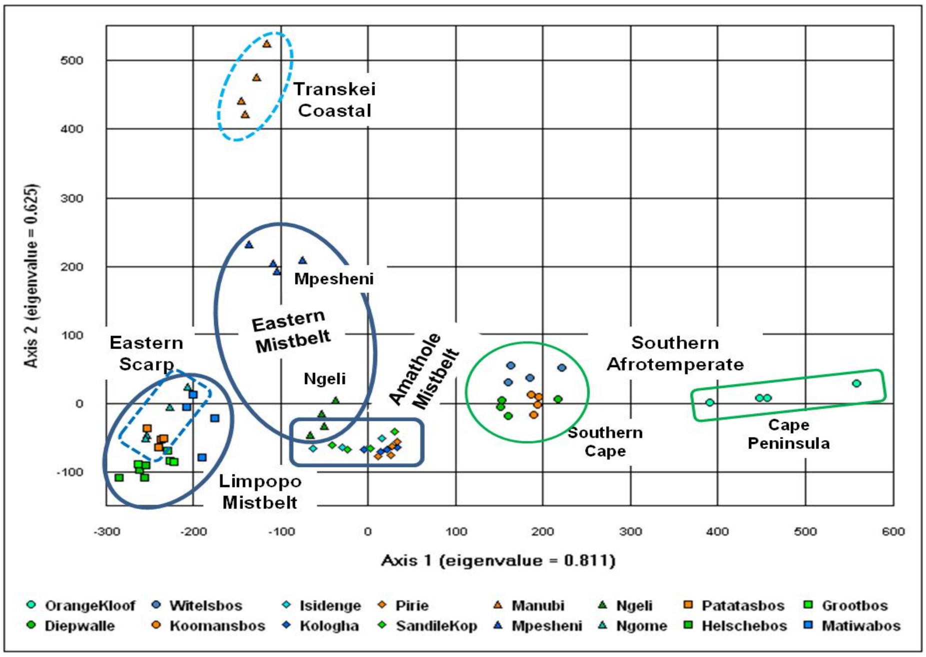


Figure 2: DCA ordination diagram for Axes 1 and 2 from the CANOCO output for the 16 long-term forest growth plots in South Africa.

Changes in growing stock (stand level)

Overall growing stock

The initial growing stock (mean stem diameter, stem density and basal area) at plot establishment, and changes in the growing stock calculated for a 10-year period show much variation between the different sites (Table 2). Stand density varied between 772 (Witelsbos) and 2,839 (Orangekloof) stems/ha, and this large variation is due to the large variation in stems below 10 cm DBH. Stem density of trees ≥30 cm DBH ranges between 96 (Kologha) and 236 (Patatasbos) stems/ha. Total basal area varied between 32.3 (Kologha) and 60.7 (Grootbos) m^2/ha. Basal area varied most in trees ≥30 cm DBH between 14.3 (Manubi) and 49.6 (Grootbos) m^2/ha, but even the basal area in trees of 10-29 cm DBH varied between 6.9 (Witelsbos) and 39.6 (Orangekloof) m^2/ha. Change over the 10 years in total stem density varied between -9.7 (Mpesheni) and 10.6 (Witelsbos) stems/ha, with the biggest change in stems below 10 cm DBH (-16.5 in Orangekloof and 19.9 in Witelsbos). The Diepwalle, Sandile Kop and Ngome plots showed a positive change and the Manubi and Helschebos plots showed a negative change in stem density in all three diameter categories over the period. Total basal area change varied between -7.2 (Kologha) and 7.4 (Ngome) m^2/ha, with the biggest change in trees ≥30 cm DBH (-15.2 in Kologha and 21.8 in Orangekloof). The Witelsbos and Ngome plots showed a positive change and the Kologha, Manubi and

Mpesheni plots showed a negative change in basal area in all three diameter categories over this period.

Changes through in-growth and mortality

Growing stock changes from ingrowth and mortality varied much between plots (Table 3). Ingrowth as percentage of initial stand density per ha varied between 1.8% in Orangekloof and 26.4% in Diepwalle, with an overall mean of 9.6%. Mortality in terms of initial stand density per ha varied between 5.1% in Ngeli and 25.3% in Manubi, with an overall mean of 10.1%. Over the stem diameter categories the mortality ranged between 54.9% of the dead stems in trees <10 cm DBH, 36.5% in stems 10-29 cm DBH, and 8.6% in trees ≥30 cm DBH. Mortality as percentage of initial total basal area varied between 0.4% in Koomansbos and 31.8% in Manubi, with an overall mean of 8.8%.

Table 2: Changes over 10 years in the growing stock of the 16 forest growth study sites in South Africa

Forest plot	Date established	Mean DBH (cm)				Stems per ha				Basal area (m^2) per ha			
		5.0-9.9	10.0-29.9	30.0+	Total	5.0-9.9	10.0-29.9	30.0+	Total	5.0-9.9	10.0-29.9	30.0+	Total
Orangekloof	12/88	7.1	16.9	36.3	14.9	869.2	1613.5	155.8	2638.5	3.61	39.58	16.61	59.80
Diepwalle	05/87	7.0	16.0	43.5	13.8	767.2	587.5	134.4	1489.1	3.04	13.05	21.19	37.28
Witelsbos	08/88	7.0	16.5	50.5	20.0	310.9	293.8	167.2	771.9	1.26	6.91	37.74	45.91
Koomansbos	08/88	7.0	17.4	40.3	14.7	783.1	649.2	167.7	1600.0	3.12	17.04	22.43	42.59
Pirie	02/87	6.9	16.5	40.8	12.5	1304.7	642.2	164.1	2114.1	5.14	15.35	23.17	43.66
Isidenge	02/87	7.0	16.7	46.6	14.3	862.5	668.8	150.0	1689.1	3.48	16.04	28.82	48.35
Sandile Kop	02/87	7.1	17.6	45.3	17.5	604.3	556.5	226.1	1387.0	2.48	14.96	39.79	57.24
Kologha	02/87	6.9	15.6	43.1	11.4	1205.0	598.8	96.3	1910.0	4.64	12.56	15.04	32.26
Manubi	10/88	7.1	17.4	41.6	14.3	640.6	631.3	98.4	1370.3	2.64	16.41	14.29	33.34
Mpesheni	10/98	7.2	16.1	56.7	18.8	412.5	304.7	148.4	865.6	1.72	6.97	42.90	51.59
Ngeli	10/98	7.3	16.2	42.0	15.3	489.1	490.6	132.8	1114.1	2.12	11.11	19.27	32.50
Ngome	11/98	7.2	15.1	48.7	14.9	840.6	457.8	189.1	1489.1	3.53	8.86	40.39	52.79
Patatasbos	07/89	6.9	17.0	46.2	19.6	414.1	384.4	235.9	1034.4	1.61	9.65	43.08	54.34
Helschebos	07/89	7.1	17.1	52.1	17.0	575.0	571.9	159.4	1306.3	2.39	14.55	39.00	55.94
Grootbos	07/89	7.0	17.7	48.6	19.7	451.6	335.9	221.9	1009.4	1.82	9.26	49.59	60.67
Matiwabos	07/89	6.9	17.7	45.8	21.7	254.7	321.9	209.4	785.9	0.99	8.75	38.25	47.98
Initial growing stock	Mean	7.0	16.7	45.5	16.3	674.1	569.3	166.0	1410.9	2.72	13.82	30.72	47.26
	SEmean	0.03	0.20	1.27	0.75	74.85	77.23	10.47	127.09	0.29	1.92	2.94	2.40
	Minimum	6.9	15.1	36.3	11.4	254.7	293.8	96.3	771.9	0.99	6.91	14.29	32.26
	Maximum	7.3	17.7	56.7	21.7	1304.7	1613.5	235.9	2638.5	5.14	39.58	49.59	60.67
% change over 10 years	Mean	0.7	-0.7	0.9	0.6	-0.7	-1.0	0.7	-0.9	0.41	-2.23	2.95	1.08
	SEmean	0.39	0.47	0.57	0.71	2.41	1.56	1.55	1.45	2.19	1.55	1.85	0.96
	Minimum	-2.7	-5.5	-3.2	-6.0	-16.5	-14.4	-10.7	-9.7	-14.86	-14.85	-15.21	-7.23
	Maximum	3.1	2.9	4.4	6.7	19.9	8.4	17.1	10.6	18.46	8.89	21.75	7.45

Table 3: Ingrowth and mortality in South African forest growth study sites, expressed per ha over 10-year period

Forest	Ingrowth		Mortality in stems over DBH classes, cm					Mortality Basal area, m^2	
	Stems	% start	5.0-9.9	10.0-29.9	30+	Total	% start	All stems	% start
Orangekloof	47.7	1.8	165.9	78.2	0.0	244.1	9.3	1.86	3.1
Diepwalle	190.5	26.4	47.6	20.4	9.8	77.9	10.8	2.88	15.9
Witelsbos	147.2	19.1	29.4	23.2	17.0	69.7	9.1	4.23	9.1
Koomansbos	196.8	12.4	116.0	68.7	10.7	195.3	12.3	0.16	0.4
Pirie	71.1	3.3	134.2	59.8	14.5	208.5	9.5	4.00	8.8
Isidenge	97.0	5.6	80.8	46.9	9.7	137.4	7.9	4.17	8.3
Sandile Kop	96.7	6.7	40.5	36.0	9.0	85.5	6.0	3.62	6.1
Kologha	89.2	4.5	73.7	58.2	19.4	151.3	7.7	5.42	16.3
Manubi	125.6	16.4	89.8	82.8	20.9	193.6	25.3	5.91	31.8
Mpesheni	59.4	3.4	96.9	43.8	3.1	143.8	8.3	3.93	3.8
Ngeli	121.9	5.5	56.3	53.1	3.1	112.5	5.1	1.95	3.0
Ngome	298.4	11.9	116.2	58.1	7.9	182.2	7.2	3.15	3.5
Patatasbos	86.8	8.5	48.0	48.0	13.9	110.0	10.7	3.73	6.9
Helschebos	58.9	4.5	54.2	77.5	17.0	148.8	11.5	5.33	9.6
Grootbos	108.5	10.8	43.4	37.2	24.8	105.4	10.5	4.69	7.8
Matiwabos	86.8	11.1	38.7	27.9	12.4	79.0	10.2	2.94	6.2
Mean	117.7	9.5	77.0	51.2	12.1	140.3	10.1	3.6	8.8
SE mean	16.2	1.7	9.9	4.9	1.7	13.2	1.1	0.4	1.9

The linear relationship between ingrowth or mortality and different stand variables is shown in Table 4. For ingrowth all the tested stand variables were insignificant but when the outliers represented by Diepwalle, Koomansbos and Ngome were removed, the relationship was significantly negative with total stem density (R^2=0.235), density of stems <30 cm DBH (R^2=0.217) and total stand basal area (R^2=0.213), i.e. the higher the values of the variables, the lower the ingrowth. For mortality of stems <10 cm DBH, the relationship was significantly positive with density of stems <30 cm DBH (R^2=0.597), density of all stems (R^2=0.596) and density of stems <10 cm DBH (R^2=0.393). For mortality of trees ≥10 cm DBH, the relationship was significantly positive with total stem density (R^2=0.331) when the outlier of the Manubi plot was removed.

Table 4. Linear relationship (Y = a + bX) between ingrowth or mortality and different stand variables

Variable	# points	R^2	a	b
Ingrowth stem density in relation to				
Density all stems	16	0.01080	136.00	-0.0132
	*13	0.23500	126.00	-0.0248
Density stems <10 cm DBH	16	0.00355	109.00	0.0129
	*13	0.11000	111.00	-0.0293
Density stems <30 cm DBH	16	0.01030	133.00	-0.0126
	*13	0.21700	120.00	-0.0232
Total stand Basal area	16	0.04380	184.00	-1.4100
	*13	0.21300	155.00	-1.3200
Mortality of stems <10 cm DBH in relation to				
Density all stems (stems/ha)	16	0.596	8.07	0.0603
Density stems <10 cm DBH	16	0.393	21.00	0.0831
Density stems <30 cm DBH	16	0.597	14.02	0.0587
Mortality of stems >10 cm DBH in relation to				
Density all stems	16	0.0828	34.90	0.0216
	*15	0.3310	24.90	0.0229
Density stems >10 cm DBH	16	0.0855	115.00	-1.1100
	*15	0.00173	53.10	0.0905
Total stand Basal area	16	0.0758	117.00	-1.0900
	*15	0.1120	45.60	0.2410

Changes in stem diameter distribution

The stem diameter distribution of the stand gives the sum total of the interactions between ingrowth (recruitment), growth and mortality of all trees ≥10 cm DBH in the stand. The graphs for stem density or basal area over the stem diameter classes give a quick overview of the kind of changes that occurred in each plot (Figure 3). The diagrams are arranged to show four groups of stands. Orangekloof presents a stand in a recovery stage of a regrowth stand with a high number of stems <25 cm DBH and a high basal area in stems <35 cm DBH, with a high mortality in the smaller stems and an increase in size (and hence basal area) in the trees ≥10 cm DBH. Koomansbos and Pirie are relatively drier forests with a large number of smaller stems but a good basal are in the middle diameter classes, with relatively little change in the stem density and basal area throughout the diameter classes. Kologha seems to have a similar pattern but is a moister forest probably recovering from over-utilization in the past; it has a good spread of trees but with a generally low level of basal area over all the diameter classes. Diepwalle, Manubi and Ngeli have a similar stand structure to Kologha, but have higher number of stems over a wider range of the smaller diameter classes >5 cm DBH, and a higher basal area over a wider range of the middle to larger diameter classes, but only show much fluctuation in the larger diameter classes in Ngeli. The other plots show a relatively low stem density in trees <10 cm DBH, except Isidenge and Ngome, but a larger basal area in the middle diameter classes and a high basal area in the largest diameter classes. The death of a single large tree can cause a large fluctuation in basal area. It may be necessary to manage forests with this type of structure to facilitate regeneration, and growth of trees through the smaller diameter classes to replace death/use of the large trees.

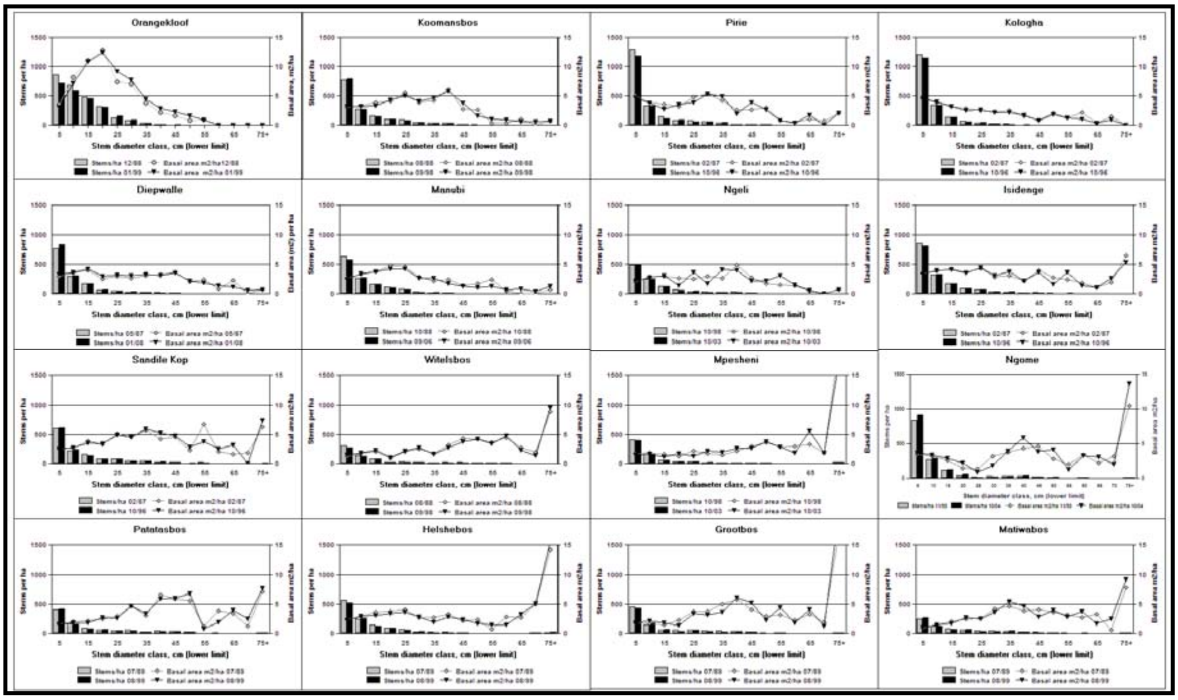


Figure 3: Changes in growing stock in each plot by stem density/ha (bars) and basal area/ha (lines) over stem diameter classes.

Stem diameter growth (stand level)

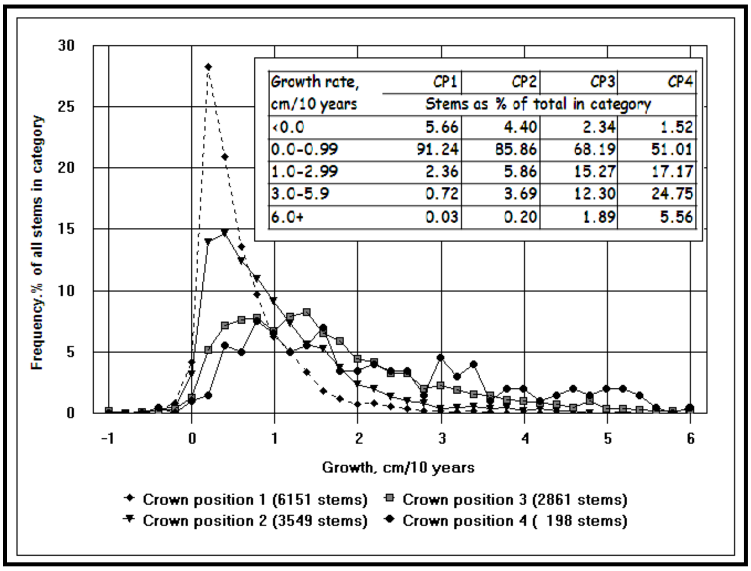
Only trees which were alive and measured during the first and last period were included in the analyses of growth. In general the trees grew very slowly, and growth rate was expressed in cm/10 years. Many factors affect the stem diameter growth of a tree. The question is to determine under what conditions a tree do not grow, and when will a tree grow really fast because this understanding has important implications for the silvicultural management of the forest for sustainable resource harvesting. In this study, the effect of crown position of a tree within the canopy of the stand, species differences, and site differences on stem diameter growth were assessed but this paper only report on the effect of crown position.

Variation in stem diameter growth of individual stems

The results show much variation in stand and tree growth, including negative growth (Figure 4). Between 0.1% and 18% of the trees in the different plots showed negative growth; 51% to 85% grew between 0 and 1.0 cm diameter; 9% to 36% grew between 1 and 3 cm; and 1% to 13% grew more than 3 cm over the 10-year. A negative growth is possible with dying trees, or with stem rot developing, or other unknown reasons.

Effects of crown position on growth

Crown position, i.e. how much direct light it receives, and whether it is a canopy tree or a sub-canopy tree, has a major impact on tree growth. The table inside Figure 4 shows the relationship between the crown position categories and the tree growth rate over 10 years – the higher the crown position category the higher the percentage of trees growing more than 1 cm diameter/10 years. All trees from all growth plots were grouped into stem diameter classes for the four crown positions to calculate the average stem diameter and growth rate within each tree size category (Figure 5). Mean diameter growth increased from 0.48 cm/10 years for crown position 1, to 2.32 cm/10 years for crown position 4, i.e. the growth rate level increased from crown position 1 trees to crown position 4 trees. However, growth rates varied much within stem diameter classes within the crown position categories. The canopy condition 4 trees showed much faster growth in the smaller diameter classes, and this could perhaps be explained by smaller trees in large gaps grow much faster than older emergent trees above the canopy which may have become more stunted with age.



Growth rate, cm/10 years	CP1	CP2	CP3	CP4
	Stems as % of total in category			
<0.0	5.66	4.40	2.34	1.52
0.0-0.99	91.24	85.86	68.19	51.01
1.0-2.99	2.36	5.86	15.27	17.17
3.0-5.9	0.72	3.69	12.30	24.75
6.0+	0.03	0.20	1.89	5.56

Figure 4: Variation in stem diameter growth of individual stems crown position categories for all plots.

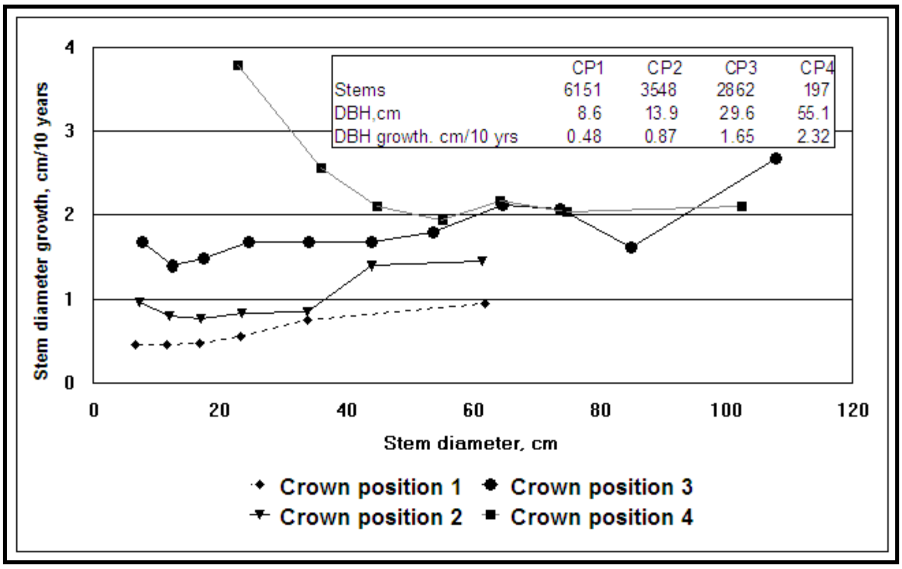


Figure 5: Stem diameter growth over stem diameter classes for different crown positions of trees.

Discussion

The selected forest growth plots are representative of most of the main forest types in South Africa, and also of local altitudinal gradients in major forest complexes within these forest types. They cover most of the main species used for resource use, except a few important targeted species in rural resources use for poles, fuel wood and fibre, such as *Ptaeroxylon obliquum* and *Millettia grandis* (Geldenhuys and Cawe this proceedings). These species, and other similar species, are more prominent near the forest margin and regrowth forest, and different strategies are needed to record their ingrowth, growth and mortality for sustainable resource use.

The changes in growing stock (mean stem diameter, stem density and basal area) calculated for a 10-year period show that the forests are not static. The different stands varied much in initial growing stock, and also in changes in stem density and basal area in the different size categories (Table 2). Only the Diepwalle, Sandile Kop and Ngome plots showed a positive change and the Manubi and Helschebos plots a negative change in stem density in all three main diameter categories over the period. Only the Witelsbos and Ngome plots showed a positive change and the Kologha, Manubi and Mpesheni plots a negative change in basal area in all three diameter categories. These changes relate to different rates of ingrowth (recruitment) and mortality (both in stem density and basal area), with a significant relationship with total stem density: negative for ingrowth (with three outliers removed), and positive with mortality (with one outlier removed. This has important implications for silvicultural management. This is further demonstrated with the changes in the total stand stem density and basal area over different diameter classes. Some stands have a high stem density in the smallest diameter classes, with relatively high mortality in the small stems, and relatively few larger stems. Other plots showed the opposite trend with much lower density of small stems but a relatively high basal area in larger stems.

Stem diameter growth showed much variation, from negative growth, to relatively fast growth, with a large number of stems showing zero up to 1 cm diameter growth over 10 years. Much of the very slow growth is related to the position of the crown of the tree below the canopy of the stand. Crown position within and above the upper canopy, with much better light conditions, showed much better growth. However, in the below canopy crown positions some relatively fast growths were recorded, and with exposed crown positions relatively slow to negative growth rates were recorded. The initial analyses on stem diameter growth show the importance of regulating stand density to provide suitable light conditions and growing space for optimum growth of trees in a stand.

The next step is to assess the growth rates of individual species, across the plots (different sites), in relation to initial stem diameter and crown position (species specific characteristics) and other stand characteristics. This will be important to understand the ecological requirements of different species in different forests for optimum silvicultural management for sustainable resource use (establishment and optimum growth of harvested species).

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PUTTING THE FORESTRY INTO PARTICIPATORY FOREST MANAGMENET - SIMPLE INVENTORY PROTOCOLS FOR SUSTAINABLE LOGGING

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Abstract

Participatory Forest Management has come a long way in Tanzania over the past twenty years, with over 380 Village Land Forest Reserves now established in the country. However, participating communities have yet to earn any revenue from significant timber resources due to the complexities of sustainable management of natural forest and typically low educational levels in rural communities. This paper describes how the Mpingo Conservation Project developed very simple protocols to allow community forest managers to assess timber resources efficiently and determine an annual quota for sustainable felling of selected species. Trees are allocated to one of just three size classes in order to minimize the number of variables which the community must manage. A simple model is used to derive quotas through a method which communities themselves can follow. This method is compared with national guidelines for Participatory Forest Resources Assessment and it is concluded that it benefits from tighter and better understood goals leading to a more efficient approach. Communities could earn US$2,000+ per year from just one or two species, thus justifying their investment in forest management, with larger sums potentially attainable later.

Introduction

Community-based conservation is an alluring paradigm that appears to hold the answers to many of the problems of conservation in the tropics. Often it can be demonstrated that local communities reap significant benefits from the ecosystem, and should therefore be ready collaborators in protecting it. However, frequently many of these benefits are intangible outcomes of a functioning ecosystem (ecosystem services) which are subject to the tragedy of the commons, and rarely appreciated until they are lost; global climate change is not regarded as a pressing issue by poor African farmers.

One solution to this challenge is to identify local natural resources which can be sustainably exploited to generate an additional financial income for the community. However, sustainable exploitation is not always easy to determine or to manage, requiring substantial investment of technical expertise.

This paper documents an innovative approach undertaken by the Mpingo Conservation Project in the forests of south-eastern Tanzania. Instead of seeking the optimal (maximum) sustainable yield, and thus community income, the problem was reduced to a simple quota determination system, which can be used by communities without outside assistance. In doing so, Participatory Forest Management was transformed from an exercise restricted to community engagement to one of technical management.

Participatory forest management in Tanzania

Participatory Forest Management (PFM) has been in development in Tanzania for around twenty years (Wily 1998). In 1998 it was put at the heart of the new forest policy of the government of Tanzania (MNRT 1998), and full legal provisions were made in the Forest Act which came into effect in 2004 (URT 2002). By 2006 over 380 Village Land Forest Reserves (VLFRs) had been established under this legislation, with many more in development (Blomley *et al.* 2008).

However, none of these communities had yet to receive any income from the most obvious source of revenue in the forests – timber. This did not happen despite PFM being seen as one of the principle strategies in the fight against illegal logging (Milledge *et al.* 2007). Villages around one of the earliest PFM sites at Duru-Haitemba reportedly earned some money from visitation fees paid by the frequent study tours by interested forestry officials from elsewhere in Tanzania and abroad (Tom Blomley pers. comm. 2007), while a sustainable charcoal project has been initiated in Iringa District (Lund 2007). In short, the social enterprise of engaging community interest and establishing Village Natural Resources Committees (VNRCs) to manage the forests had been successful, but little extractive forestry was taking place despite it being at the heart of the intellectual case for PFM.

One of the reasons for this lack of exploitation has been the lack of technical understanding of natural forest processes and management within Tanzania; university courses and technical training focus mostly on plantation management with only general guidance given with regards to management of natural forest. Guidelines developed by the Forestry and Beekeeping Division for Participatory Forest Resources Assessment (PFRA) (MNRT 2005) are more appropriate for assessing NTFPs such as firewood than timber resources, and when field tested (Ball unpubl. data.) did not yield sufficient data for the accurate determination of appropriate harvesting quotas.

African blackwood and the Mpingo conservation project

East African Blackwood (*Dalbergia melanoxylon*, locally known as mpingo), is one of the most valuable timber trees in the world fetching up to US$18,000 per cubic metre (Jenkins *et* *al.* 2002) on the export market where the principle demand is to make musical instruments such as clarinets, oboes and bagpipes. Most exports come from southern Tanzania and northern Mozambique where it is reasonably common. The tree has been proposed as a good conservation flagship species because of the high regard it is held in by local people and its ease of identification (Ball 2004). This strategy is being followed by a Tanzanian NGO called the Mpingo Conservation Project (MCP), which since 2004 has been working in Kilwa District in south-eastern Tanzania to develop PFM with a particular focus on sustainable exploitation of the valuable hardwoods to be found in the forests there. Illegal logging is widespread in that part of Tanzania, accounting for up to 96% of the timber extracted (Milledge and Elibariki 2005), and so MCP is pursuing forest certification to Forest Stewardship Council (FSC) standards in order to secure a market for timber from community managed forests.

The forest landscape of south-eastern Tanzania is a mixture of Miombo woodlands with a variety of patches of East African Coastal Forest (a biodiversity hotspot of global importance) which are found predominantly on the higher ground. Blackwood and most of the other valuable timber species are found in Miombo woodlands, although some species, such as *Milicia excelsa* and *Pterocarpus holtzii*, are mostly found in evergreen riparian vegetation. The woodlands are fairly open allowing easy access for selective logging which is the norm in the area.

Sustainable resource extraction

As well as providing a framework for PFM, the 2002 Forest Act stipulates that all natural forests must be managed sustainably (URT 2002), but does not explicitly define sustainable. Sustainability can and has been defined in many different ways. The definition provided here is limited to an ecologically sustainable harvest in natural forest that is subject to minimal management or silvicultural intervention.

The VLFRs which are set aside by communities in following the PFM process may be quite small (as low as ~500ha in size), and so geographically dividing the VLFRs into coupes according to the estimated rotation time of the tree (a simple and common way of managing a sustainable harvest) may leave some coupes entirely free of target species. This is not appropriate for rural communities who expect to receive a sustainable income from the forest, and so instead an Allowable Cut across the entire forest is considered.

Typical management plans for VLFRs developed by communities supported by the MCP have a duration of five years. The interest is therefore to define a total allowable cut which should not be exceeded over the five year duration of the management plan. How that cut should be distributed spatially within the forest and temporally over the five years is outside the scope of this paper. This concept is referred to as the Total Allowable Cut over 5 years or TAC5. It has to be separately defined for each species that are of commercial interest in a community forest.

Materials and Methods

The Mpingo Conservation Project has developed a method for a Participatory Forest Inventory which focuses entirely on timber resources. The participatory element is important since it reduces the chance of 'leaving communities in the role of policeman for someone else's policies' (Ball 2007), and in this case extends to the data analysis too. The materials required are cheap and easily within the scope of any project working in support of community forestry:

- Printed map (with scale) of the forest
- Compass
- 10 m long rope, with a mark at 5 m
- 1.5 m standard tailors' tape measures (longer is better if you can find them)
- Pen and notebook

A GPS unit can be used to mark transect start and end points but it is not necessary.

Laying out the transects

The Participatory Inventory method does not involve a fixed sampling intensity. Instead surveyors should aim to record 50+ trees of each species of most interest, and 20+ trees for species of lesser interest. Thus the number of transects required cannot be known precisely in advance, although an experienced facilitator who is familiar with the area may be able to guestimate, and advise the community accordingly. Instead an initial number of transects (4-5 is usually appropriate) should be walked, with more added later if necessary. If the axis of the forest the transects are traversing is much shorter than the other then more transects will clearly be needed (6-8 may be appropriate in this case as a starting number).

Transects are initially plotted as lines on a map of the forest roughly where they are intended to pass. They should be reasonably spaced out and follow a standard compass bearing, which is decided at the beginning. From the map scale the distance along the forest boundary (which should be either cleared or at least marked) to the start of the transect can be estimated, and then reached through a timed march. MCP assumes that 4 km/hr is possible in rough terrain, and 6 km/hr along a path or cleared boundary.

The transects walked should be 10 m wide (5 m on either side of the line), using the pre-measured rope. Alternatively, a human chain can be formed; five people walking broadside, hands outstretched, roughly covering 10 m. The group can detach and come back together to go around obstacles.

The inventory should only assess a limited number of tree species (max 6-8), which should be decided in advance, so most trees encountered on the transects can just be ignored. When an individual of a species of interest is found then its species is noted and its circumference at breast height recorded. The data is sufficiently simple that it can just be recorded in an ordinary exercise book without printing out dedicated data collection sheets.

Size classes

In order to keep the analysis as simple as possible, trees are assigned to one of three size classes defined according to the Legal Minimum Diameter for Harvesting (LMDH). The size classes are colour coded for easy reference and drawing of simple bar charts. They are defined as follows (DT = diameter of tree):

- Red (not yet harvestable) : 0.5 × LMDH ≤ DT < LMDH
- Green (harvestable) : LMDH ≤ DT < 2 × LMDH
- Blue (extra large trees / seed trees) : 2 × LMDH ≤ DT

For practical use the size classes, which vary according to species, need to be converted into circumference terms in advance. In Swahili the three size classes are termed Miti Midogo, Miti ya Kati and Miti Mikubwa respectively; these are abbreviated to MD (red), KT (green) and MK (blue) during the Participatory Analysis and in the Harvesting Plan.

Participatory analysis

The calculation of the TAC5 can be run entirely in the community, and runs as follows (abbreviations are based on the Swahili):

1. Estimate the total length of transects from the scale map. A 10 m transect width conveniently means the length of transects in kilometres is the same as the area in hectares. Later on 10% will be added to account for deviations from the actual path plotted but this is encapsulated in the reference table so does not need to be explicitly computed at this point. From this the area-based extrapolation factor (NZE) is calculated.
2. The number of trees in each size class counted during the Participatory Inventory is then listed for each species, and a sustainable quota for those trees is determined (these are termed MKT for green trees and MMK for blue). This calculation is done by simple lookup on a reference table of sustainable quotas, see below.
3. Red trees will grow into green and blue trees to replace the ones that have been felled. But if there are not enough it is necessary to revise the quota downwards in order to be sustainable. Also roughly one third of red trees will die before they ever reach green tree size. This next stage calculates the necessary adjustment factor.
    - Adjusted total of Red Trees MD' = MD x 2 / 3
    - Total J1 = KT + MK
    - Total J2 = (MD' + KT + MK) / 2
    - Total J3 = Minimum (J1, J2)
    - Red Ratio Adjustment Factor NZM = J3 / J1

4) Finally all of the above calculations are combined to give the quota of trees that can be harvested sustainably from the entire productive area of the forest. The formulae to use are:-
   - Harvesting Quota of Green Trees: KKT = MKT x NZE x NZM
   - Harvesting Quota of Blue Trees: KMK = MMK = KBT x NZE x NZM

Reference table

All the sophisticated statistics are combined in the table of sustainable quotas referenced in step 2 above (Table 1). This may vary from one species to another according to the model used (see the relevant section below; an example showing the current look-up table for *Dalbergia melanoxylon* is shown below). The table computes the 75% lower confidence limit, adds on the 10% for transect deviations, and then applies a quota from a model of sustainable off take, which is based on a combination of cutting cycle and volume increment models (MCP 2008):

- Green trees = 9.4% over five years
- Blue trees = 5.8% over five years

Community representatives simply use the table to look for the row with the same or lower number of trees as seen on the transects and then scan across to determine the quota for the green or blue tree size class as appropriate.

Table 1: Reference table for *Dalbergia melanoxylon* for looking up the sustainable harvesting quota based on 75% lower confidence limit, 10% transect deviation and MCP's model for a sustainable off-take. Results need to be scaled by sampling intensity and ratio of red-sized trees to green and blue ones

No. Trees seen on Transects	Green Trees TAC5	Blue Trees TAC5
5	0.19	0.12
6	0.24	0.15
7	0.29	0.18
8	0.34	0.21
9	0.39	0.24
10	0.44	0.27
12	0.54	0.33
14	0.65	0.40
16	0.75	0.46
18	0.85	0.53
20	0.96	0.59
25	1.22	0.75
30	1.49	0.92
35	1.76	1.08
40	2.03	1.25
45	2.30	1.42
50	2.57	1.58
60	3.11	1.92
70	3.66	2.26
80	4.20	2.59
90	4.75	2.93
100	5.30	3.27

Results

MCP has tested the above methodology in four villages in central Kilwa District, of which two have completed, while the other two still have to conduct the participatory analysis. *Dalbergia melanoxylon* (LMDH 24 cm) has been the principle species of interest in the forests of all four villages, and the commonest high value timber species, with much smaller quantities of *Pterocarpus holtzii* and *Millettia stuhlmannii* (both LMDH 45 cm). The results for the two villages completed are given in Table 2.

Table 2: Results of a Participatory Forest Inventory in two community-managed forests in Kilwa District, south-eastern Tanzania

Village		Kikole		Kisangi	
Area of Productive Forest (ha)		407		1,756	
Length of Transects (km)		20.5		26.7 **	
Species *	Size Class	# trees seen	TAC5	# trees seen	TAC5
Dalbergia melanoxylon	red	51	0	0	0
	green	136	75	60	102
	blue	26	8	5	3
Pterocarpus holtzii	red	1	0	7	0
	green	0	0	18	51
	blue	0	0	2	0
Millettia stuhlmannii	red	10	0	12	0
	green	0	0	10	36
	blue	0	0	2	0

** Other species were surveyed but were too few to be commercially harvestable.*

*** Actually walked 13.3 km of 20 m wide transects.*

Discussion

In all four villages where the transects have been walked, the method was picked up readily enough by the local communities who were enthusiastic participants. All inventories were closely supervised so opportunities for error were limited. Both Kikole and Kisangi were experimental villages where one or more aspects were trialled; in Kikole an excessive number of transects were walked looking for trees of other valuable species, whilst in Kisangi the transects were 20 m wide making it more likely that small trees are missed. This was probably a major factor in the absence of any red blackwood trees recorded on the transects, together with the fact that blackwood is a pioneer species (Ball 2004) while the forest at Kisangi is semi-closed canopy climax miombo. Based on these experiences the simpler but less efficient 10 m wide transect was adopted by MCP.

With each green-sized blackwood tree worth at least US$20 and most blue-sized blackwood trees worth in excess of US$100 (MCP 2008), the inventories found over US$2,300 worth of blackwood that can be sustainably harvested from Kikole's forest in five years, and some US$11,000 worth of timber (conservatively valuing green-sized *P. holtzii* and *M. stuhlmannii* at US$100 each) can be sustainably felled in the same period from Kisangi's forest. Kikole are prepared to expand massively their VLFR to close to 3,000 ha suggesting that both communities could earn at least US$2,000 per year from timber sales. MCP expects this figure to increase substantially with FSC certification and when less highly sought-after but commoner species such as *Brachystegia spp*. are included. At the very least this should more than pay for the labour and opportunity costs of setting aside the forest as a VLFR, and potentially in future earn the villages a useful dividend from the forest.

The Participatory Forest Inventory method outlined in this paper addresses a number of weaknesses manifested in the guidelines for PFRA issued by the Forestry and Beekeeping Division (FBD):-

1. Lack of Focus
   A PFRA that follows the FBD guidelines seeks to assess all forest resources which risks wasting effort on resources that are either very common or very rare, or are not actively utilised.
2. Greater Proportion of Time Spent Surveying
   The FBD guidelines use sample plots which take a long time to locate and set out. With transects the inventory team can be surveying for up to 80% of their time in the forest.
3. Insufficient Data
   Instead of adopting a fixed sampling intensity the method encourages communities to decide the level of effort they wish to put in.
4. Over-reliance on the Mean
   Use of the 75% lower confidence limit explicitly penalises communities who do not invest sufficient effort into forest assessment, and avoids the problem of substantial quotas being granted on the basis of a handful of tree sightings.

The mathematics is sufficiently simple that poorly educated communities can follow the entire analysis procedure. Once communities have gained more experience in the procedure MCP expects them to be able to conduct their own inventories using just a printed method for guidance and copies of the reference table provided.

At present MCP is covering the entire cost of inventorying the forest so communities do not yet have to decide the level of effort which is instead guided by the facilitator based on the 50 tree rule of thumb that is based on the Poisson distribution equation for confidence limits (Ball unpubl. data). However, in future when communities begin earning substantial sums from their forests, MCP will withdraw this subsidy at which point it will be interesting to see how the communities decide the appropriate level of effort.

The method for laying out transects and locating starting points is a compromise between scientific robustness and practicality; communities are warned in advance about the problems of bias and that they may be penalised if manipulation of the data is detected. However, in practice most communities are not sufficiently map-literate to pinpoint certain stands on an outline map of their forest, meaning such opportunities are limited.

In order to assess transect deviation, MCP compared point-to-point distances between waypoints recorded by a GPS roughly every 100 m when walking the transects in Kikole’s forest with the Pythagorean straight line distance from start to end of the transect. Deviation varied from 0.6% to 6.2% with an average of 4%. Ball (2003) found that practical deviation by student surveyors from pre-determined short courses in rough terrain averaged under 4.8° and did not exceed 8°, a 1% variation in length. Putting all this together and invoking the precautionary principle this MCP assumes 10% deviation for the purpose of estimating actual stocks.

Conclusion

The sample plot versus transects approach is indicative of the history of PFM being primarily about management of NTFPs in small Forest Management Units in largely deforested areas, whereas the communities supported by MCP are establishing VLFRs up to 4,000 ha in size in a landscape which itself is generally forested. Here, where deforestation is yet to become a major issue, the principle perceived benefit of PFM is to capture timber rents for the community, and the tight focus of the inventory method is better served to this purpose than the wider PFRA method advocated by FBD. However, the difference is also symptomatic of another major weakness of PFM, that it is often pushed by local development or conservation agencies with little thought to local goals. If you do not know why you are conserving some forest, then you will not know what to assess. PFM facilitators should instead agree clear goals of PFM with participating communities, and only assess forest resources relevant to those goals.

When those goals are clear, and a simple method constructed around them, this paper demonstrates that it is possible to do good science whilst fully involving participating communities – the forest managers. Harvesting plans for the villages of Kikole and Kisangi based on the above research have been approved by the Forestry and Beekeeping Division, and MCP hopes they will be able to begin harvesting early in 2009. This will be a first for PFM in Tanzania, and means that communities can at last start benefitting from the most tangible asset in the forests they are managing. We will thus have succeeded in putting the forestry back into Participatory Forest Management.

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ASSESING THE SUSTAINABLE MANAGEMENT OF *Entandrophragma cylindricum* USING THE STOCK RECOVERY RATE

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Abstract

The renewal of the forestry codes of the countries of the Congo Basin in the 90's has legalized management plans for forest concessions. These plans intend, among other objectives, to ensure the sustainable exploitation of commercial species. Sustainability is assessed using the stock recovery rate, which is defined in national directives as the ratio of the exploitable timber stock at the end of a felling cycle over the exploitable timber stock at the beginning of this cycle. Computing this rate requires forecasting the temporal development of each species during a felling cycle, which is usually achieved using the so-called "stock recovery formula". This paper shows that this formula corresponds to a Leslie model, and then proposes a generalization as a Usher matrix model. Using the data from the M'Baïki experimental plots in the Central African Republic, the stock recovery rate for sapelli (*Entandrophragma cylindricum*, Meliaceæ), a major timber species in Central Africa, was estimated. The estimate was completed by its confidence interval using bootstrap methods. Although 225 observations were available for sapelli, the stock recovery rate was estimated with no more than an accuracy of about 45% at confidence level 95%. This did not permit to conclude whether the asymptotic stock recovery rate was greater or less than one. This suggested that much more observations than usually acknowledged are required to estimate the stock recovery rate with an acceptable accuracy. Different logging scenarios were finally tested to assess the impact of management parameters on the stock recovery rate of sapelli.

Introduction

Between 1990 and 2002, all six countries of the Congo Basin in Central Africa (namely Cameroon, Central African Republic, Congo, Democratic Republic of Congo, Equatorial Guinea, and Gabon) have voted new forestry codes (Nasi *et al.* 2006). The new forestry codes have set as a legal obligation the use of management plans for forest concessions. Management plans schedule the set of all activities to be achieved in the forest concession during one rotation, and ensure that these activities are consistent with a sustainable exploitation in the long-term. In practice, sustainability is assessed for each commercial species using the stock recovery rate, which is defined in national forestry directives as the ratio of the exploitable timber stock at the end of a felling cycle over the exploitable timber stock at the beginning of this cycle, just before logging (Durrieu de Madron *et al.* 1998).

The timber stock that is potentially exploitable is defined as the number of stems with a diameter greater than a threshold called the “diameter cutting limit” (DCL). The DCL is legally fixed for each commercial species by national forest services. To ensure sustainability, only one part of this potential is actually harvested. This part is delimited by another threshold diameter, called the “minimum harvest diameter” (MHD) that is necessarily greater than the DCL (Catinot 1997, Nasi *et al.* 2006). Every tree to be harvested must have a diameter greater than MHD. Harvest is periodic, and the time interval between two successive logging operations is the length of the felling cycle. During this time, the forest is left so that the timber stock naturally regenerates. Contrary to the DCL that is legally fixed, the MHD and the length of the felling cycle are flexible parameters that are adjusted for each forest management unit. The length of the felling cycle is the same for all species, whereas the MHD is adjusted separately for each commercial species.

MHD and the length of the felling cycle are adjusted to ensure an acceptable level for the reconstitution of the timber stock, i.e. an acceptable value of the stock recovery rate. This computation is done separately for each commercial species. If the stock recovery rate for a given species is too low, then the length of the felling cycle or the MHD for this species has to be increased. Increasing the length of the felling cycle in turn changes the value of the stock recovery rate for all other commercial species. A key point for the management of natural tropical forest in Central Africa is thus to predict the stock recovery rate.

Computing the stock recovery rate requires forecasting the temporal development of each species during a felling cycle, using estimates of the species growth, recruitment, and mortality. In most national forestry directives, this is achieved using the so-called “stock recovery formula”, that was established during the pilot management plan of Dimako in Cameroon (Durrieu de Madron *et al.* 1998). This formula gives an estimate of the stock recovery rate, but does not specify the confidence interval around this estimate. Yet the demographic parameters (growth, recruitment, mortality) used to forecast the temporal development of the population can yield significant uncertainties around the predicted value.

In this study, the stock recovery rate of sapelli (*Entandrophragma cylindricum* Sprague, Meliaceae), a major timber species in Central Africa, is estimated using data from the experimental site of M'Baïki in the Central African Republic. The study shows that the stock recovery formula corresponds to a Leslie model, i.e. a model of population dynamics for structured populations, and then proposes an extension of it as a Usher matrix model. More importantly, the study shows how to compute a confidence interval around the estimate of the stock recovery rate, and how this estimate of the prediction uncertainty permits a better interpretation of the value of the stock recovery rate.

Materials and Methods

Study site and focus species

Data for this study comes from the M'Baïki experimental site (3°54'N, 17°56'E) in the Central African Republic. This experimental site is dedicated to studying the effects of logging damage on stock recovery (Bedel *et al.* 1998). The site lies in a terra firme moist forest, at the northern limit of the moist forests of the Congo basin. The experimental design of the site consists of two blocks of three and one block of four 300 m × 300 m permanent sample plots with a 50 m inner buffer zone (Figure 1). In each central 200 m × 200 m square, all trees over 10 cm dbh (diameter at breast height) were identified and georeferenced. Since 1982, girths at breast height, tree deaths and newly recruited trees over 10 cm dbh have been monitored annually. Between 1984 and 1985, two silvicultural treatments have been applied: three plots (including the buffer zone) were logged, and four plots were logged and thinned (Bedel *et al.* 1998). Logging here designates the removal of exploitable trees from commercial species with a diameter above the DCL, whereas thinning designates the removal of trees of any size of non-commercial species. The three remaining plots were left as control.

The study for this paper focused on sapelli and used the sapelli data from the M'Baïki plots from 1992 to 1994. Sapelli is a large canopy tree that is found from Sierra Leone and as far as Ouganda to the East and the Mayombe forests in the Democratic Republic of Congo to the South. It is the most abundant of the great Meliaceae commercial species. Its physical and ecological characteristics are described in Palla *et al.* (2002). The DCL for sapelli is 80 cm dbh in the Central African Republic (République Centrafricaine 1990). The length of the felling cycle is typically 30 years, i.e. the reference felling cycle in Cameroon (République du Cameroun 2002) and in the Central African Republic based on the pilot management plan for PEA no 169 at Ngotto (Bonannée 2001).

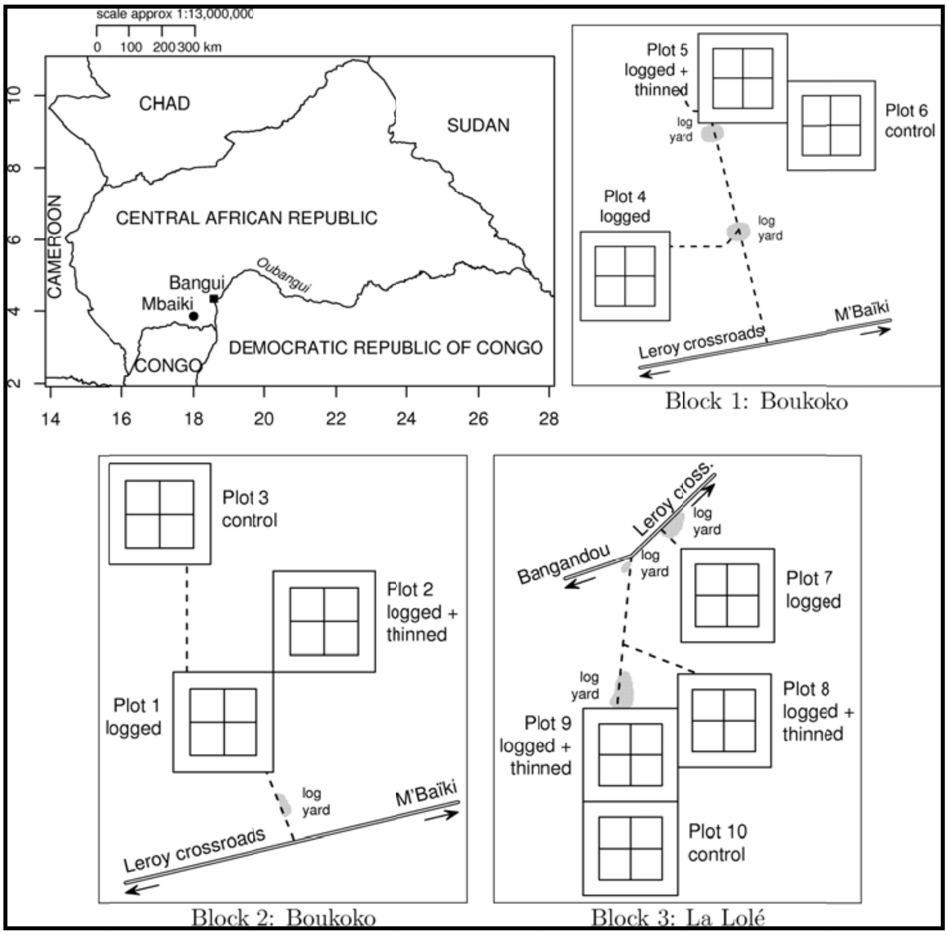

Figure 1: Location of the M'Baïki experimental site in the Central African Republic and schematic view of the 10 permanent sample plots.

The stock recovery formula and its extension

The stock recovery formula supposes that all the trees of a given species have the same growth rate irrespective of their size, and that their mortality rate is constant too. Let *a* be the constant growth rate in cm yr^{-1}, and *m* the constant mortality rate in yr^{-1}. Time is discrete with a time step τ (in *yr*). The population is described by a vector *N(t)* giving the number of trees in *K* diameter classes. Diameter classes have a constant width $\delta = a\tau$, except the last class that gathers all trees with a diameter greater than $(K-1)\delta$. Let $c = \frac{DCL}{\delta} + 1$ be the class index that corresponds to the *DCL*: classes 1 to $c-1$ are below the *DCL*, whereas classes *c* to *K* are above the *DCL*. Let $N_i(t)$ be the *i*th component of *N(t)* (*i = 1, …, K*). By definition, the exploitable timber stock at time *t* is:

$$S(t) = \sum_{i=c}^{K} N_i(t)$$

Suppose that logging takes place at time $t = 0$. It is assumed that logging is instantaneous with respect to forest dynamics. Let $T \in N$ be the number of time steps corresponding to the length of the felling cycle. Then, by definition, the stock recovery rate at the end of the first felling cycle is:

$$R = \frac{S(T)}{S(0)} = \frac{\sum_{i=c}^{K} N_i(T)}{\sum_{i=c}^{K} N_i(0)}$$

Moreover, the number of trees in the *i*th diameter class at time *t* is related to the number of trees in the $(i-t)$th diameter class at time 0 by the following relationship:

$$N_i(t) = (1-m)^t (1-p_{i-t}) N_{i-t}(0) \qquad (i < K)$$
$$N_K(t) = \sum_{i=K-t}^{K} (1-m)^t (1-p_i) N_i(0)$$

where p_i is the logging intensity in class *i*, that is: $1-p_i$ is the ratio of the number of trees in the *i*th class before and after logging. Carrying forward this expression in the expression of *R* gives the stock recovery formula (Durrieu de Madron *et al.* 1998):

$$R = \frac{\sum_{i=c-T}^{K} (1-m)^T (1-p_i) N_i(0)}{\sum_{i=c}^{K} N_i(0)}$$

In matrix notations, this is equivalent to:

$$R = \frac{\mathbf{I'}_c \, \mathbf{L}^T \mathbf{H} \, \mathbf{N}(0)}{\mathbf{I'}_c \, \mathbf{N}(0)}$$

where prime denotes the transpose, I_c is the vector of length *K* whose *i*th element equals zero if $i < c$ and one if $i \geq c$, *H* is a diagonal *K*×*K* matrix whose *i*th element on the diagonal equals $1-p_i$, and *L* is a Leslie *K*×*K* transition matrix:

$$\mathbf{L} = \begin{pmatrix} 0 & & & \mathbf{0} \\ 1-m & \cdots & & \\ & \cdots & 0 & \\ \mathbf{0} & & 1-m & 1-m \end{pmatrix}$$

This proves that the model of forest dynamics that underlies the stock recovery formula is a Leslie (1945) matrix model.

A generalization of the Leslie matrix model is the Usher (1966) matrix model. A generalization of the stock recovery formula gives:

$$R = \frac{\mathbf{I'}_c\,\mathbf{U}^T\mathbf{H}\,\mathbf{N}(0)}{\mathbf{I'}_c\,\mathbf{N}(0)}$$

Where U is a Usher $K \times K$ transition matrix:

$$\mathbf{U} = \begin{pmatrix} q_1 & & & \mathbf{0} \\ p_1 & q_2 & & \\ & \dots & \dots & \\ \mathbf{0} & & p_{K-1} & q_K \end{pmatrix}$$

where q_i is the probability for a tree to stay alive in class i between two consecutive time steps, and p_i is the probability for a tree to stay alive and grow up from class i to $i+1$ between two consecutive time steps. The Usher extension of the stock recovery formula permits to relax the hypothesis of constant growth, taking into account the relationship between size and growth. As a consequence, the estimate of the stock recovery rate that it provides is less biased than with the standard stock recovery formula. More details about the Usher matrix model and its use to estimate the stock recovery rate can be found in Picard *et al.* (2008).

By definition, the stock recovery rate at the end of the kth felling cycle is the ratio of the exploitable stock at time kT over the exploitable stock at time $(k-1)T$. As felling cycles follow each other, the stock recovery rate converges towards a limit that is the asymptotic stock recovery rate. It corresponds to the dominant eigenvalue of $\mathbf{L}^\mathbf{T}\mathbf{H}$ or $\mathbf{U}^\mathbf{T}\mathbf{H}$ (Picard *et al.* 2008). The asymptotic stock recovery rate has to be interpreted as an index of long-term sustainability: if greater than one, harvest is less than regrowth and the exploitable stock indefinitely grows; if equal to one, harvest balances regrowth and the exploitable stock converges to an equilibrium; if less than one, harvest is greater than regrowth and the exploitable stock vanishes to zero. More precisely, this index indicates what would happen if the current conditions remain the same for infinite time (same growth rate, same recruitment, etc.) As this cannot occur in reality, the asymptotic stock recovery rate must not be interpreted as a prediction of what will occur in the long-term.

Statistical analyses

The data on sapelli at M'Baïki and both versions (the standard version, and its Usher extension) of the stock recovery formula were used to compute the stock recovery rate of sapelli. Both the stock recovery rate at the end of the first felling cycle and the asymptotic stock recovery rate were computed. A confidence interval around each predicted value was computed using bootstrap (Efron and Tibshirani 1993). This consists in drawing with replacement in the original dataset as many observations as there are in the original dataset. This bootstrap dataset is then used to compute a new estimate of the stock recovery rate. These operations are repeated B times, which provides B bootstrap replicates of the stock recovery rate. The confidence interval is finally computed as the empirical confidence interval of the B bootstrap replicates. Here we used B = 10,000 replicates. This confidence interval was used to test whether the estimate of the stock recovery rate obtained here was significantly different from one, and from the estimate obtained in a previous study on sapelli (Karsenty and Gourlet-Fleury 2006). The accuracy was also computed as the width of the confidence interval divided by the estimate of the stock recovery rate. Thus a good accuracy corresponds to a low accuracy value.

Computations were achieved for a typical logging scenario consisting of a logging intensity of 90%, MHD = DCL = 80 cm, and $Tx\tau = 30$ years. Longer felling cycles were subsequently tested (40, 50 and 60 years). All computations were performed using R software (R Development Core Team 2005). Bootstrap algorithms were implemented in C language interfaced with R. The code is available at http://agents.cirad.fr/index.php/Nicolas+Picard.

Results

Figure 2 shows the temporal development of the exploitable stock of sapelli submitted to periodic harvest every 30 years, according to the Usher model and as predicted by another study by Karsenty and Gourlet-Fleury (2006). The development observed at M'Baïki on logged plots is shown till 2005. The confidence intervals of the predicted stock for the short-run development during the first felling cycle (years 1984–2014) approximately match the observed stock. The exploitable stock at the end of the first felling cycle is 0.45 stems ha^{-1} on average according to the Usher model, which is 28% of the initial stock (1.58 stems ha^{-1}). This value of the stock recovery rate at the end of the first felling cycle is quite low as compared to standard values found in management plans, where 50% is usually taken as a minimum to reach. This low value can be explained in the present case by the shape of the initial diameter distribution. It is not a consequence of unviable vital rates, as it will appear in the long run. The diameter distribution in 1984 (before logging) is indeed U-shaped, with an overstocking of big trees (dbh$\geq$80 cm) and an under-stocking in intermediate diameter classes (25$\leq$dbh<55 cm). Logging depletes the largest diameter class that is not subsequently fed by the intermediate classes due to their low level.

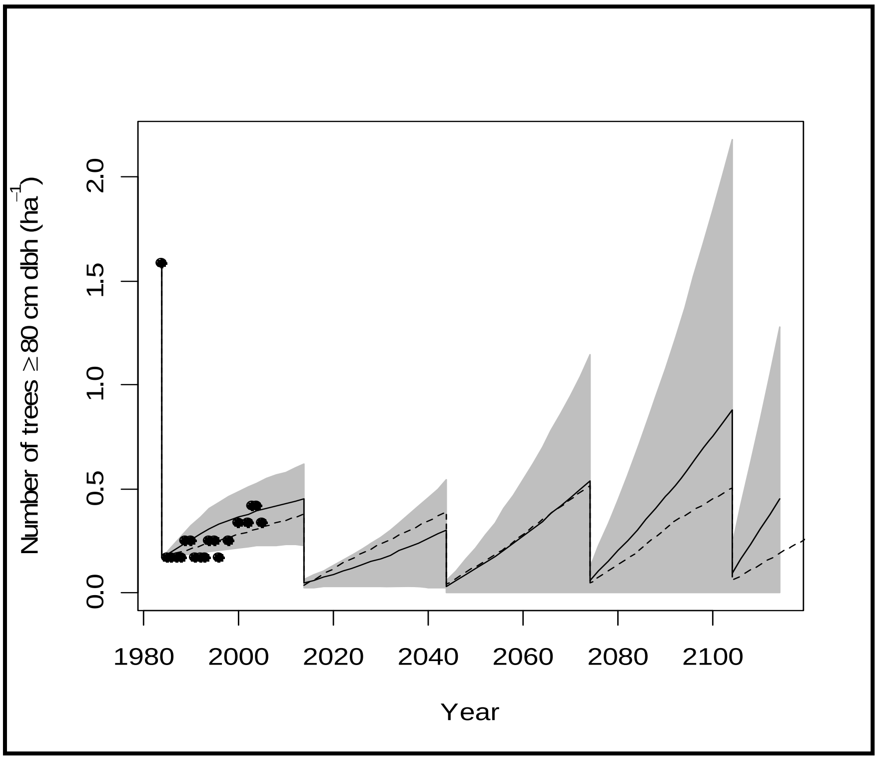

Figure 2: Temporal development of the exploitable stock of sapelli at M'Baïki, when submitted to periodic harvest with a felling cycle of 30 years. Dots represent the observed development. The solid line is the development predicted by a Usher matrix model, with its 95% confidence limits in grey. The broken line is the development predicted by Karsenty and Gourlet-Fleury (2006).

Other statistical properties of the estimator of the stock recovery rate at the end of the first felling cycle are given in Table 1. The accuracy of the estimation corresponding to Figure 2 is 43.4% at level 95%: this is much more than the level of accuracy usually considered as acceptable (about 10%). This low accuracy is to be related to the high standard errors when estimating the parameters of the Usher transition matrix. Table 1 also shows the influence of the formula used and of the length of the felling cycle on the estimate of the stock recovery rate at the end of the first felling cycle. The standard stock recovery formula brings a better accuracy than its Usher extension, but it underestimates the stock recovery rate. This is a classical case of trade off between bias and variance. The hypothesis of constant growth that underlies the standard stock recovery formula reduces the variance of predictions (since there are fewer parameters to estimate in the model), but it induces a bias (here an underestimation of growth, that results in an underestimation of the stock recovery rate). As expected, the stock recovery rate increases as the length of the felling cycle increases. Not surprisingly, the accuracy of the stock recovery rate estimate gets worse as the length of the felling cycle increases: the longer the predictions of the model are, the less precise they are.

Table 1: Estimates and distribution statistics of the stock recovery rate at the end of the first felling cycle for sapelli at M'Baïki, according to the stock recovery formula and its Usher extension.

T (yr)	Estimate (%)	Std. error (%)	95% Conf. Limits (%)	Accuracy (%)	p-value*
A. Standard stock recovery formula					
30	19.6	2.0	15.5-23.0	19.1	< 0.001
40	22.2	3.0	16.1-27.6	25.9	< 0.001
50	25.4	4.2	17.0-33.2	31.9	< 0.001
60	29.6	5.8	18.2-40.8	38.3	< 0.001
B. Usher extension of the stock recovery formula					
30	28.5	6.8	14.6-39.3	43.4	< 0.001
40	31.9	8.9	13.9-46.0	50.2	< 0.001
50	36.3	11.4	13.3-55.4	58.0	< 0.001
60	42.1	15.2	12.1-68.9	67.5	< 0.001

** This the p-value of the test of the null bypothesis H0:R = 1.*

Over a longer period, as felling cycles follow one another, the exploitable stock shows on average a sawtooth development, with increasing periodic peaks (just before logging; see Figure 2). The asymptotic stock recovery rate is accordingly greater than one on average (Table 2). However, this average evolution hides a great variety of trajectories, as shown by the 95% confidence limits around the average trajectory (Figure 2). The lower bound of the 95% confidence limits decreases to zero: some of the bootstrap replicates thus have an asymptotic stock recovery rate that is less than one. Accordingly, the 95% confidence limit for the asymptotic stock recovery rate includes one (Table 2). Thus, although the estimate of the asymptotic stock recovery rate in Figure 2 is 1.24, it cannot be excluded that the true value of this rate is actually less than one.

Comparing the results of our study with that of Karsenty and Gourlet-Fleury (2006) brings an interesting result. The development predicted by Karsenty and Gourlet-Fleury (2006) (shown as a dashed line in Figure 2) is close to ours at the beginning (the best agreement is during the third felling cycle). However the two predicted trajectories diverge in the long run. Whereas the periodic peaks increase according to the Usher model, with a corresponding asymptotic stock recovery rate of 1.24, they decrease according to Karsenty and Gourlet-Fleury's model, with a corresponding asymptotic stock recovery rate of 0.95. If one only looks at these average values, there is an apparent contradiction regarding the long-term sustainability. However, taking account of the uncertainties around these predictions erases this contradiction. Given the bad accuracy of estimates, there is actually no significant difference between our estimate of the asymptotic stock recovery rate and that of Karsenty and Gourlet-Fleury (p-value = 0.24).

Table 2: Estimates and distribution statistics of the asymptotic stock recovery rate for sapelli at M'Baïki, according to the stock recovery formula and its Usher extension

T (yr)	Estimate (%)	Std. err. (%)	95% Conf. Limits (%)	Accuracy (%)	p-value*
A. Standard stock recovery formula					
30	125.2	28.0	77.9-190.0	45.0	0.36
40	137.1	41.4	71.0-236.9	60.5	0.35
50	151.0	57.4	66.5-296.0	76.0	0.35
60	168.4	77.5	62.6-370.6	91.5	0.33
B. Usher extension of the stock recovery formula					
30	124.5	28.0	76.9-189.3	45.1	0.38
40	136.6	39.9	72.3-232.0	58.5	0.36
50	152.0	55.8	68.2-291.3	73.4	0.32
60	168.5	75.1	64.4-362.9	88.6	0.32

** This the p-value of the test of the null hypothesis H0: R = 1.*

Table 2 shows the influence of the formula used and of the length of the felling cycle on the estimate of the asymptotic stock recovery rate. Contrary to the stock recovery rate at the end of the first felling cycle (Table 1), the standard stock recovery formula and its Usher extension bring very similar estimates for the asymptotic rate. The Usher model is slightly more precise. As expected, the asymptotic stock recovery rate increases when the length of the felling cycle increases, whereas its accuracy gets worse.

Discussion and Conclusion

The stock recovery rate of sapelli at the end of the first felling cycle is quite low as compared to values commonly found in management plans, even when taking into account the bad accuracy of the prediction. The reason is not related to the value of the parameters (growth, mortality, and recruitment) of its dynamics, since the asymptotic stock recovery rate is greater than one on average, but rather to the unbalanced initial diameter distribution that is U-shaped. A balanced distribution would have an exponential shape. A solution to increase the stock recovery rate at the end of the first felling cycle consists in increasing the length of the felling cycle. Other solutions (not shown here) would consist in decreasing the logging intensity or increasing the MHD.

As acknowledged before, the asymptotic stock recovery rate for sapelli must not be interpreted as a prediction of what will occur in the long-term, since the computation of this rate assumes that all vital rates remain constant. As large trees, that are also the seed trees, are harvested, it is likely that recruitment will decrease rather than remaining constant. Then the long-term vision that is offered by Figure 2 is presumably optimistic.

The most striking feature of the estimation of the stock recovery rate is its poor accuracy, much above the level of accuracy generally considered as acceptable (about 10%). The standard stock recovery formula permits to improve the level of accuracy, but at the price of a bias that is far from negligible. The only reliable solution to improve the accuracy would consist in increasing the number of observations from which the parameters of stand dynamics (growth, mortality, and recruitment) are estimated. The present study was based on all available observations for sapelli at M'Baïki, i.e. 225 observations on 40 ha. Getting an accuracy of 10% at confidence level 95% for the stock recovery rate at the end of the first felling cycle would require 2,400 observations (Picard *et al.* 2008). Given the average density of sapelli at M'Baïki (5.625 ha^{-1}), this would correspond to an area of 427 ha.

The results that we obtained for sapelli remain valid for other commercial species (Picard and Gourlet-Fleury 2008). The levels of accuracy that are obtained from a few hundred observations are well above the targeted level of 10%, and a few thousand observations are generally required to improve the level of precision. Given the low densities of some commercial species (e.g. 0.2 ha^{-1} for sipo, *Entandrophragma utile*, at M'Baïki; Bedel *et al.* 1998), this may lead to tremendous areas to monitor to get observations.

A first conclusion of this study is thus to reinforce permanent sample plots (PSPs) in Central Africa to get more observations on population dynamics for commercial species. Such observations would permit a better precision of the estimate of the parameters (growth, recruitment, mortality) of population dynamics, which would result in more accurate estimates of stock recovery rates. Reinforcing PSPs means (1) designing new kinds of PSPs that are more efficient (e.g. trails that connect permanently monitored trees rather than classical plots), (2) increasing the number of PSPs, and (3) harmonizing PSPs at the regional level, so that data coming from different sites can be used in a consistent way (Picard and Gourlet-Fleury 2008). Such a network of PSPs could serve many other objectives such as biodiversity assessments or carbon stock assessments.

A second conclusion is that estimates of stock recovery rates should always be accompanied by their confidence interval. This is presently not the case in management plans where the values are given alone. Using a similar study by Karsenty and Gourlet-Fleury (2006) as an example showed that the inspection of the estimate alone could lead to erroneous conclusions regarding the long-term sustainability. The confidence interval permits a correct interpretation of the stock recovery rate. Hence national forestry directives should complement the stock recovery formula with another formula that gives its precision.

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THE QUEST FOR SUSTAINABLE HARVESTING OF NON-TIMBER FOREST PRODUCTS: DEVELOPMENT OF HARVEST SYSTEMS AND MANAGEMENT PRESCRIPTIONS

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Abstract

There is a growing appreciation of the importance of non-timber forest products (NTFPs) and the role they could play in the socio-economic wellbeing of especially rural communities. Harvest systems to ensure sustainable harvesting are largely still lacking and overutilisation is of growing concern. Three case studies of different products harvested from natural forest in the southern Cape, South Africa, were used to scrutinise the process of developing harvest systems for NTFPs viz. fern (*Rumohra adiantiformis*) fronds (leaves) as greenery in the florist industry, medicinal tree bark, and the corm (stem) of the geophyte *Bulbine latifolia* for medicinal use. The results demonstrate that a simple generic process that provides for research to be focused on the relevant fields can be followed effectively with the development of harvest systems for NTFPs. This paper explores and discusses the process, and the complexities and constraints with its successful implementation.

Introduction

Non-timber forest products (NTFPs) are important in rural livelihoods and for economic growth (Lawes *et al.* 2004). However, strategies and the development of harvest systems for their sustainable use have been neglected worldwide and overutilisation is of growing concern (Mudekwe 2007, Ndangalasi *et al.* 2007).

The objective of the study was to use three case studies of different forest species and products to assess the requirements and process of developing systems and prescriptions for successful and sustainable harvesting of NTFPs within a socio-economic and political framework of sustainable use. The study was motivated by the management objective of ensuring optimum, sustainable harvesting of NTFPs from natural forests in the southern Cape, South Africa.

Study area

The study was conducted in natural, closed-canopy forest in the southern Cape, South Africa, i.e. part of the Southern Afrotemperate Forest group (Mucina and Rutherford 2006). These forests form the largest forest complex in southern Africa, covering approximately 60,500 ha between 22°00' and 24°30'E at 33°45'S latitude. The area receives orographic rain throughout the year and has a moist, warm-temperate climate. Conservation, resource use and ecotourism are important land-use types within the applied multiple-use management system. Harvesting of NTFPs has become increasingly important after being overshadowed by commercial timber production in the past. Participatory forest management (PFM) was adopted to ensure an equitable distribution of benefits from natural forests in the region (DWAF 2004).

Materials and Methods

The systematic process for the development of harvest systems and management strategies for NTFPs is well-documented (Peters 1996, Cunningham 2001). It entails defining the product, delineation of the resource area, studies of population dynamics and demography of target species, and continued monitoring and system refinement after development and implementation of the harvest system. The three case studies to scrutinise this process included the fronds (leaves) of the fern *Rumohra adiantiformis*, the corm (stem) of the geophyte *Bulbine latifolia* and medicinal tree bark.

Rumohra adiantiformis fern fronds are used in flower arrangements. Little was known about its ecology, dynamics and productivity when commercial harvesting started in 1982. Applied research was initiated at different levels and an adaptive management approach followed with the development of harvest prescriptions for the species. This approach was interrogated, studying historical records of fern yield and research conducted, and results of long-term monitoring of population dynamics and harvest impact (see Vermeulen 2009 for more detail).

Tree bark is a commonly used traditional medicine in South Africa and overexploitation is a growing concern (Grace *et al.* 2002). Responses of six tree species to bark harvesting was assessed in terms of wound closure, susceptibility to fungal and insect attack, and how it could inform harvest prescriptions for medicinal bark use. The species were *Curtisia dentata, Ilex mitis, Ocotea bullata, Prunus africana, Rapanea melanophloeos* and *Rhus chirindensis* (see Vermeulen 2009 for experimental layout and assessment protocols).

The corm of *B. latifolia* is used widely in South Africa for various medicinal purposes. With little information available on the species, it was the ideal case study to assess the process of developing harvest systems for NTFPs. Detailed studies of the habitat and distribution, community association, population dynamics, demography and reproductive phenology of the species were conducted to inform harvest prescriptions for the species, as described in detail by Vermeulen (2009).

Results

The research approach enabled valuable insight into the complexities of developing harvest systems for NTFPs, the input and expertise required to conduct applied research, and the variation in approach required for different products and plant growth forms. Detailed results on the three case studies are presented by Vermeulen (2009).

The study on *R. adiantiformis* showed that the adaptive management approach can be used effectively with NTFPs provided that the precautionary principle is applied. Long-term monitoring, assessing harvest impact on the resource and natural fluctuations in population dynamics, are essential for system refinement. The study on medicinal bark showed that tree species respond differently to bark stripping, in terms of both bark regrowth and susceptibility to fungal and insect damage. Species-specific results on tree response can be obtained in a relatively short period to assess harvest options and to provide for the development of harvest prescriptions. The study on *B. latifolia* showed that the species has a complex population dynamics. It has a slow rate of renewal in terms of corm diameter and length growth, limiting its harvest potential. The difference in population dynamics between ecotone and forest populations complicates the development of harvest prescriptions for the species.

The overall results demonstrate that the systematic process can be followed effectively in the development of harvest systems for NTFPs, but this could be constrained or influenced by socio-economic circumstances, institutional arrangements, policy directives and availability of resources and expertise.

Discussion

Systematic process for harvest system development

The generic process for the development of harvest systems and management strategies for NTFPs is simplified in Figure 1, based on experience with the case studies in the southern Cape. This includes the following key components:

Identification of user groups, stakeholder consultation and defining the product

The first step is the identification of the key user groups and an assessment of user needs (Figure 1). Knowledge of the characteristics of the specific user group is also essential. Participatory forest management (PFM) forums provide an essential platform for engagement with the user groups. Communicating user rights to stakeholders are also important as illegal harvesting may be regarded by ill-informed user groups as the only way to gain access to resources. Engagement with specific user groups – rather than the community at large – is most effective in initiating development and implementation of harvest prescriptions in a collaborative way.

Users and markets need specific products, and the products need to be clearly defined. Where this is not done, it could result in indiscriminate harvesting and wastage, with an unnecessary additional impact on the resource. Field observations of harvesting are most time- and cost-effective in identifying species being used. However, to ensure that real stakeholder needs are addressed, additional quantitative and qualitative data need to be obtained through inventories and interviews with stakeholders.

Community association of target species and delineation of harvest area

Information on the habitat and vegetation type where the target species is found needs to be gathered to enable identification and mapping of the potential harvest area (Figure 1). A site-based, forest type classification proved to be indispensable for sound management planning where multiple-use management objectives are pursued. It provides the ecological foundation for forest management and could be used to assess the distribution of a target species if its habitat preference is known. A more detailed phytosociological classification would allow for more accurate mapping of the potential harvest area, and is also of great benefit where there is a demand for a range of species in the same forest area. However, within forest or vegetation types, species could have a patchy distribution, making it difficult to clearly define the potential harvest area. For some species the area cannot be fixed but has to be dealt with at landscape level, aligned with and adjusted to spatio-temporal variations of populations of the target species.

Resource inventory, population dynamics and plant demography

Once the distribution of the target species and potential harvest area has been identified, a more detailed inventory of the target species is required (Figure 1). This provides information on the abundance and dynamics (e.g. population density and size class distribution) of the species. Information on the distribution pattern of the target species is essential in planning for surveys and inventories (Wong *et al.* 2001). The inventory of plant parts, e.g. fruit, seed and bark would require a different sampling approach to whole plants (Cunningham 2001).

The rate of production indicates how much of the resource (as determined by the resource survey) can be harvested on a sustainable basis. Definition of rate of production largely depends on the species' growth form and plant part being harvested. Baseline studies on production rates should be conducted in both undisturbed and production areas, emphasising the importance of zonation and setting aside areas where consumptive resource use is prohibited.

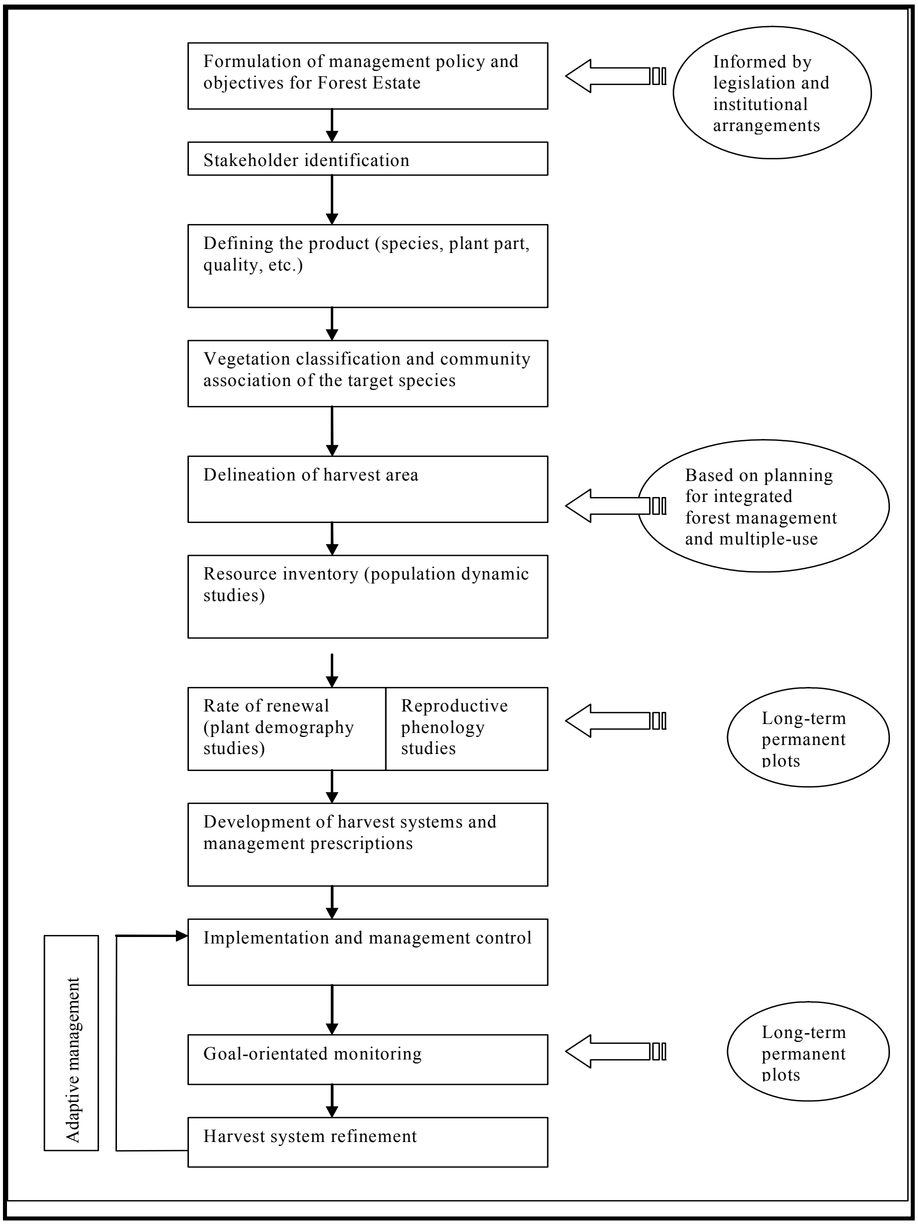

Figure 1: Flow diagram indicating the generic process for the development of harvest systems and management prescriptions for NTFPs.

Reproductive phenology

Where permanent plots are established, information on the reproductive biology and phenology of the target species should also be collected (Figure 1). Information on the phenology of the target species is important to identify the times of the year that the population is most sensitive to harvesting. The relevance of phenology would depend on the plant growth form and plant part harvested. Phenology includes, for example, flower and fruit production, frond bud development and rate of development over different seasons to guide fern frond harvesting, and seasonal differences in bark regrowth following medicinal bark harvesting. Also of relevance is that growth and phenology of groundflora species are more likely to be influenced by extremes of weather (e.g. drought).

Development of a harvest system, continued monitoring and adaptive management

Key aspects to the harvest system would include harvest rotation, the number or percentage of plants that could be harvested from the population, minimum harvestable size and harvest method. Continued monitoring is required to allow for refinement of harvest prescriptions (Figure 1). This should include (a) long-term monitoring both inside and outside harvest areas to gather further baseline data on population dynamics and plant demography, (b) monitoring plant populations to assess harvest impact, and (c) monitoring the yield (quantity and quality) from harvest areas. The pressing demand for forest resources often does not allow scientifically sound harvest systems to be developed before access for consumptive use is granted. The solution is an adaptive management approach whereby conservative, interim harvest prescriptions based on existing knowledge are implemented together with applied research and monitoring programmes.

Complexities with the development and implementation of harvest systems

Sustainability has an ecological, social and economic dimension and needs to be addressed at the confluence of all three spheres, within a political framework and with due consideration of institutional arrangements (Cunningham 2001, Geldenhuys 2004).

Ecological dimension

The generic process for harvest system development ensures that research is focused on the relevant fields. However, it is questionable to what extent it could be widely implemented to culminate in scientifically sound harvest prescriptions for NTFPs, considering the following:

Complexities of vegetation ecology and population dynamics

Ecosystems are not stable and harvest systems should accommodate both temporal and spatial variation in population dynamics. Unpredictable changes in environmental conditions and other stochastic events should also be considered. Furthermore, the vulnerability of a species to harvesting is also determined by the competition hierarchy within the community. Population dynamics of species occurring as metapopulations are defined by factors of population size, life history parameters and the spatial variation in these factors, the number and geographic configuration of habitat patches, and spatial correlation among these patches (Akcakaya 2000). These complexities do not make for “easy” research to provide the scientific basis for the development of harvest prescriptions.

Interpretation of results and conversion into harvest prescriptions

There is no fixed way of converting the relevant research and survey results into harvest prescriptions. Interpretation of research results and conversion into a harvest system and management prescriptions require insight into the fields of both vegetation ecology and forest management. Harvest prescriptions need to be simple, and little scope exists to incorporate all the ecological drivers and population dynamic characteristics of a species in the key prescriptions of harvest rotation and intensity.

Ongoing monitoring and harvest system refinement

The development and refinement of a harvest system for a target species or product is ongoing, through applied research and goal-orientated monitoring. Such studies cannot easily be outsourced, as is a growing trend, but require in-house expertise. Different levels of monitoring are required for different species and products harvested. Considering the extent of resource use, it is likely that sound monitoring programmes can only be implemented for the more vulnerable species.

Diversity of products and species harvested

A wide range of products and species are being harvested from natural forest and woodland (Lawes *et al.* 2004, Shackleton and Shackleton 2004). The process to develop harvest systems and the nature of required research could vary greatly between different plant species, growth forms and plant parts. Expertise or knowledge is required in the different fields of botany (e.g. phytosociology, autecology, population dynamics, plant anatomy and physiology), from project design and experimental layout to data analysis and interpretation of results.

Socio-economic dimension

Socio-economic circumstances could seriously hamper the successful development and implementation of harvest systems for sustainable use of NTFPs. The following issues are relevant:

Dependence on forest resources and expectations

It is a major challenge to obtain buy-in from user groups for the implementation of sustainable harvest systems where this could negatively affect the current levels of supply of forest products to sustain daily livelihood needs or the current extent of commercialisation. The new South African National Forests Act (Act No. 84 of 1998) (NFA) and national forest policy promote benefit sharing. Of concern is that unrealistic expectations could arise amongst communities of the potential economic benefits that NTFPs could provide (Horn and Clarke 2002). If the value of NTFPs is overrated, more people will enter the commercial market and may become dependent on forest resources that are already overutilised.

Costs of developing and implementing harvest systems

The costs of developing, implementing and monitoring sustainable harvest systems are substantial in terms of expertise and resources required. Such expenses should, arguably, be regarded as part of management's cost to sustain social benefits when harvesting is for domestic use by rural communities dependent on the resource. For commercial harvesting, these costs should be absorbed by the commercial harvester, which could render many NTFP harvest ventures economically unviable.

Commercialisation potential of NTFPs and trade chains

Horn and Clarke (2002) expressed the concern that forests offer limited economic opportunities for significant benefit flows to local, poor people, considering the restrictions necessary to achieve the overriding goal of sustainable forest management. Many attempts at NTFP commercialisation have failed to deliver expected benefits (Belcher and Schreckenberg 2007). Also, where trade chains are not clearly defined, it results in undervaluation and wastage of products along the trade chain from forest resources already under pressure.

Demand versus supply

It is often argued that, based on indigenous knowledge and practices, rural people have harvested natural resources on a sustainable basis for centuries, but this is unlikely to prevail with high population growth (Godoy and Bawa 1993) and commercial incentives. Dasmann (1985) stated that the low level of resource exploitation under sustainable harvest systems will not satisfy the demands of increasing populations, and that resources will be depleted progressively. Alternatives to harvesting from the wild thus have to be high on the agenda in the efforts to achieve sustainable forest management.

"Use-it-or-loose-it" scenario

Considering the socio-economic conditions and dependence of rural communities on forest resources in South Africa, pressure on resources will continue through the "use-it-or-lose-it" scenario (Price and Butt 2000). Furthermore, where there are uncertainties in sustaining livelihoods, an "open access" situation could develop, resulting in an attitude of "cut the tree before outsiders do" (Kusumanto *et al.* 2005). These scenarios create a huge threat to the implementation of sustainable harvesting systems for NTFPs in certain forest areas, especially where commercial benefits are at stake.

Required social skills for community engagement

Social skills are required to engage with communities, develop harvest systems and take implementation to its conclusion (Horn and Clarke 2002). The often lack of social skills amongst forest managers is a further stumbling block in achieving sustainable harvesting of NTFPs. Furthermore, user groups in rural communities are often insufficiently organised or empowered to effectively engage with participatory forest management and related issues.

Institutional arrangements and policy directives

Access to resources and the development of harvest systems for sustainable use need to be accommodated with due consideration of national policy and legislation. In South Africa, the NFA and a policy of PFM provides for shared responsibility with forest management and to ensure a sustained flow of benefits to stakeholders (DWAF 2004). Dasmann (1985), however, argues that, because of political realities, long-term investment in sustainability is often neglected as it only pays off politically if the public values it more than short-term profit – which is seldom the case in poverty-stricken rural areas. Where legislation and policies are pro resource use, it is thus essential that the necessary capacity is built by management institutions, and that human and financial resources are available for the development and implementation of systems for sustainable use. The ease with which the generic process of sustained yield determination can be applied is therefore influenced by the socio-economic dynamics in the region, and by the policy and socio-political aspirations of relevant institutions.

Conclusion

Studies of the ecology, population dynamics and demography of plant species provide a scientific basis for the development of harvest prescriptions for sustainable use – prescriptions that can be refined over time through an adaptive management approach. Considering the wide range of NTFPs used and the dependence of especially rural communities on resources, a major challenge awaits forest managers to develop harvest systems through applied research, its implementation and continued monitoring to allow for system refinement. Policy and decision makers need to appreciate the skills, expertise and financial resources required to realise this, and the importance of addressing the socio-economic circumstances within which many user groups find themselves.

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Resource harvesting and use management practices:

REGENRATION OF SELECTED TREES IN DAMBWA FOREST RESERVE FOLLOWING INTRODUCTION OF JOINT FOREST MANAGEMENT

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Abstract

Joint forest management was initiated in Dambwa forest reserve in southern part of Zambia in 2001. One of the objectives was to improve the condition of the forest reserve through community involvement in forest protection and management. The forest has an area of 10,766 ha. A study was conducted to determine the regeneration of five commercially valuable tree species: *Baikiaea plurijuga, Pterocarpus angolensis, Afzelia quanzensis, Guibourtia coleosperma* and *Colophospermum mopane*. Forest resource assessment was carried out in April 2008 to determine regeneration levels seven years after the introduction of joint forest management. The results showed that there are almost 10,000 seedlings/saplings growing per hectare. The most predominant species were *Diplorhynchus condylocarpon* (2,007 sph) and *Bauhinia petersiana* (1,986 sph). The other species observed included *Ochna pulchra*, *Baphia massaiensis* and *Pseudolachnostylis maprouneifolia*. Among the selected commercial trees, *Pterocarpus angolensis* had 118 saplings per hectare, *Baikiaea plurijuga* 72 saplings per hectare and *Colophospermum mopane* 67 saplings per hectare. No regeneration was observed for *Afzelia quanzensis* and *Guibourtia coleosperma*. Overall, 89% of the stems for the selected commercial species were less than 30cm DBH; rendering them unsuitable for harvesting. The high regeneration levels also conform to PRA findings in which the local communities perceived the forest to have adequately regenerated. The high number of stems in smaller diameter size classes indicated an inverse J-shaped type of forest, which is considered as an indicator of adequate regeneration and population maintenance. Promotion of community involvement in forest protection and management can therefore contribute greatly to regeneration of selected commercially valuable tree species.

Introduction

Management of the forests by central government was a common approach in most African and Asian countries before and soon after the attainment of the political independence. The approach did not consider the aspiration of the local communities, as it was more concerned with conservation and exploitation of forests in the central government interest (Vandergeest 1996, Arnold 2001, Ham *et al.* 2008). However, lack of local community participation can cause local communities to have negative attitudes towards conservation efforts and the enforcement of conservation-related regulations (Heinen 1996).

In Zambia, the system did not allow access of local communities to the forests except with special permits (GRZ 1973, FD 1998, PFAP 2005). Under such circumstances local people do not have power over forest reserves or meaningful incentive to conserve and manage the forest resources. The government on its own also failed to effectively manage the forest reserves due to financial constraints and inadequate manpower (ZFAP 1998).

Following the realisation of past policy inadequacies, the national forestry policy and forests acts were revised in 1998 and 1999 respectively. The revision of the forest policy and forest legislation allowed participation of local communities, traditional institutions, NGOs and the private sector in the management and development of the forest sector. The main feature of the revised national forest policy was the stakeholders' participation in the promotion of sustainable forestry development (FD 1998, GRZ 1999, PFAP 2005).

The revision necessitated the introduction of joint forest management (JFM) on a pilot basis to protect and manage forest reserves under the Forestry Department. This was in recognition of the links between poverty and forests, and giving equal emphasis to both sustainable forest management and rural livelihoods. The main objective of the joint forest management project was therefore to improve the livelihoods of communities and condition of forests in Zambia. The programme was aimed at implementing sustainable collaborative forest management practices in the Luapula, Copperbelt and Southern provinces and share experiences.

Joint forest management was initiated in Dambwa forest reserve in the southern part of Zambia in 2001. One of the objectives was to improve the condition of the forest reserve through community involvement in forest protection and management.

This part of the study focused on evaluating the regeneration of economically important tree species, since the inception of JFM; including the perception of the communities on the condition of the forest. The information generated was part of the wider evaluation of the performance of the JFM project; that seeks to improve project effectiveness and create opportunities to share information with other stakeholders.

Materials and Methods

The study was conducted in Dambwa forest reserve with an area of 10,690 ha in extent located in Livingstone district in the southern part of Zambia. A forest resource assessment was carried out in April 2008 to determine and assess levels of regeneration of the five commercially valuable tree species after the introduction of joint forest management: *Baikiaea plurijuga, Pterocarpus angolensis, Afzelia quanzensis, Guibourtia coleosperma* and *Colophospermum mopane*.

In April 2008 a total of 25 circular plots of 20 m radius were sampled. All trees >2 cm diameter at breast height (DBH) on a plot were measured and recorded. Tree regeneration (shrubs, saplings and seedlings) <2 cm DBH in a 5 m radius sub-plot located within the main plot, was counted by species. The forest inventory data were analyzed using Excel.

Participatory research methods (see Babbie 1999, Stanley and Sedlack 1992) were used to collect information on perception of local communities on the status of the forest reserve. The heads of a total of 447 households from 11 villages in the immediate vicinity of Dambwa forest reserve were interviewed, representing a sampling intensity of 25% (as used by Appiah 2001, Turyahabwe 2006).

Results and Discussion

Vegetation assessment

The forest assessment recorded 35 tree species for trees >2 cm DBH with an average stocking of 219 stems/ha (sph). *Baikiaea plurijuga* was the selected species most frequently present with 39 sph followed by *Pterocarpus angolensis* (14 sph), *Guibourtia coleosperma* (5 sph) and *Afzelia quanzensis* and *Colophospermum mopane* (3 sph).

Ninety per cent of trees in the forest had a DBH of <30 cm (Figure 1), with the five selected species having 89% of their trees with DBH <30 cm (Figure 2). *Pterocarpus angolensis* and *Colophospermum mopane* had 100% of their stems <30 cm DBH, followed by *Baikiaea plurijuga* (90%), *Afzelia quanzensis* (67%) and *Guibourtia coleosperma* (57%). The minimum DBH considered suitable for timber harvesting is 30 cm (Takawira-Nyenya 2005).

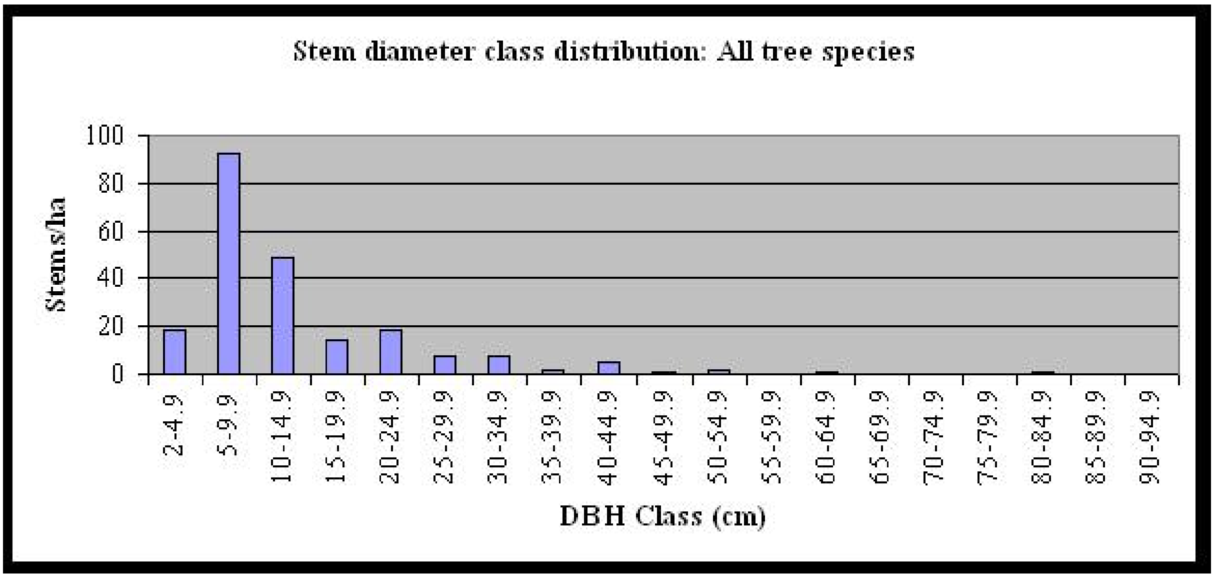

Figure1: Stem diameter class distribution for all the sampled trees in Dambwa forest

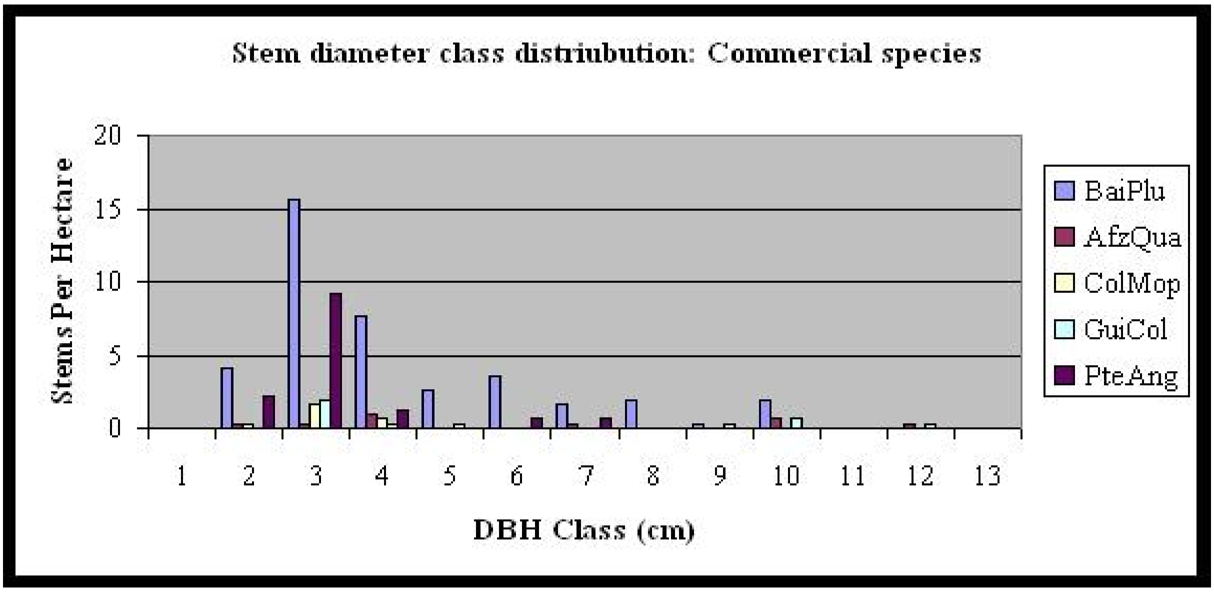

Figure 2: Stem diameter class distribution of commercial tree species in Dambwa forest

The regeneration results showed that there are almost 10,000 seedlings/saplings growing per hectare. The most predominant species were *Diplorhynchus condylocarpon* (2,007 sph) and *Bauhinia petersiana* (1,986 sph). The other species observed included *Ochna pulchra* (764 sph), *Baphia massaiensis* (571 sph) and *Pseudolachnostylis maprouneifolia* (230 sph) (Table 1). Vigorous regeneration was also observed for commercially valuable tree species (Table 1) particularly for *Pterocarpus angolensis (*118 sph), *Baikiaea plurijuga* (72 sph), and *Colophospermum mopane* (67 sph). However, no saplings were observed for *Afzelia quanzensis* and *Guibourtia coleosperma*.

Perceptions on condition of the forest

The results of the PRA showed that the local communities perceived the forest reserve to have regenerated after the introduction of joint forest management, conforming to the results of the forest resource assessment (see resource assessment). Almost 65% of the respondents indicated that the forest had regenerated, while only 19% indicated that the forest had degraded and 12% thought it had remained the same (Figure 3). The perception of women (71%) and men (60%) that Dambwa forest has regenerated is in line with the overall perception of the community (65%). Only 16% of women and 22 % of men indicated that the forest status had worsened compared to the 11% of women and 13% of men who perceived that the forest condition remained the same as before introduction of JFM (Figure 4). More than 50% of all age groups indicated that regeneration of Dambwa forest has improved (65%) but 50% of the young people (<20 yrs) did not know (Table 2). Those younger than 35 years or older than 65 years had a higher percentage (27%) thinking that the regeneration status is worse than the general perception.

Table 1: Forest regeneration in Dambwa forest: Including commercial tree species

Species (*=commercial timber species)	Stems/ha
Diplorhynchus condylocarpon	2,006
Bauhinia petersiana	1,986
Others	1,849
Ochna pulchra	764
Baphia massaiensis	570
Combretum zeyheri	560
Diospyros batocana	530
Friesodielsia obovata	234
Pseudolachnostylis maprouneifolia	229
Combretum molle	163
Boscia angustifolia	127
*Pterocarpus angolensis**	117
Brachystegia spiciformis	107
Terminalia sericea	102
*Baikiaea plurijuga**	71
Burkea africana	66
*Colophospermum mopane**	66
Strychnos spinosa	41
Lannea stuhlmannii	36
Strychnos cocculoides	36
Albizia antunesiana	31
Canthium grangula	25
Xylopia rubenscene	25
Annona Senegalensis	10
Dichrostachys cinerea	10
Combretum imbrerbe	5
*Afzelia quanzensis**	0
*Guibourtia coleosperma**	0

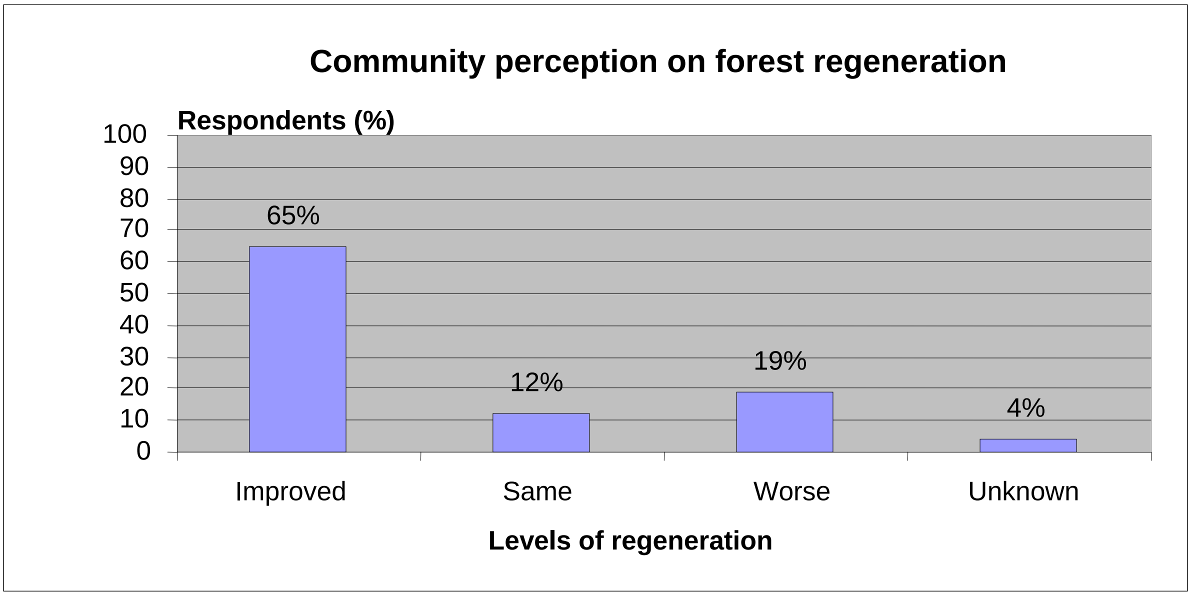

Figure 3: Overall perception amongst the local community on the status of forest regeneration

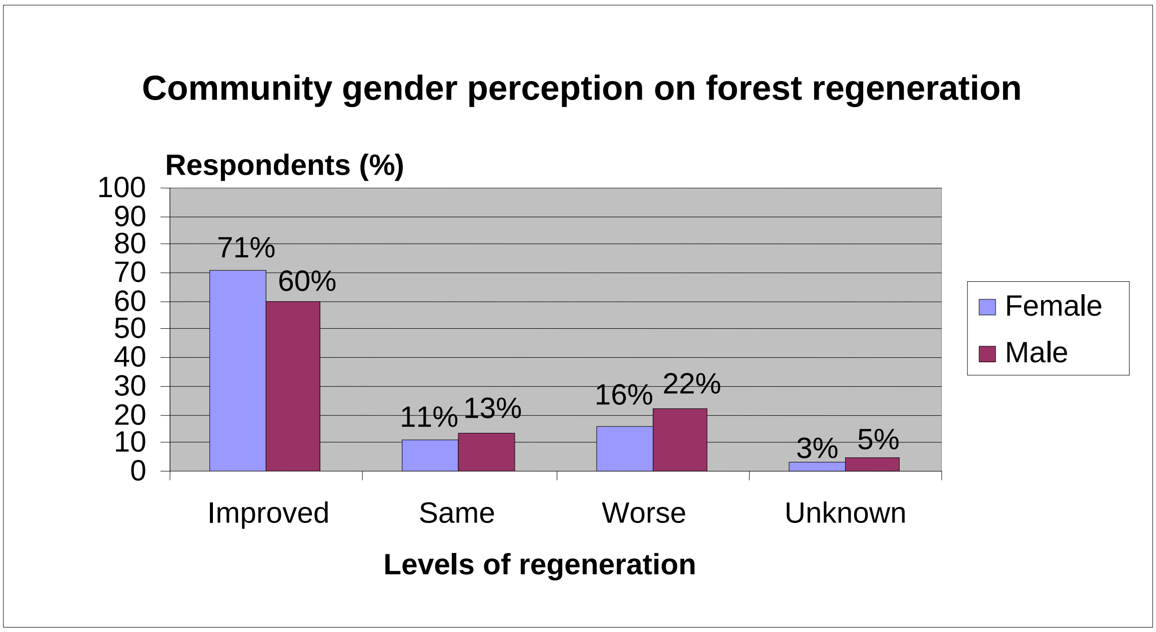

Figure 4: Perception of the men and women on the status of forest regeneration in Dambwa forest

Regeneration plays an important role in the renewal and perpetuation of forest or woodland ecosystems. With proper management, most of these saplings will grow into trees replacing bigger trees, which might have been harvested, securing the future of these commercially valuable tree species. Factors reported to promote rapid regeneration include higher precipitation, adequate supply of nutrients, full light, absence of fire, and absence of root competition (Caro *et al.* 2005). If the regeneration is not disturbed, it can depict how the structure of the forest will likely to be in the near future. It is important therefore to ensure the survival of the regeneration in order to maintain the forest or woodland.

Table 2: Perception of different age groups within the local community on forest regeneration in Dambwa forest

Age class, years	**Perception of regeneration by age groups, %**			
		Same	**Improved**	**Unknown**
≤20	0	0	50	50
21-35	27	15	58	0
36-50	14	11	71	4
51-65	16	11	68	5
≥66	27	9	64	0
Missing	14	14	57	14
Total	19	12	65	4

The absence of stems in the upper diameter classes for selected tree species, as observed in Figure 2, render them unsuitable for harvesting and also indicates that they were heavily and selectively harvested for timber. The observed high number of individuals in smaller size classes indicates a typical inverse J-shaped structure (Figure 1 & 2). The inverse J-shaped size class distribution is regarded as an indicator of adequate regeneration and population maintenance (Zagt and Weger 1998).

Figure 1 shows diameter distribution for the different species. A desired diameter distribution from a management point of view is one where the bulk of the stems are in the lower diameter classes, and the number of stems gradually decreasing as the diameter gets bigger. In this case, there is a progression of trees from smaller diameter classes into larger diameter classes, creating an opportunity for continuous harvesting of timber and poles. If the actual diameter distribution deviates from the desired class distribution, it will certainly affect management decisions in the short or long term.

There has been growing awareness on the loss of forest cover and the inability of government ownership, control and management of forests to produce the desired results. Usually, financial sustainability of centralised systems of forest management through the Forestry Departments is of growing concern. At the same time local communities are emerging as more organised than in the past and are not amenable to forest management regimes and regulations, which are inappropriate to local conditions (Matose and Wily 1996).

The local communities in the study area were involved in forest patrols and controlled early burning to promote sustainable forest management following the introduction of joint forest management. As Fisher (1995; in Matose and Wily 1996) observed, collaborative approaches to natural resources management seek the active involvement of local people in environmental care and management.

The preliminary results have shown that protection and controlled early burning of the forest reserve can enhance natural regeneration. The results are supported by DFSC (2001), Caro *et al.* (2005) and Takawira-Nyenya (2005) who have reported that controlling undergrowth and protection against late bush fires enhance tree regeneration and growth by reducing competition and fuel loads in the forest. When regeneration is promoted and there are no disturbances, it depicts the forest structure of the near future (Angombe 2004).

Conclusion

The high number of stems in smaller diameter size classes indicated an inverse J-shaped type of the forest, which is considered as an indicator of adequate regeneration and population maintenance. Promotion of community involvement in forest protection and management can therefore contribute greatly to regeneration of selected commercially valuable tree species. However, total protection and good management cannot be achieved due to inadequate forestry staff and reduced budgetary allocation for forest protection and management. Thus promotion of community involvement in forest protection and management can therefore contribute greatly to regeneration of selected commercially valuable tree species.

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PRELIMINARY DATA ON TRADE AND MANAGEMENT OF RATTAN IN AND AROUND KISANGANI (DEMOCRATIC REPUBLIC OF CONGO)

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Abstract

Rattan is an important non-wood forest product in the economy of Democratic Republic of Congo (DR Congo) and in the subsistence of populations in the Congo Basin. This paper presents preliminary results of a survey conducted with rattan stakeholders in Kisangani and the Yoko Forest Reserve (YFR) neighbourhood, in the Orientale Province, DR Congo. The aim of the study was to identify areas supplying rattan canes and to characterise the rattan sector in and around Kisangani. Over a 3-month period (104 days), canes traded from villages to Kisangani were recorded, and various rattan stockholders were interviewed with submitted questionnaires. According to preliminary results, 10 villages supply 71,709 linear metres of small-diameter cane monthly, of which 64,226 m are processed by 12 workshops in Lubunga Commune. Rattan items were found in 98% of 556 households studied in the six communes of Kisangani town. More trade data from different rattan stakeholders, together with ecological data are required to define appropriate management guidelines for sustainability of the resource.

Introduction

Many studies demonstrate the role of non-wood forest products (NWFPs), notably rattan, in the economy of the Democratic Republic of Congo (DR Congo) and in the subsistence of populations in the Congo Basin. This suggests that rattan offers a good opportunity for economic development, which could provide benefits to both rural areas (supplementing income generated through sales) and urban zones, in spite of the imbalance often noted in the distribution of profits generated by the harvesting of the product (Zoro Bi and Kouakou 2004). Rattan is among the NWFPs that are presently strongly marketed at national or international level (Sastry 2001).

In Kisangani, rattan is a major NWFP of high value that provides important income along the market chain, from rural harvesters to urban consumers (Kahindo 2007). Similar observations were reported from other urban areas of Central Africa (Falconer 1994, Morakinyo 1994, Ndoye 1995, Sunderland 1998, Nzooh-Dongmo 1999, Trefon and Defo 1999, Balinga 2001, Minga 2002, Oteng-Amoako and Obiri-Darko 2002), suggesting that rattan is a product of the future for many African countries and so deserves particular attention. Because of its (physical) flexibility, rattan is used to manufacture cane furniture and other articles. African rattan, if it is well conditioned and treated, could compete in terms of quality with those of Asia (Sunderland 2002).

Rattan has been extensively studied in Cameroon, mainly in terms of its socioeconomic aspects (Clark and Tchamou 1998, Defo 1999, 2004a, Ndoye and Perez 1999). Compared with other countries of the region, the DR Congo is behind in its development of a structured NWFP sector, in spite of its vast areas of forest. Nevertheless, the products are widely used throughout the country, but this use is poorly studied or understood (Kahindo 2007, Liengola 1999, Minga 2002) and thus poorly known by scientists and potential investors.

In Asia, particularly in Malaysia and The Philippines, the native area of most of the known species, rattans have been well studied, notably their biology, taxonomy, ecology, inventory, domestication and socioeconomics (Evans 2001, Liese 2001, Renuka 2001, Siebert 2001, Sunderland and Nkefor 2002). After exhausting their natural stocks, Asian buyers are now in search of resources to harvest in Central Africa. This contact with the old Asian industry has added to the development of African rattan technology, including conditioning and transformation techniques. As a result, rattan products have improved in quality, notably in Yaoundé and other cities of the region.

DR Congo is home to about half of the identified African rattan species (see study of Sunderland 2001 on African rattans), of which three are frequently used in rattan crafts: *Eremospatha haullevilleana, E. macrocarpa* and *Laccosperma secundiflorum* (Kahindo 2007, Minga 2002). Besides generating income to the active 'rustic' households in the sector in the countries of the wet forest zones of Southeast Asia and Africa, rattan also generates employment to stakeholders because of the high labour demand for the various operations and processing, from collection to sale (Cody 1983, Falconer 1992, Morakinyo 1994, Siebert *et al.* 1994, Ndoye 1995).

Rattan articles are variously consumed at the level of either urban or rural households. Given its level of use, especially in furnishing houses, rattan is a product of the future, potentially able to substitute wood and thus able to reduce the pressure on the forest in this period when the international community is mobilising against climate change.

The present study aimed to show the economic and social potential of rattan and rattan products in and around Kisangani, with the following objectives:

- to assess the importance of rattan in the lives of stakeholders;
- to determine the level of organisation of the rattan sector in and around Kisangani compared to elsewhere in the world;

- to suggest some concrete actions for the promotion of this 'resource of the future' for rapid expansion in the other towns of the Congo Basin and globally.

Materials and Methods

Kisangani is the third largest town of DR Congo, and the largest in the Orientale Province. It is situated at 0°31'N, 25°11'E, and has six Communes including Lubunga, which is geographically isolated by the Congo River and directly connected to the villages in the neighbourhood of Yoko Forest Reserve. It benefits from a tropical wet rainforest climate, i.e. Af type of Köppen (McKnight and Hess 2000), characterised by plenty of rain not uniformly distributed over the year, an average relative humidity of more than 80%, average temperatures oscillating around 25°C, and only a few sunny days. Its population, estimated at 600,000 inhabitants, is heterogeneous and obtains a living essentially from agriculture, small business and fishing (Kahindo 2007).

Throughout the study, qualitative and quantitative data were collected by using a questionnaire based on the model proposed by Sunderland (2001) and adapted to different levels of intervention. Questions notably concerned the quantities of rattans harvested in the Reserve and the surrounding villages up to 30 kilometres to the north of the Reserve along the axis Kisangani-Ubundu, and those transformed and marketed in Kisangani town. The data are partial, covering the period 21 June to 2 October 2008, i.e., 104 days of observations and inquiries.

The quantity of rattan canes transported to the town was systematically noted at the village level from two 'lookout posts'. During the observation, only rattans from the Reserve and its immediate neighbourhood (not exceeding 30 km) were counted. For calibration of the material, certain packages of slender canes were bought, weighed and measured in the Non-Wood Forest Products Laboratory of the Science Faculty of the University of Kisangani.

Inquiries were also made with the rattan processors of 12 workshops in the Lubunga Commune, comprising 119 processors and 69 manufacturers (81.2%), sellers (14.5%), and retailers of rattan articles (4.3%), most of whom were unmarried young people aged 18 to 30 years. The choice of this administrative entity lies particularly in its geographical isolation (on the western bank of the Congo River) and its direct connection with the neighbourhood villages of the RFY, supplying rattan canes exclusively used in the workshops.

SPSS 14.0 software and MS Excel were used to organise the quantitative data, to describe their distribution characteristics (frequency, mode, median, sum), and to compare them by means of the appropriate tests (analysis of the variance and Pearson correlation).

Results and Discussion

Supplies to Kisangani

Ten villages along the main Kisangani-Ubundu highway, in and around the Forest Reserve of Yoko are the major suppliers of *E. haullevilleana* canes. In 104 days of observation, 791 packages comprising 248,589 linear metres of small rattan (71,709 m a month) were recorded. Most of the material came from the villages of Biaro (7 km to the south of the Reserve; 48%), Babusoko 1 (18 km; 19%), and Bagao (23 km; 13%), with a daily average of four vehicles transporting rattan canes.

At the local scale, these quantities seemed rather high according to Trefon and Defo (1999) for the countries of Central Africa. However, they are estimated to be less than half of those used monthly by workshops in Lagos (Morakinyo 1994) and a quarter of those supplied to 15 large rattan markets in the forest zone of Cameroon (Sunderland 2001, Sunderland and Nkefor 2002).

Rattan workshops in Kisangani

Rattan processing in Kisangani is almost exclusively of the small rattan *E. haullevilleana* and very rarely *L. secundiflorum*. Most of the time, rather than use *L. secundiflorum*, workshops will use either the lower portion of *E. haullevilleana* canes or any fresh sticks of shrub or liana that are flexible and have suitable dimensions.

The canes of *L. secundiflorum*, called ‘macara’, are the most appreciated in Cameroon. Their use requires preliminary treatment, which consists of warming them with a blowtorch or similar before shaping them (Defo 2004b). This kind of treatment is still unknown in the Congolese workshops, which lack equipment and information; therefore, processors cannot use the big rattan for furniture (only for the frames). Consequently, they resort to using any ‘stick’ for furniture arms. Regrettably, once these sticks shrink when they become dry, the stalks loosen and the piece of furniture quickly loses its tone and shape, and shortly thereafter will have to be disposed of.

Status of labour force and infrastructure

Rattan workshops in Kisangani are really groupings of independent craftsmen organised around ‘bosses’, very often the oldest member of the group. These organisations, which have been in operation for 4-26 years, use a reduced labour force estimated at 4.8 workers per workshop. They are (for the most part) untrained and badly equipped, and dominated by young people and minors having an average of 9.8 years in the profession. The presence of these young people (52.2%) and minors (26.1%) in the profession can be explained by the multiple 'liberation' wars in Kisangani over the decade 1995-2005. The work experience declared by the dean of craftsmen (34 years) shows, however, that the rattan trade predates this political instability and that the population is culturally attached to it.

The sole obstacle to the rattan market remains the quality of the products. Concerning the embryonic level of the craft in Kisangani, age does not determine the quality, but rather training does. The most striking example is southern Cameroon, where rattan workshops date back to the 1980s and benefit from Asian expertise. Rattan working is practised by 66.9% of those having another professional joinery qualification; this technical knowledge is an asset of the Cameroonians, who experience the effects of the progressive transfer of the Asian experience (Defo 2004b).

Supply of rattan canes and article processing

Weekly supplies of rattan canes are obtained from urban traders or from the municipal markets. Twelve workshops process 168 compact packages of 28-50 canes of small rattan per month, i.e. 64,226.4 linear metres, into the manufacture of articles with an estimated value of US$4,657 (Table 1). The urban craftsmen are particularly specialised in the production of rattan stools, called 'caneton' and 'sinatosi' according to their size, chairs and tables. Basketwork is more developed in rural areas and provides other domestic articles such as cradles, baskets, winnowing baskets, mats, flowerpots and lampshades.

Table 1. Level of monthly consumption of the rattan in workshops in Kisangani

Workshop	Packages	Rattan value ($)	Product value ($)	Specialities
1	16	77.6	672.5	Stools, chairs
2	20	97.0	600.0	Stools
3	8	38.8	400.0	Stools
4	24	116.4	300.0	Stools
5	8	38.8	385.0	Stools, chairs
6	32	155.2	150.0	Stools
7	8	38.8	200.0	Stools
8	24	116.4	550.0	Stools
9	4	19.4	500.0	Stools
10	8	38.8	200.0	Chairs
11	8	38.8	150.0	Stools
12	8	38.8	549.0	Stools
Totals	**168**	**814.8**	**4,656.5**	
Mean	**14**	**67.9**	**388.0**	

The activities in workshops are diversified. During their processing, the rattan canes undergo drying, scraping and splitting, before the weaving around frames of sticks. In The Philippines and other countries of Southeast Asia where the sector has reached a very advanced level, these three processes correspond to the initial operations of the process, which includes several others, notably sizing, smoothing, polishing, cutting and fumigation. The product is then sold to factories of various technical levels and various sizes, which manufacture furniture for export (Defo 2004b).

According to the kind of item, the processing time varies between 4.6 and 71.5 minutes with material of various lengths (Table 2). For example, the 'caneton', a small stool intended for children, consumes 4.8 m of small rattan and requires only about 5 minutes to make. The manufacture of a 'sinatosi', which requires almost the same quantity of rattan as a chair (10 m), seems more profitable. Based on the estimated value for each category of rattan furniture, a workshop that makes exclusively 'sinatosi' stools should make the most profit.

Table 2: Processing and value of rattan articles in Kisangani

Articles	Processing time (min)	Total length used (m)	Monthly capacity		Unit price ($)	Generated monetary value($)
			Number	Consumption (m)		
Caneton	4.6	4.8	1242	1080	0.18	223.56
Sinatosi	11.1	10.4	621	630	0.52	322.92
Chair	71.5	10	172.5	189	1.15	198.38
Table	52.5	10	195	195	1.27	247.7

Commercialisation of rattan articles

The domestic consumption of rattan articles in Kisangani town is widely covered by 12 processing units in Lubunga Commune. The articles are sold by the manufacturers, salesmen and sometimes retailers (Table 3).

Table 3: Actors in the marketing of articles of rattan to Kisangani

Place in the trade	Number	Percentage
Manufacturers	56	81.2
Salesmen	10	14.5
Retailers	3	4.3
Total	69	100.0

An analysis of data collected from 69 market actors, shows the following:

- The greater the diversity of articles offered, the lower the sales ($r = 0.050$; $P = 0.684$) and the less the seller is paid;
- The highest sales are taken by adults (harmonic mean sample size just over $15), who sell their products more easily than minors, who earns much less (< $10).

Conclusion

After 104 days of observation, 248,589 m of small rattan (71,709 m per month) harvested in 10 villages around the RFY were forwarded to Kisangani. The major part, i.e. 64,226 m, is taken by 12 workshops in the Lubunga Commune. Various articles are crudely manufactured, notably stools, chairs and tables, and sold and consumed in Kisangani town, and even in the distant eastern cities such as Goma.

It is not easy to speak about an industry of rattan in and around Kisangani. The low level of financial security and serious lack of capacity constitute major constraints to the development of the sector in Kisangani. This situation is associated with the low level of education of craftsmen, lack of equipment, and ignorance of the processes of treatment and transformation of rattan canes. Given the potential of this resource to slow down deforestation in and generate foreign earnings for the country, it would seem worthwhile to improve the rattan sector for the wellbeing of all the stakeholders. To achieve this, it is recommended that:

1. The craftsmen get organised to create exposure points throughout the town to exhibit their products, and that they think about improving the quality of their products, without which the sector will not be valued by the consumers.
2. The consumers value the sector by preferentially and correctly using rattan articles to reduce resource waste.
3. The authorities promote NWFPs in general, and rattan in particular, by providing grants to the craftsmen and technical training to ignite their spirit of creativity and production of better-quality articles.
4. The Congolese researchers expand and spread these kinds of studies throughout the national territory to construct a database to allow the DR Congo NWFP sector to catch up with the other countries of the region.

More trade data covering different rattan stakeholders, together with ecological data are required to define appropriate management guidelines for sustainable use of the resource, which would reduce pressure on the harvesting of forest trees.

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FOREST AGRICULTURE: SUSTAINABLE LIVELIHOODS STRATEGIES AND BIODIVERSITY CONSERVATION IN SOUTHERN CAMEROON

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Abstract

Forest-agriculture, also known as 'slash-and-burn agriculture' or 'shifting cultivation', are generally associated with biodiversity loss, rapid soil erosion, land degradation, low yield return and profitability, increased rural poverty and unsustainable land use. This paper challenges the relationship between forest-agriculture, sustainable livelihood strategies and conservation of biodiversity in the humid forest zone of southern Cameroon. To do this, the management of agricultural plant diversity has been captured within selected land uses of agricultural landscape mosaics. The farmers' livelihood strategies and biodiversity conservation are built on the management of about 159 woody plant species distributed over 79 families and more than 25 crop varieties with more than 55 cultivars. The natural domestication of woody species and the cultivation of several crop cultivars affect the household consumption needs, income generation and biodiversity conservation. Forest-agriculture is a source of ecological resilience, socio-economic sustainability and adaptive management. The integration of forest and agriculture is based on local multi-criteria analysis of biophysical indicators for the selection of appropriate land where crops will be cultivated and associated with domesticated woody species towards a threshold of agricultural and forest land productivity outcomes.

Introduction

Forest-agriculture, also known as 'slash-and-burn agriculture', or 'shifting cultivation' just to quote these labels which portray the practice, has been associated over the past decades to biodiversity loss, rapid soil erosion, land degradation, low yield return and profitability, increased rural poverty and unsustainable land use outcomes (GEF 1993, ASB 1995, Roper and Robers 1999). Moreover, the research and development processes behind this practice have been guided by a segregation approach, based on a separation of forests and agriculture spatially, administratively and conceptually into two separate units for management and research (Instone 2003a). The implications of this conceptual approach are that dynamic interactions between societies and ecosystems were not properly captured and the socio-ecological systems became non-responsive to incorporate changes and new technologies (Diaw *et al.* 1999, Scheffer *et al.* 2002, Prabhu 2003, Olsson *et al.* 2004). These limits have inspired the emergence of new classes of conceptual thinking, research and intervention processes around adaptive management (Ruitenbeck and Cartier 2001, Gunderson and Holling 2002, Prabhu 2003). Meantime, the conventional portrayal of forest-agriculture was challenged around the understanding of its socio-ecological resilience (Dounias 1996, Dounias and Hladik 1996, Diaw 1997, Fujisaka and Escobar 1997, Carrière 1999) and of its nature regarding the correlations between historical human-nature relationships and the development of global environmental narratives (FitzSimmons and Goodman 1998, O'brien 2002, Instone 2003b). In southern Cameroon, forest-agriculture is embedded within the cropping-fallow-forest conversion cycle. The natural resource management that takes place around forest-agriculture delineates two types of management sequences: temporary food-crop agricultural systems; and more permanent cocoa or palm-tree agroforests.

The temporary food-crop agricultural systems start with *Cucumeropsis* agroforestry. This is followed by a rotation of mixed food-crop agroforests and/or by different stages of fallow systems until the cycle starts again. Carrière (1999) shows that fallows are mostly cleared rather than the global claim of clearing 'virgin forests'. The specific characteristic of this sequence is that a certain number of woody species are kept (domesticated) during the clearing for the better development of crops and different human uses. The major outcome is the capacity of the socio-ecological system to regulate land and forest productivity through the process of fallows (Dounias 1996, Diaw 1997, Carrière 1999, Gockowski *et al.* 2005). The more permanent cash-crop agroforestry systems start with food-crop or *Cucumeropsis* agroforests, followed by the implementation of cocoa or palm-tree agroforests, and/or by conversion into mature secondary forests (Diaw 1997, Oyono *et al.* 2003). The specific characteristic of this sequence is that the land use mimics the structure and composition of the natural forest. Each element of the conversion cycle belongs to a social unit ranging from a household, extended family and lineage in order to regulate the governance of natural resources on which the economy, the livelihoods, the social reproduction systems and the functioning of social institutions are based (Diaw 1997). Each land use phase is attached to a social control ranging from lineage or segmented lineage or extended family to household, household-man-woman, household-man and household-woman (Diaw 1997).

The studies of historical ecology of forest landscape mosaics have shown that local knowledge management and associated practices influence the patterns of forest regeneration and regrowth (Carrière 1999, Van Germeden *et al.* 2004). Forest-agriculture landscape mosaics are a source for the collection of non-timber forest products (NTFPs) for food, commercial and medicinal purposes and various other socio-economic needs (Ndoye 1997, Gockowski and Dury 1999, Van Dijk 1999). The descriptions show that forest-agriculture is based on a complex system which requires new processes in knowledge. As in any local management practice, it is the result of interactions between environment, genetic resources, history, culture, migrations, institutions and cognitive processes used by people over centuries in developing complex and diverse agricultural systems (Dounias 1996, Dounias and Hladik 1996, Carrière 1999, Oyono *et al.* 2003). To challenge this knowledge gap in research and intervention, a resilience-based framework of sustainable forest-agriculture outcomes is required in order to better capture its links with ecology, economy and society (Penkuri and Jokinen 1999, Ruittenbeck and Cartier 2001, Prabhu 2003, Campbell *et al.* 2006, Plummer and Armitage 2006). The socio-ecological and socio-economic resilience background of forest-agriculture practices need to be put into a better conceptual framework. This paper challenges the conventional resilience framework of forest-agriculture for sustainable livelihoods and biodiversity outcomes.

Materials and Methods

Study area

The study was done in the forest margins benchmark area of southern Cameroon designed to assess natural resource use intensification and population density gradients in three blocks at three levels, i.e low (Ebolowa), medium (Mbalmayo) and high (Yaoundé). The biophysical and socio-economic characteristics of the study area are well documented (Figure 1; Gockowski *et al.* 2005). Its climax vegetation represents three main types of forest ecosystems: dense, semi-deciduous forest characteristic of the Yaoundé block, which extends southwards into the Mbalmayo block; dense, humid, Congo Basin forest in the southern reaches of the Mbalmayo block, which extends to the Ebolowa block; biologically diverse, moist, evergreen, Atlantic forests in small pockets along the western border of the Ebolowa and Mbalmayo blocks (ASB 1995). The inhabitants of this study area are Western Bantu forest dwellers who practice shifting cultivation. The area represents the physical and cultural characteristics extending from the Sanaga to the Ntem and Woleu rivers in southern Cameroon, northern Gabon and Equatorial Guinea, and emphasizes its cultural and linguistic coherence (Diaw 1997). Farms in the Cameroon benchmark area are generally small and fragmented. The average number of annual-crop fields is slightly more than four. The area of the field of the predominant annual food crop is on average slightly over 0.13 ha. The mean annual land cover associated with productive agricultural land use (a figure which does not include fallow fields) was 2.6 ha per household in the Yaoundé block, 2.4 ha in the Mbalmayo block, and 3.6 ha in the Ebolowa block. Roughly 50% of this area is covered by complex cocoa agroforests (Gockowski *et al.* 2005).

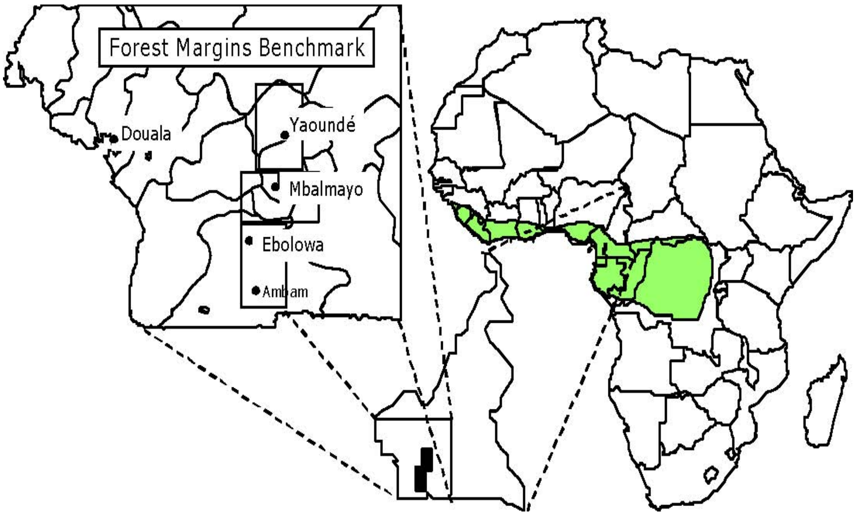

Figure 1: The ASB forest margins benchmark area in southern Cameroon (Gockowski *et al.* 2005).

Sampling methods

Six villages were selected within the study area, with two villages selected in each block. Selection was based on three categories of intensity of monthly interactions with external stakeholders (extension services): low = three days of activities; medium = one week of activities; high = more than 10 days of activities with the support of reports of the field activities. Thirty (=5*6) households, equally distributed between six villages. Household selection was based on the socio-diversity of each village in terms of gender, number of clans or lineages, and age category (young, adult and old). Five land uses (LUS) were selected from nine land uses based on the following criteria: (i) the LUS with a high number of crop species; (ii) the LUS having both the high economic importance and a combination of high density of crops and non agricultural plant species such as seedlings, saplings, poles and trees kept (domesticated) during the clearing of primary or old secondary forest; (iii) the key LUS in the spatial deployment of cropping-fallow–forest conversion cycle; iv) the LUS with a number of economic plant species; (iv) the length of the fallow period corresponding to different rotations, i.e 15 years as the mean of 9 to 23 years old. The combination of these criteria guided the selection of five land use types from the logical sequence in the conversion cycle: cocoa agroforest; *Cucumeropsis* agroforest; mixed food-crop agroforest (or mixed groundnut-based crop farm), young preforest fallow (5 years old), young secondary forest (15 years old).

Data collection

Structured questionnaires divided into two sections were administrated to the households. Section one collected data on the bio-physical characteristics of selected land uses related to the former non-agricultural land use categories (virgin forest, old secondary forest, intermediate secondary forest, pre-secondary forest fallow and young fallow) prior to the current state of the land uses.

Section two collected data on agricultural plant biodiversity at land use level. Plots of 20 m x 20 m and 40 m x 5 m were used, adapted from the multidisciplinary landscape assessment approach (Sheil *et al.* 2003). One to four plots of 20 m x 20 m were sampled in cocoa and *Cucumeropsis* agroforests, depending on the total size of the farm. One plot of 20 m x 20 m was sampled in each of regrowth fallow (five years old) and secondary forests (15 years old), depending on the size of previous farms or agricultural land use. This was used to avoid the problems of boundaries and size of the former farm. For mixed food-crop agroforest, 40 m x 5 m plots were systematically sampled. Each 20 m x 20 m plot has subdivided into four sub-units of 20 m x 5 m, and each 40 m x 5 m plot was divided into 10 consecutive 5 m wide subunits. Within these plots, the following data were collected for each plant: (i) local name of the place; (ii) scientific name including family, genus, specie and author; (iii) local name of the woody plants and crop varieties for mixed food crops; (iv) quality of a plant within three categories (standing plant = 1; plant stem resprouting = 2; plant stem not resprouting = 3); (v) basal diameter of each measured stem (cm); (vi) height of each plant; (vii) index of forking (defined as the ratio between the height of the plant from its first fork over the total height of the plant stem, based on a proposed framework ranging from 100% when the first fork is at ground level, up to 0% when there is no forking).

Data analysis

The data collected were codified and computed in Excel, and the count of woody plant species were summarized via Excel pivot tables per land use per block. The number and occurrence of woody plant species were calculated based on the total number of species and the results expressed per ha for appropriate comparison. The frequency of each parameter has been calculated based on the total number of responses.

Results

Historical-ecology of agroforestry land use based on stage of vegetation/forest on field prior to clearing

The local collective memory indicated that the fields of current cocoa agroforests were established on either cleared secondary/degraded forest (41%) or young preforest fallow

(32%) compared to 'virgin forest' (27%). There is much variation in the frequencies of former vegetation/forest between blocks (Table 1). The 25 *Cucumeropsis* agroforests were mainly established in cleared secondary/degraded forest (74%) with contrasting patterns in other former land uses between the Ebolowa and Mbalmayo blocks (Yaoundé block had none). The cultivation of a *Cucumeropis* farm is highly influenced by the length of the fallow period. Most of the current 30 preforest young fallow fields were secondary/degraded forest prior to clearing (86.1%). All (100%) of the current 30 young secondary forest fields were secondary/degraded forest before the clearing of a forest patch, but the pattern in terms of old fallows (secondary forest) and young fallows in the Yaoundé block is different from the pattern in the Ebolowa and Mbalmayo blocks.

Forest-agriculture outcomes and sustainable livelihood strategies

Contribution of food crops and forest products in household consumption needs

The importance of different food crops and forest products to satisfy household consumption needs follows a relatively similar pattern across the 12 categories, with slight variations (order of importance) between blocks in some of the categories (Table 2). Cassava and its derived products is mentioned by most respondents (72.2%), followed by groundnuts, plantain and cocoyam (around 30% each). NTFPs appear in the fifth position (25.6%) but this resulted from the high response in Mbalmayou block (63.3%).

Trends of income generated from forest products within the forest landscape mosaics

Five main forest products contributed to income generation but the general trend is that the mean values for the HF Zone do not vary much, and that the importance of the different product groups varies much within/between blocks (Table 3). At Ebolowa fuel wood is a source of income for all the respondents (100%), with zero in the other two blocks because here most of respondents use fuel wood for cooking but not to generate income. At Ebolowa the next most important products are timber, bush meat, fishery products and wild fruit species. At Mbalmayo, fishery products (41%) and wild fruit species (36%) currently make the highest contributions. At Yaoundé, the general contribution of the different products was overall low.

Table 1: Frequency of the vegetation/forest conditions of a specific field preceding the current land use

HF Zone block	**Cocoa agroforest**		
	Virgin forest	Secondary/degraded forest	Preforest young fallow
	% of responses		
Ebolowa	12.1	47.8	40.2
Mbalmayo	85.1	14.9	0.0
Yaoundé	11.1	48.2	40.7
HF Zone	27.2	40.9	31.9
	***Cucumeropsis* agroforest**		
	Virgin forest	Secondary/degraded forest	Preforest young fallow
Ebolowa	10.6	71.6	17.8
Mbalmayo	17.2	82.8	0.0
Yaoundé	0.0	0.0	0.0
HF Zone	12.7	73.5	13.8
	Preforest young fallow		
	Virgin forest	Secondary/degraded forest	Preforest young fallow
Ebolowa	0.0	100.0	0.0
Mbalmayo	0.0	100.0	0.0
Yaoundé	0.0	64.8	35.2
HF Zone	0.0	86.1	13.9

Table 2: Percentage of responses of food/forest products contribution to household consumption needs

Agricultural and forest products	**Ebolowa**	**Mbalmayo**	**Yaoundé**	**HF Zone**
Cassava & derived products	73.3	50.0	93.3	72.2
Groundnuts	40.0	30.0	30.0	33.3
Plantain	33.3	33.3	30.0	32.2
Cocoyam & derived & sub-products	30.0	33.3	30.0	31.1
NTFPs	6.7	63.3	6.7	25.6
Oil palm & derived products	3.3	16.7	40.0	20.0
Horticultural crops	6.7	20.0	30.0	18.9
Maize & derived products	10.0	13.3	23.3	15.6
Cucumeropsis mannii (ngon)	30.0	3.3	0.0	11.1
Sweet potatoes	3.3	3.3	20.0	8.9
Yam	0.0	10.0	3.3	4.4
Mushrooms	0.0	3.3	0.0	1.1

Table 3: Percentage of responses of income generated from forest products

Forest products	Ebolowa	Mbalmayo	Yaoundé	HF Zone
Fuel wood	100.0	0.0	0.0	36.9
Timber	51.7	30.9	17.1	36.9
Fishery products	48.9	40.8	11.4	35.2
Bushmeat	51.1	26.2	22.9	34.4
Wild fruit species	42.2	35.7	22.9	34.4

Management of biodiversity within the permanent forest-agriculture conversion

A total of 76 woody species were recorded, distributed over 41 plant families with the most representative families being Sterculiaceae, Euphorbiaceae, Apocynaceae, Moraceae, Lauraceae, Caesalpiniaceae and Burseraceae. The top 10 woody species domesticated within the cocoa agroforest systems, by stem density per ha, show much variation between blocks (Table 4). Most of these are pioneer species and fast growing. The highest stem density for these species occurs in the Yaoundé block, followed closely by the Ebolowa block with a much lower density in the Mbalmayo block.

Table 4: Stems/ha for the 10 most abundant woody species found in the cocoa agroforests

Species	Ebolowa	Mbalmayo	Yaoundé	HF Zone	Characteristics*
Persea americana	35.0	16.3	15.9	22.4	1
Elaeis guineensis	20.0	10.0	34.1	21.4	1
Margaritaria discoides	35.0	16.3	4.5	18.6	3c
Dacryodes edulis	12.5	22.5	20.5	18.5	1
Funtumia spp	35.0	16.3	0.0	17.1	1
Macaranga spp	25.0	10.0	6.8	13.9	1a,b
Didelotia letouzeyi	0.0	5.0	36.4	13.8	1
Albizia spp	15.0	7.5	18.2	13.6	1,3
Musa spp	0.0	3.8	29.5	11.1	1
Tabernaemontana spp	5.0	0.0	22.7	9.2	1b
Grand Total stems/ha	182.5	107.7	188.6	159.6	
Relative frequency	38.1	22.5	39.4		

**Wood quality: 1 = soft woody; 2 = semi-woody; 3 = hard woody; Successional status: a = pioneer; b = early regrowth; c = advanced regrowth; d = mature forest*

Management of agricultural biodiversity within the non-permanent cropping-fallow-forest conversion cycle

The results present the abundance of stems of woody species found within the ideal sequence of *Cucumeropsis* agroforests - mixed food-crop agroforests - preforest young fallows - young secondary forests. The conversion is based on the management of 119 woody species distributed in more than 59 families with the most representative families being, by order of importance: Apocynaceae, Moraceae, Euphorbiaceae, Mimosaceae and Caesalpiniaceae. The common woody species found within the four land uses are: *Albizia* spp, *Tabernaemontana* spp, *Elaeis guineensis* and *Myrianthus arboreus*. Woody species such as *Funtumia* spp, *Macaranga* spp and *Voacanga africana* are common within *Cucumeropsis* agroforests, preforest young fallows and young secondary forests. The other woody species are common to either two or one land use system.

Management of agricultural biodiversity in mixed food-crop agroforests: crop species and their cultivars

Twenty five crop species were recorded with a total of 55 cultivars with 12% having four or more cultivars, 8% with three cultivars, 60% with two cultivars and 24% with one cultivar (Table 6). The higher number of cultivars per crop species is within cassava (*Manihot esculenta*), plantain (*Musa* AAB) and groundnuts (*Arachis hypogea*). The crops with a higher marketable proportion (90%, 80%) are represented by *Colocasia esculenta* and *Musa* species (AAB).

Table 5: Stems/ha of top 10 woody species found within non-permanent land use conversion cycle

***Cucumeropsis* agroforests**		**Mixed food-crop agroforests**		**Preforestry youngfallow**		**Young secondary forest**	
Woody species	**HFZ**	**Woody species**	**HFZ**	**Woody species**	**HFZ**	**Woody species**	**HFZ**
Musanga cecropioides C2	55.0	*Tabernaemontana* spp C4	86.0	*Macaranga* spp C3	33.3	*Funtumia* spp C3	50.3
Macaranga spp C3	53.0	*Didelotia letouzeyi* C2	37.5	*Elaeis guineensis* C4	29.0	*Macaranga* spp C3	34.3
Albizia spp C4	53.0	*Albizia* spp C4	30.5	*Myrianthus arboreus* C4	28.7	*Elaeis guineensis* C4	29.0
Funtumia spp C3	45.7	*Pseudospondias longifolia* C1	19.1	*Albizia* spp C4	25.3	*Albizia* spp C4	26.3
Tabernaemontana spp C4	34.5	*Myrianthus aboreus* C4	16.0	*Didelotia letouzeyi* C2	22.0	*Tabernaemontana* spp C4	21.0
Voacanga africana C3	34.1	*Rauwolfia vomitoria* C1	14.3	*Antiaris africana* C1	18,7	*Myrianthus arboreus* C4	21.0
Elaeis guineensis C4	30.9	*Alchornea floribunda* C2	14.3	*Tabernaemontana* spp C4	14.7	*Voacanga africana* C3	19.7
Pycnanthus angolensis C1	27.9	*Elaeis guineensis* C4	14.2	*Celtis* spp C2	14.7	*Oncoba welwitschii* C1	13.3
Terminalia superba C1	26.5	*Celtis* spp C2	13.2	*Alchornea floribunda* C2	13.3	*Musanga cecropioides* C2	13.3
Myrianthus arboreus C4	21.2	*Spathodea campanulata* C1	11.2	*Funtumia* spp C3	13.0	*Margaritaria discoides* C1	12.7
Total Grand	381.8		256.4		212.7		240.9

C4: common to 4 land uses; C3: common to 3 land uses; C2: common to 2 land uses; C1: specific to 1 land use.

Table 6: Crop species with their local names and number of cultivars used within mixed food-crop agroforests

Crop species	**Local names**	**Cultivars per crop species**	**Crop species**	**Local names**	**Cultivars per crop species**
Manihot esculenta	mbon	6	*Cucumeropsis mannii*	ngôn	2
Musa (AAB)	ekon	5	*Cucurbita* spp	ndzeng	2
Arachis hypogea	owondo	4	*Hibiscus esculentus*	etetam	2
Zea mays	fon	3	*Solanum incanum*	zong	2
Solanum nigrum	zom	3	*Capsicum* spp	ondondo	2
Vernonia amygdalina	metet	2	*Lycopersicon esculenta*	ngoro	2
Musa (AAA)	odjoé	2	*Cucumeropsis mannii*	ngon	2
Ipomoea batatas	meboura	2	*Colocasia esculenta*	atu	1
Xanthosoma sagittifolium	akaba	2	*Talinum triangulare*	elók soup	1
Allium spp	ayan	2	*Solanum aethiopicum*	zom nnam	1
Amaranthus spp	folong	2	*Nicotiana tabacum*	ta'a	1
Carica papaya	fofo	2	*Cucumis sativa*	ombalak	1
Corchorus olitorius	tegue	2	*Solanum tuberosum*	atora	1

Discussion

The conventional portrayal of forest-agriculture does not reflect both the processes associated with it and the context within which it takes place. This study showed that very few primary forest areas are opened in a cultivation year (Table 1). In reality, the farmers manage a pool of fallows of different age and development stage in order to sustain land use management within their livelihood strategy (see study of Carrière 1999).

The variations observed in the contribution of agricultural and forest products in household consumption needs, percentage contribution of forest products to income generation, the pool of woody species within the non-permanent cropping-fallow-forest conversion cycle, and distribution of the top ten woody species (Tables 2-5) show the role of specific context in the management of natural resources. The observed patterns confirm the role of knowledge and spatial context in biodiversity policies (Penkuri and Jokinen 1999) rather than a generalization as is done with the global environmental narratives (O'Brien 2002, Instone 2003a, 2003b).

The global environmental narratives, such as the loss of biodiversity associated with forest-agriculture practices, are expressed in the creation of protected areas to consolidate human-nature divisions; the fixed boundaries (in time and space) of such conservation territories contradict the environmental flows that feature in global discourse, and perpetuate human-nature separation (Prabhu *et al.* 2001, Scheffer *et al.* 2002, Instone 2003a, Prabhu 2003, Olsson *et al.* 2004). However, Deleuze and Gauttari (1988), cited in Instone (2003a), suggests the notion of territorialisation to overcome this division as a particular form of spatial and conceptual translation. It may be helpful for rethinking conservation space in relation to forest-agriculture, not as a fixed and rigid natural resources management practice, but as a socio-ecological system with dynamics and non-linear interactions of societies and ecosystems (Scheffer *et al.* 2002, Prabhu 2003). For them, territorialisation is about connection, ordering and organization across all scales, from the genetic to the global, and across all forms of life - human and non human. The results from this study show how human intervention within the forest to satisfy consumption needs and market strategies affect plant composition and vegetation structure of forest landscape mosaics (Dounias 1996, Dounias and Hladik 1996, Carrière 1999, Van Garmeden *et al.* 2003). They indicate that forest-agriculture practices, embedded within the cropping-fallow-forest conversion cycle, provide the conditions for building resilience for adaptive capacity in social-ecological systems (Folke *et al.* 2002). The issue of space of biodiversity, which is a key component of the conventional portrayal of forest-agriculture from the human-nature perspective, is affected by local forest knowledge systems on both ecological ordering but also for cultural, political, ecological and economic re-alignment (Instone 2003a). The effect of human-nature interactions through forest-agriculture practices on the composition of forest landscape mosaics, challenge its conventional portrayal and provide the resilience-based framework under which forest-agriculture innovations could be addressed in the context of high biodiversity that prevail in southern Cameroon.

Conclusion

Forest-agriculture is a traditional management practice that affects sustainable livelihood strategies and biodiversity conservation. Results from this study confirm that these practices are based on local management of agricultural biodiversity knowledge and affect the composition and patterns of forest landscape mosaics. The practices are largely influenced by the cultural, social, agronomic and economic motivation behind the diversity of crops and woody plants used. The patterns of land use mosaics of farms, fallows and forests reflect the household consumption strategies for sustainable livelihoods and biodiversity conservation through adaptive management of natural resource use practices. Such adaptive management of forest-agriculture practices in the use of forest biodiversity has influenced the specific composition of forests over centuries. The results suggest that there are real opportunities to manage sustainable biodiversity outcomes in protected areas to address both the challenge of conservation and the objectives of improved sustainable livelihoods.

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HOW PEOPLE, BIODIVERSITY AND TREES CAN GET IN EACH OTHERS WAY

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Abstract

Forest(ry) is often about people, more than it is about trees. This is also the case in the fringes of the Mount Elgon National Park (MENP) in Uganda where the population pressure is extremely high, resulting in a high demand for fertile land on the often instable slopes of the Mount Elgon volcano and incidences of encroachment in the park. Simultaneously the biodiversity in MENP is extremely valuable, hence worth protecting. The UWA-Face project therefore, not only aims to restore the integrity of the degraded forest ecosystems and enhance the biodiversity, but also aims to improve the livelihood of the local population. Co-benefits like watershed protection and the protection of the lower lying agricultural land and homesteads against erosion are also of paramount importance. But providing employment opportunities and impart forest skills and knowledge through the UWA-Face project is not enough: there are simply too many people and too little land to sustain the traditional way of life. The key to the successful protection of the MENP is therefore the sustainable development of the area. Supporting the development of a local agro-industry and using the opportunity to generate carbon credits will increase the income of local households. Provided these activities do not out-compete a minimum level of food production in the area, there is a future for people, biodiversity and trees living together after all.

Introduction

National parks in extremely poor rural areas require integrated environmental-social-economic developmental management systems to reconcile socio-economic needs and expectations with environmental conservation. The issues around the management of the Mount Elgon National Park (MENP) in Uganda provide such a case study. The general objective of the MENP authorities is to safeguard the biodiversity and integrity of the physical and ecological processes of the park in perpetuity for the health, welfare, employment and inspiration of present and future generations. However, the fertile land caused the encroachment of a high density of rural farmers to settle in the area, encroach onto the area of the MENP, and exert much pressure on the park management authority to achieve the stated objective of conserving the natural area.

The objective of this paper is to describe the biophysical environment of the MENP, the historical development of the park, the problems experienced to integrate the needs of the people with the rehabilitation and conservation of the Mt Elgon landscape, and to outline the approaches taken to improve the future sustainable management of the MENP area.

Study area

Mount Elgon

This extinct solitary volcano has a huge crater spanning 8 km across. The volcano is located on the border of Uganda and Kenya. The rim of the crater reaches 4,322 m above sea level, but due to the large basal area (80 km across) the overall slope averages only 4%. The mountain descends to the plain in a series of precipitous shelves and is deeply dissected by numerous streams. Annual rainfall varies from 1,250 mm to more than 2,000 mm. Mt. Elgon is an important watershed: 20 rivers originate from the mountain and flow into Uganda en Kenya. About four million people are dependant on this watershed function. It serves as a water catchment for the Nile River, Lake Victoria, and Lake Turkana.

Biodiversity

The vegetation types that naturally occur in the area are montane tropical high forest, a bamboo zone and moorland. Mt. Elgon National Park (MENP) has a high biodiversity value. It is part of the eastern edge of Africa's western and central tropical forest. There is a sequence of vegetation types that is related to altitude. Afro-montane and Afro-Alpine endemic species are present in the zone above 2,000 m. Overall, 37 faunal species figure on IUCN's red list. A number of species are endemic to Mt. Elgon. Forests on Mt. Elgon belong to the top 10 most species rich forests in Uganda. The biological significance was further recognized when the park was declared a Man and Biosphere Reserve in 2005 (Howard 1991).

Population

The population density in the Mt Elgon area varies from 100 to more than 600 inhabitants per km^2 (Figure 1) compared to the average population density in Uganda of 133 per km^2. In Mbale, one of the largest districts of the Mt. Elgon region, the population growth is 3.5%, which is the highest in Uganda. The majority of the inhabitants live from agriculture. The average size of a land holding varies from 0.25 to 1 ha, while a household exists of 10 – 15 people. Generally over half of the household members are children. The major crops cultivated are maize, sweet potatoes, bananas, yam and cassava. The population density in

Kapchorwa District, north of Mbale District but also part of the Mt. Elgon region, is lower and landholdings are larger.

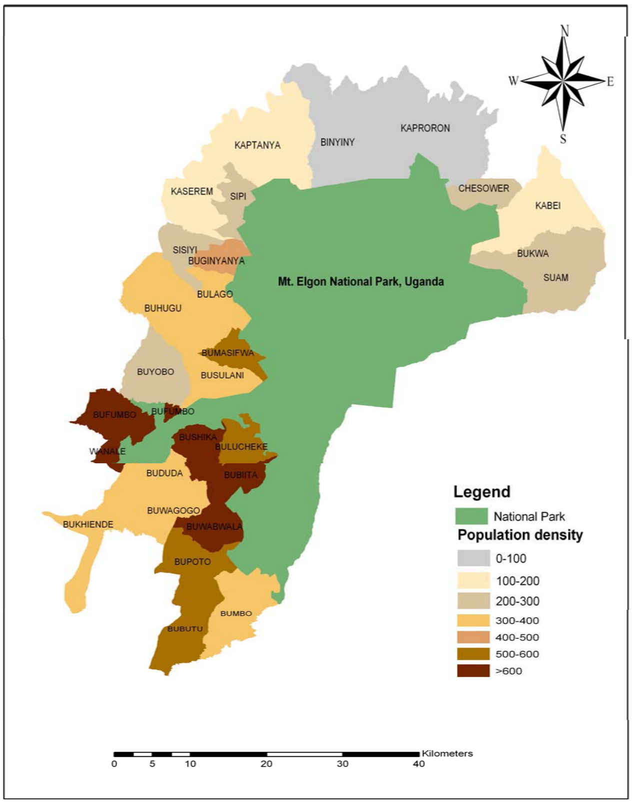

Figure1: Population density in the areas around Mt. Elgon National Park

Management issues of Mount Elgon National Park

Mount Elgon National Park

Mount Elgon National Park covers a large part of the volcano – the total size at the Ugandan side is 114,000 ha. The area was first gazetted as a Crown Forest in 1938. From 1968 to it was administered as a Forest Reserve under the Forest Act. During 1993 the status was changed into a Forest Park and it finally elevated to a National Park when the MENP was established in 1993. MENP is managed by the Uganda Wildlife Authority (UWA). The general objective of UWA for Mt. Elgon is to safeguard the biodiversity and integrity of the physical and ecological processes of the park in perpetuity for the health, welfare, employment and inspiration of present and future generations.

Initial encroachment

Encroachment into the Mount Elgon area took place mainly in the period from 1970 to 1985. The main reason was the political instability of the country, which caused people to move to relatively safe (and fertile) areas like Mt. Elgon. At the same time, because of this instability, there was hardly any control and law enforcement. About 25,000 ha of montane forest were damaged or destroyed as a result of pit-sawing and slash and burn practices for agriculture. Since the 1990s encroachment was stopped and areas were only re-encroached on a very small scale.

Landslides

The steep slopes of Mt. Elgon are inherently unstable and prone to erosion and landslides. The area in Uganda that is most sensitive to landslides is located within the district of Mbale, in the south western part of the mountain. Natural factors that contribute to landslides are high annual rainfall, the soil type, high weathering rates and the steep slopes. Other factors are related to human interference and the increasing population pressure: deforestation, excavations and the concentration of runoff water through linear landscape elements (like roads or parcel boundaries). Triggering factors that cause the eventual landslide are extreme rainfall events or even excavations. In the years 1933, 1964, 1970 and more recently in 1997 – 1999 landslides have caused a lot of fatalities and damage to the infrastructure and environment. In 1997 in the Manjiya county (close to the south western part of the forest rehabilitation area) 48 people were killed, crops and dwellings of 885 families disappeared and 5,600 people became homeless. Arable land was reduced, adding to the land scarcity and contributing to conflicts over land, and water supplies were polluted. According to an estimate of the Ministry of Water, Lands and Environment, the economic costs for the repair of bridges and roads amounted to US$1.273 million for the Mbale district (Knapen *et al.* 2006; Claessens *et al.* 2007).

Restoration of Mount Elgon National Park

Background to restoration activities

In 1988 the Government of Uganda made a commitment to the conservation of Mt. Elgon and received technical support from IUCN and financial support from NORAD to assist in the rehabilitation and to develop a strategy for the conservation of the forest (Mupada 1997). The costs for the restoration of the former encroached area, that was partly covered with Kikuyu grass (*Pennisetum clandestinum*), were prohibitive. In 1993 and 1994 Face Foundation was identifying areas to establish forest and was invited to undertake restoration activities in MENP. The funds for the project activity from the Face Foundation were specifically meant for reforestation in order to sequester CO2 from the atmosphere and contribute to climate change mitigation. The 1 – 3 km wide zone of degraded land along the boundary within the park on an altitude of 2,000 to 3,000 m was assigned as restoration area (Figure 2).

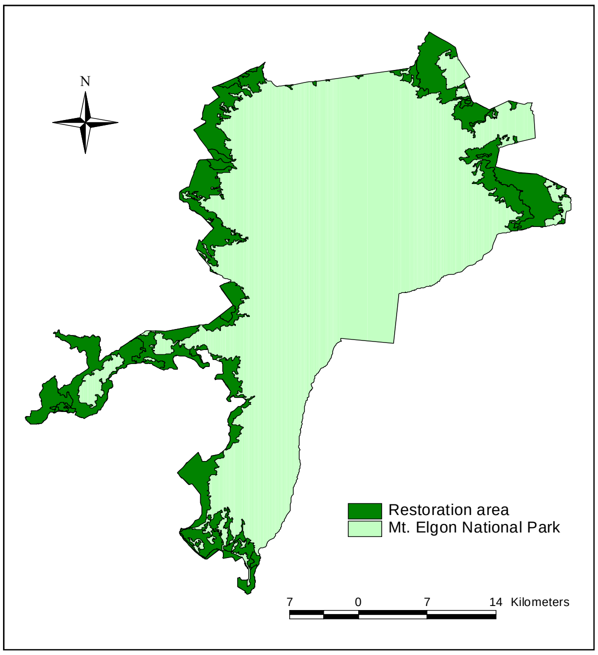

Figure 2: The restoration area within Mt. Elgon National Park

The objective of the UWA-Face project was to restore the natural vegetation in the MENP area. This is achieved by planting indigenous tree species in compartments along the boundary and protecting the area beyond the planting area. The project enhances the biodiversity values of the park, provides employment opportunities to communities adjacent to the park and imparts forest skills and knowledge to the local communities. Between 1994 and 2007 about 8,125 ha of the 25,000 ha restoration area had been planted and maintained.

The restoration area consists of the following main vegetation types: grassland (dominated by Kikuyu grass), ferns dominated vegetation, shrub dominated vegetation (mainly *Vernonia auriculifera*) and riverine vegetation. The intended forest is classified as rich, medium and poor forest. Rich forest is high forest that corresponds to the *Prunus africana* moist montane forest as described by Synnott (1968). Medium rich forest is open high forest with tall trees over a dense dark understorey. It is a poorer version of the former type with almost the same species composition. The poor forest consists of occasional large trees over herbs and shrubs. It corresponds with *Hagenia-Rapanea* moist montane forest and *Juniperus-Podocarpus* dry montane forest (Synnott 1968). The selection of species for planting depends on the site conditions. Fast growing and light demanding species are planted in the areas dominated by grass and ferns, while shade tolerant species are planted on spots with a canopy cover.

Social benefits

In the design of the project it was believed that the reforestation activities would benefit the local population. The forest protects the soil and diminishes the occurrence of landslides, preventing casualties and damage to houses, cropland and infrastructure. It also forms a natural resource that people can use to obtain non-timber forest products. The project itself has provided many labour opportunities – it has been recognized as one of the few significant employers in the region. The many field operations require well-maintained roads that improve as a side effect the accessibility of villages on the mountain slopes. In addition to income the workers receive food, medical care and social security. The workers also received training and capacity building. The practical knowledge of raising and planting trees could be (and has been) applied outside the park on the farms for their own purposes (e.g. for the production of coffee seedlings, fruit trees and *Eucalyptus* seedlings). Income is also generated through the sale of seedlings from farmer nurseries to the project and other interested communities.

Apart from the project-specific benefits, the MENP as a whole provides benefits and UWA considers the interests of the local population. There are mainly two mechanisms through which local people have a profit from the park. The first is UWA's revenue sharing mechanism: 20% of the park revenues from tourism are invested in projects for the villages around the park. Local people are invited to submit proposals and request for funding. Examples are constructing or renovating schools, drilling wells or establishing dispensaries. Active projects include bee keeping activities, Bushuy Dairy Project and the Bushiy-Manafwa trail project. The second mechanism is the Collaborative Resource Management Agreements (CRMA). Those agreements between local people on parish level and UWA give the population access to specific park resources, like firewood, bamboo, honey and medicinal plants. Within the agreements it is specified how much of the resources can be harvested and in which periods. The boundary of the park is demarcated with a 10 m wide strip of *Eucalyptus* trees, which is also used by the adjacent communities. In each parish a Boundary Management Committee is elected by the community members to supervise and coordinate harvesting and management of the boundary trees.

In addition to revenue sharing and the CRMA's, the population participates through the local government in a dialogue about park management issues. For this purpose the Community – Protected Area Institution (now the Interdistrict Link Committee) was established in 2000. It serves as a platform for the park management and the local government. The objective of the Interdistrict Link Committee is to promote communication between the stakeholders, share information, express concerns, provide a platform for conflict resolution and to enhance the participation of stakeholders in the management of the park.

In conjunction with IUCN's Mt. Elgon Conservation and Development project (MECDP), the UWA has raised awareness in the region about the importance of conservation of the park. In collaboration with district authorities and local NGO's sustainable development in the area outside the park has been promoted. Examples of promoted activities are agroforestry, beekeeping, improved farming systems, and fruit growing for cash income (Chhetri *et al.* 2003). This project ended in 2003. It is now followed up by the Mt. Elgon Regional Ecosystem Conservation Program (MERECP).

Renewed encroachment

In the period from 1993 to 2003 the situation along the park boundary remained stable. However, encroachment started again in the period 2004 – 2007. The size of the areas affected is respectively 190, 238, 999 and 542 ha. It is explained by the ever continuing growth of the population, the competition for land, grievances that stem from the evictions of the early 1990s and the fertile volcanic soils. However, the factor that triggered the waves of encroachment very often arose from the pronouncements of national and local politicians.

A consequence of encroachment is that investments in further rehabilitation of the park were deferred, because there was no guarantee for a long-term forest carbon sink anymore. There was no security that the planted forest would ever generate carbon credits. The result was that the number of jobs that had already been reduced as a result of the changed financial support for Face was again reduced as no new planting activities were being undertaken. The only labour that remained (50 – 70 men) was for the maintenance of the already established forest.

Encroachment is concentrated in the south-western part of the park, in the Mbale District. Incidences in Kapchorwa District are less frequent. Disturbance of the forest is limited to illegal cutting of trees or tree branches. Encroachment seems to coincide with the population density, but the role of local politicians might also be a factor. Probably the interaction of both the population pressure for land and the attitude of local politics explain the occurrence of encroachment.

The future for Mount Elgon National Park

High population pressure combined with poverty, a lack of a clearly defined park boundary and political campaigning gave cause to conflicts and encroachment. The experience of the past years has shown that the strong involvement of the local population is crucial for maintaining the forest. It also shows that all activities undertaken with the aim to involve local communities in the park management, to share benefits and to reduce pressure by promoting rural development, are no guarantee for the absence of conflicts between the park management and the local population. Another lesson is that encroachment is very often induced by opinions and statements of local and national politicians.

Still, a renewed effort to improve the relationships between the park management and the local population and their representatives is the only way to improve the situation. A long term solution should mainly focus on the areas that gave rise to conflicts, i.e. the areas that have been encroached in the past five years. In order to reach a sustainable solution for the people, the environment and the biodiversity, the community livelihoods need to be enhanced and nature conservation needs support from the local communities and their political leaders. The following strategies could contribute to a more stable situation:

1. Community based forest rehabilitation: parts of the former encroached area can be rehabilitated by involving the communities that live adjacent to the park boundary. When provided with seedlings the local people can plant the indigenous trees and practice intercropping for the period that the trees would allow that (e.g. until canopy closure). The trees can be harvested, under supervision of the manager of the park, when they are mature. In this way the forest protects the slopes and the people profit from the land and the trees. At the same time these areas function as a buffer between the agricultural land and the protected natural forest, i.e. forest not meant for harvesting.
2. Carbon revenue sharing: a part of the revenues generated by the sale of carbon credits that result from the forest rehabilitation can be used for the benefit of communities. It is comparable to UWA's revenue sharing mechanism. A fixed percentage of the revenues could be deposited in a community carbon fund. Communities can submit proposals for activities like the construction or renovation of schools, establishing dispensaries or maintain a road. Another possibility is to contribute to the development of income generating activities like bee keeping, improving agricultural techniques and promoting eco and cultural tourism. A condition to such a mechanism is that rehabilitated forest remains intact and there is a low risk of encroachment in the park.
3. Contribute to rural development: the main problem in Mt. Elgon is the scarcity of land as a result of the high population density. Part of the solution is to enhance the agricultural productivity in order to yield more crops of high value (wheat, groundnut, highland rice, watermelon) from the same area of land, which decreases the competition for land. In addition, the introduction of agro-industries may add value to the regional agricultural production. The introduction of other types of industry may cause a shift towards a more balanced regional economy, that is less dependant on agriculture alone.
4. The overarching strategy is to intensify the dialogue with the stakeholders of the park. This is to create mutual understanding of the parties involved and reach consensus where possible.

The first strategy is the most clear and promising solution. It is a compromise between the desires of the communities and the park management and it focuses directly on the problematic areas. The advantage of the second strategy is that it links the growth of the forest to the income for the communities and provides an incentive to keep the forest intact. However, its feasibility depends very much on the stability in the area. The risk of encroachment should be low and that can only be determined afterwards, when the approach has proved itself after at least one year. Otherwise the permanence of the carbon sink cannot be guaranteed and the forest will not generate any carbon credits. The third strategy is the most complex and indirect measure. It is beyond the scope of UWA, Face and the local authorities and cooperation with other organisations is required.

The strategies are being explored and discussed with the stakeholders in Mt. Elgon. In the past year there have been extensive discussions with the local leaders on district, parish and village level about the park and the need to improve livelihoods. There was also a workshop organized for district leaders and Members of Parliament from the districts surrounding the National Park. The effect of those meetings is an increased mutual understanding and agreement on the importance of combining nature conservation with local livelihoods. Since that workshop the following activities are being undertaken:

- Consultation meetings with local communities are organized and the issues such as carbon revenue sharing and tree planting, intercropping and harvesting are being discussed and agreements with the communities are being devised (Bududa selected as a pilot district);
- UWA and Face are identifying partners and discussing with possible partners for participation in the coordination of a rural development programme to enhance the local livelihoods;
- UWA and the local government are requesting the national government to promote investments in (agro)industrial activities in the Mt. Elgon region;
- UWA is consulting local communities that live along the park boundary about their opinion of participating in managing some of the restoration areas (tree planting, intercropping and tree harvesting);
- UWA is developing agreements for participation in the restoration area by local communities;
- Local people that have illegally occupied park land are leaving the area after having harvested the crops they have planted;
- There is support from the President, the relevant Ministers, Members of Parliament from the Mt. Elgon region and the local government to adopt an approach of further reconciling the interests of the park with the interests of the local communities.

About 800 ha of encroached land within the restoration area has been left by encroachers and it is expected that more encroachers will follow. This does not apply to the areas that are subject to court cases. Some communities claim property of land that is now within the park (e.g. in Wanale and the Namisidwa Land Claimant in Buwabwala). Some of these lands are part of the restoration area. The progress of the court cases is very slow; it might take several years before a judgement is made. A decision on reforestation of those parcels must wait until the court has made clear what the status of those areas is.

At this stage it is unclear which organization will be involved and what role they will have in the future. It is clear that UWA will remain manager of the park and will have a crucial role in the whole process.

Although there are positive signals that socio-economic, natural and environmental interests can be reconciled it is still too early to assume that the new initiatives and agreements result in a sustainable solution for the whole area. The interests of the local people for land and of the politicians to win votes remain high, especially because of the increasing population. Long-term security that the forest remains intact is required for the long term to ensure carbon certification of the forest. In the current situation the permanence of the forest carbon stock is still under risk. The new adopted approach has yet to prove itself.

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MODELLING WOODY-PLANT DOMESTICATION AND LOCAL KNOWLEDGE WITHIN AGRICULTURAL LANDSCAPE MOSAICS IN SOUTHERN CAMEROON

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Abstract

Traditional forest-agriculture, or slash-and-burn, contrary to the conventional perception, incorporates local knowledge of forest species and ecological process in their management. This paper analyses the relationships between the domestication or retention of woody species and local knowledge. Socio-economic characteristics of sites and farmers as well as the quantity and quality of woody species (standing stems and re-sprouting) and 10 local tree uses associated within *Cucumersopsis* farms are captured. The decision to domesticate woody species during the clearing of the forest was analyzed with logistic regression. The results show that the number of woody species domesticated is positively correlated with the natural and social capital of the farmer but the relationship with his financial capital is less clear. The annual domestication of woody species within the *Cucumeropsis* agroforest, a key land use within the cropping-fallow-forest conversion cycle, is strongly regressed with some of the 10 woody-plant uses, particularly food, fuel wood, timber and traditional medicine. This confirms that only woody species with multiple uses are domesticated by farmers. The paper recommends that current developments in tropical agroforestry and agricultural sciences towards natural resource management (NRM) will not succeed without incorporation of local knowledge of agricultural biodiversity in general, of domestication of woody species, and management affecting the viability of agro-ecosystem within socio-ecological context.

Introduction

Forest-agriculture, also known as ‘slash-and-burn agriculture’ or ‘swidden cultivation’, has been portrayed over the past decades as a cause of deforestation and biodiversity loss (GEF 1993, Garrity and Bandy 1996). This negative portrayal has been challenged over the past decade by the rethinking of the nature and the biophysical and socio-economic processes of forest-agriculture taking place in the field (O’brien 2002, Instone 2003a). This critical knowledge was generated all over the tropics to understand the socio-ecological resilience of this practice (Diaw 1997, Oyono *et al.* 2003) and its positive impacts on forest regrowth and regeneration (Dounias 1996, Carrière 1999, Van Germeden *et al.* 2003). Meantime, in order to deal with the issues of deforestation, there has been a rapid development of technical domestication of woody species. The challenge is to link genetic improvement research with marketing to ensure income generation and food security; crucial components in the release of new tree crops on a sufficient scale in sustainable agroforestry systems (Leakey and Izac 1996). For this perspective, the domestication of woody species seems to be both about product development and product creation, i.e. rebuilding forest resources (Leakey and Newton 1994). However, it has been shown that the forest landscape mosaics resulted from the management of woody species, both wild and domesticated, that have been combined, modified and managed by people for millennia, in complex and diverse agricultural systems (Reichardt *et al.* 1994, Dounias 1996, Carrière 1999, FAO 1999a, 1999b, 2005, Lefroy *et al.* 1999, Toledo *et al.* 2003). These human-nature processes for managing natural resources have been documented. However, the big challenge is to understand how and under what conditions the woody species are domesticated when a forest patch is cleared, and to be able to link this knowledge to the development of forest-agriculture innovations.

In southern Cameroon, the ecology of selected land uses has been studied mainly from the sustainable tree management perspectives and to propose alternative agroforestry systems (Dounias 1996, Dounias and Hladik 1996, Carrière 1999, Ngobo 2002, Sonwa 2004). In cocoa plantations, these studies often focused on the understanding of the relationships between the management of shade and the productivity of cocoa. It appears that three of the 10 most frequent woody species found in this land use by order of importance are *Dacryodes edulis, Persea americana* and *Terminalia superba* (Gockowski and Dury 1999, Sonwa 2004). In mixed food-crop and *Cucumeropsis* farms, four broad categories of woody species are often associated with food crops: (i) woody species with agronomic, cultural an ecological qualities such as indicators of soil fertility with *Terminalia superba, Triplochiton scleroxylon* and *Pycnanthus angolensis*; (ii) soft-woody and semi-woody pioneer species and hard woody long-living species; (iii) woody species that do not inhibit crop development (Dounias 1996, Dounias and Hladik 1996, Carrière 1999); and (iv) timber species and species used for non-wood forest products (NWFPs). Carrière (1999) showed that the number of tree species increase from the small-size to large-size tree category for remnant trees found in mixed food-crop and *Cucumeropsis* farms. Farmers use several criteria to manage land uses based on their agricultural biodiversity knowledge of land use age and of active agricultural land use practices (Carrière 1999). However, the cognitive processes that take place when the forest is cleared and that lead to an accumulation of different types of woody species, their size and their spatial distribution remains insufficiently analyzed. Furthermore, very little is known about how far the interactions between the environment and the size-categories of woody species maintained during the clearing of the forest would determine the specific current composition of forest landscape mosaics. This understanding is a crucial step in the design of research and intervention processes, and the appropriate conditions for the implementation of adaptive co-management of natural resource options in the context of high biodiversity systems (Prabhu 2003, Woodley 2004, Colfer 2006).

Our working definition of the domestication of woody species in the context of the farmers' practices refers to the process of maintaining/retaining (domesticating) plants of woody species when the farmers clear a patch opposed to the plant species that they systematically fell. These species include both woody species found in *Cucumeropsis* and cocoa agroforests and by extension in mixed food-crop agroforests that will directly affect the regrowth of the forest, i.e. the change over from the cultivated product towards regrowth forest. The domestication of woody species also refers to wild plant species planted by farmers. Sometimes in the secondary and mature forests, people clear herbaceous species around the woody species.

The objective of this paper is to analyse the relationships between the domestication of woody species and local knowledge management of agricultural biodiversity. The main hypothesis is that the domestication of woody species is influenced by local management of ecological and socio-economic knowledge within the cropping-fallow-forest conversion cycles at the earlier stage of the conversion cycle.

Material and Methods

Study area

The study was done in the forest margins benchmark area of southern Cameroon designed to assess natural resource use intensification and population density gradients in three blocks at three levels, i.e low (Ebolowa), medium (Mbalmayo) and high (Yaoundé). The biophysical and socio-economic characteristics of the study area are well documented (Figure 1; Gockowski *et al.* 2005). Its climax vegetation represents three main types of forest ecosystems: dense, semi-deciduous forest characteristic of the Yaoundé block, which extends southwards into the Mbalmayo block; dense, humid, Congo Basin forest in the southern reaches of the Mbalmayo block, which extends to the Ebolowa block; biologically diverse, moist, evergreen, Atlantic forests in small pockets along the western border of the Ebolowa and Mbalmayo blocks (ASB 1995).

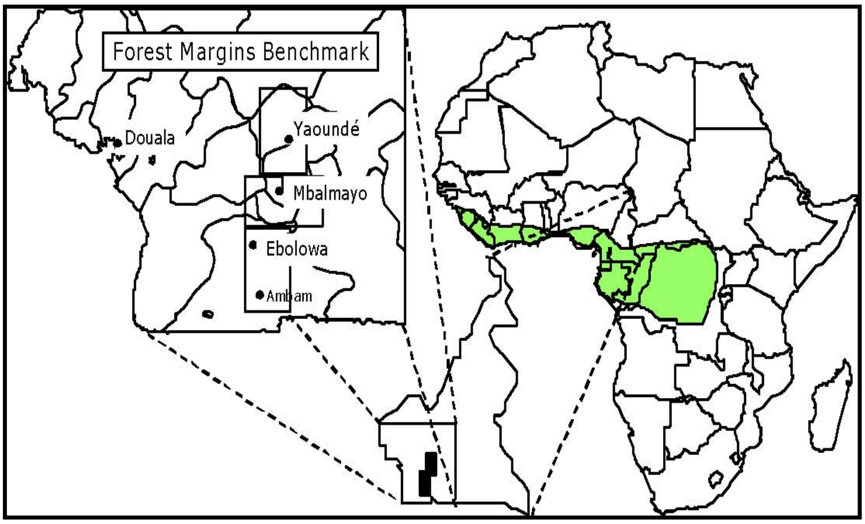

Figure 1: The ASB forest margins benchmark area in southern Cameroon (Gockowski *et al.* 2005).

Sampling methods

Six villages were selected within the study area, with two villages selected in each block. Selection was based on three categories of intensity of monthly interactions with external stakeholders (extension services): low = three days of activities; medium = one week of activities; high = more than 10 days of activities with the support of reports of the field activities. Thirty (=5*6) households, equally distributed between six villages. Household selection was based on the socio-diversity of each village in terms of gender, number of clans or lineages, and age category (young, adult and old). The *Cucumeropsis* agroforest land use was selected from nine land uses because of its key role in the beginning of the cropping-fallow-forest conversion cycle, its role in the land tenure processes with access rights and for its potential in the domestication of non-agricultural plant species such as seedlings, saplings, poles and trees kept as markers of land ownership.

Data collection

A structured questionnaire divided into 4 sections was administrated to the households. Section 1 provided for collection of data on the socio-economic characteristics of villages: distances (km) to the closest and most important markets; the perception of market access (bad=1; manageable=2; good=3). Section 2 provided for data on the socio-economic characteristics of the respondents: name of respondent; main occupation (1=peasant farmer; 2=retired civil servant; 3= civil servant), gender (1=male; 2=female); marital status (1=married; 2=single; 3= widow(er)); age, in years (<30; 30-45; >45); education level (1=never being to school; 2=primary education; 3=secondary education; 4=tertiary education); belonging to social organizations (1=yes; 2=no); family or household size (1=1; 2=2-4; 3=5-8; 4=8); natural capital i.e. size of farm in ha (1=5-10; 2=10-15; 3=15-20; 4=>20);

and financial capital in FCFA (local currency with US$1=FCFA525.5, November 2008) (1=<250000; 2=250000-350000; 3=>350000). Section 3 provided for data on agricultural plant diversity at the land use level. One to four plots of 20 m x 20 m size were implemented in *Cucumeropsis* agroforests depending on the total size of the farm. Within these plots, the following data were collected for each plant: (i) local name of the place; (ii) scientific name of woody plant including family, genus, specie and author; (iii) local name of the woody plant; (iv) quality of a plant (standing plant = 1; plant stem resprouting = 2; plant stem not resprouting = 3); (v) stem diameter of each measured stem (cm) at breast height (DBH); (vi) height of each plant; (vii) index of forking (defined as the ratio between the height of the plant from its first fork over the total height of the plant stem, based on a proposed framework ranging from 100% when the first fork is at ground level, up to 0% when there is no forking. (viii) woody quality of plant species (1=soft; 2=semi-woody; 3=hard woody). Section 4 provided for data on different uses of plant species: 1=food; 2=medicinal; 3=material for house building; 4=tools; 5=fuel wood; 6=cultural or ritual; 7=marketable NWFP; 8=useful for hunting; 9=security for the future; 10=special use).

Data analysis

The data collected were codified and computed in Excel, and the count of woody-plant species were summarized via excel pivot tables per land use and for the six stem size categories of plant per block. The plant size categories of woody species were defined based on adaptation from the Letouzey (1979) model for the dense humid forest as follows: small seedlings and sprouting stems: stems ≤2 m height; medium-sized saplings and poles: stems ≤10 cm DBH; large-sized poles: stems 10-20 cm DBH; small-sized trees: stems 20-50 cm DBH; medium-sized trees: stems 50-100 cm DBH; and large-sized trees: stems >100 cm DBH. Stem density was expressed in stems/ha. The Chi-square statistics were used to assess the relationships between the number of woody species domesticated and stem density of six plant-size categories. A Wald test with logistic regression statistic was used to predict the probability of keeping/maintaining plant species based on farmer knowledge of their diameter, height, size categories and index of forking, and uses of woody plants during the clearing of the forest using XLStat2007 (Menard 1995).

Results

Socio-economic profile of villages and households

The study showed that the minimum and maximum distances to the closest (1-15 km versus 12-60 km) and important markets (5-40 km versus 33-115 km) do not the follow the resource intensification gradient of the study area. The variation in distance is high for both the closet and important markets, between the three blocks particularly for the Mbalmayo block (generally far) versus the Yaoundé and Ebolowa blocks (generally closer). Most respondents in all three blocks considered market access as manageable (all three blocks) to good (Mbalmayo). The socio-economic profile indicated that most respondents were (i) peasant farmers (64.6%) followed by retired civil servants (31.4%) and civil servants (4%); (ii) females (77.7%) followed by males (22.3%); (iii) married (92.2%) followed by single (4.2%) and widow (3.6%); (iv) >45 years old (70.5%) followed by 30-45 years old (29.5%) (none younger than 30 years); (v) had done secondary education (54.7%) followed by primary education (45.3%); (vi) belong to social organizations (95.8%); (vii) had a family size of 5-8 people (44.3%) followed by >8 people (38.8%) and 1-4 people (16.8%); (viii) owned >20 ha of land (55.2%) followed by 15-20 ha (20.2%), 5-10 ha (15.2%) and 10-15 ha (9.5%); (ix) earned an estimated annual revenue of >350 000 FCFA (65.2%) followed by <250 000 FCFA (23.1%) and 250 000-300 000 FCFA (11.7%).

Abundance of woody species in Cucumeropsis agroforests

Cucumeropsis agroforest fields included 108 woody species distributed over 57 families with the most representative by order of importance: Apocynaceae, Moraceae, Euphorbiaceae, Mimosaceae and Caesalpiniaceae. The top 10 tree species over all size categories represented 22 species. The general trend in all three blocks (Table 1) is a relative high percentage of small-sized seedlings and resprouting stems (53.9%), a much lower percentage of medium-sized trees (16.7%) and small-sized trees (13.8%), and a relatively small percentage of large-sized poles (9%), medium-sized saplings and poles (6.2%) and large-sized trees (0.3%). In the Ebolowa block, the 10 top species were represented by 11 species and the main species, in order of total stem count of small and medium sized trees, were *Musanga cecropiodes, Macaranga* sp, *Elaeis guineensis* and *Albizia adianthifolia*. The woody species were predominantly small-sized seedlings and resprouting stems (58.6%) and small-sized trees (31.0%). In the Mbalmayo block, the 10 top species were represented by 11 species and the main species was *Elaeis guineensis*. The woody species were predominantly small-sized seedlings and resprouting stems (37.3%) and both small-sized and medium-sized trees (22.7% each). In the Yaoundé block, the 10 top species were represented by 10 species and the main species was *Celtis* spp. The woody species were predominantly small-sized seedlings and resprouting stems (60%) and medium-sized trees (18.3%). The only large-sized tree was found in the Ebolowa block. There are variations of the total number of trees domesticated between blocks, with more timber species present within the top 10 woody species in the Mbalmayo block than in the Yaoundé and Ebolowa blocks (Table 1).

Relationship between decision to domesticate woody species and perceptions of distance to markets and market access

The Wald test of logistic regression found that the decision by farmers to keep/maintain woody species are influenced very highly significantly by the financial capital of the respondent, and both distance from villages to the closer and the important markets, highly significantly by the natural capital (levels 2 and 3) of the farmer and significantly by the perception of village access, and not influenced by natural capital (level 1). The coefficient of the equation (B) is positive for closer market, financial capital and natural capital (level 2) and negative for important market and natural capital (level 3) (Table 2).

Relationship between biophysical characteristics of woody species and farmer's decision to domesticate them in Cucumeropsis farms

The results of the contingency table analyses indicate that plant size per type of use influence the decision to fell or to keep/maintain plant species (Chi-square=11.1, df=5, $p<0.05$). The number of felled trees increases from the small-sized seedlings and resprouting stems to the large-sized trees while the number of plant species kept follows the inverse. The farmer's decision to maintain certain plant species during the clearing of forest patches is positively influenced by the stem diameter ($P<0.05$) and negatively influenced by the stem height ($P<0.05$) and its index of forking ($P<0.05$) (Table 3). The equation of the regression model of decision to keep plant species is as follows:
= 1 / (1+exp(-(3.15165868225324+7.87435474127973E-03*(Tree dbh)
-7.03419127790424E-03*(Tree height)-2.82850084361277E-02*Tree forking index))).

Relationship between tree domestication status, respondents' knowledge of tree uses and household needs/perspectives

The relative high percentage of woody species are used for fuel wood (54.7%) and medicine use (47.1%) that follow the resource use intensification gradient as well as the use of woody species in the management of shade, soil fertility and special uses such as hosts for edible caterpillars (Mala 2009). There are variations between blocks such as that the respondents in Ebolowa and Mbalmayo blocks rely more on the uses of woody species than those in Yaoundé block. The results of the Wald test of logistic regression (Table 3) found that three of the ten plant use categories affect the decision of farmers to keep them: food uses are very high significantly (P.=0.000)' medicinal uses are highly significant (P=0.001); and timber uses are significant (P=0.045). The coefficients of the regression equation per variable are negative.

Table 1: Stem density (stems/ha) for the top 10 woody species per tree size category in *Cucumeropis* agroforest for the three blocks in the study area

Block in Humid forest zone	Woody species	Tree size category						Total
		Small seedlings, saplings & sprouts	Medium saplings & poles	Large poles	Small trees	Medium trees	Large trees	
		≤2 m high	>2 m high to ≤10 cm dbh	11-20 cm dbh	21-50 cm dbh	51-100 cm dbh	>100 cm dbh	
Ebolowa	*Musanga cecropioides*	2.9	0.0	0.0	11.8	0.0	0.0	14.7
	Macaranga sp	5.9	0.0	2.9	1.5	0.0	0.0	10.3
	Elaeis guineensis	7.4	0.0	0.0	1.5	0.0	0.0	8.8
	Albizia adianthifolia	2.9	0.0	0.0	5.9	0.0	0.0	8.8
	Icacina mannii	5.9	0.0	0.0	0.0	1.5	0.0	7.4
	Voacanga africana	4.4	0.0	1.5	0.0	0.0	0.0	5.9
	Tabernaemontana spp	5.9	0.0	0.0	0.0	0.0	0.0	5.9
	Panda oleosa	4.4	0.0	1.5	0.0	0.0	0.0	5.9
	Margaritaria discoides	0.0	0.0	0.0	4.4	0.0	1.5	5.9
	Funtumia spp	4.4	0.0	0.0	1.5	0.0	0.0	5.9
	Enantia chlorantha	5.9	0.0	0.0	0 .0	0.0	0.0	5.9
Total Ebolowa: Stems/ha Relative density (%)		50.0 (58.6)	0,0 (0.0)	0.0 (0.0)	26.5 (31.0)	1.5 (1.7)	1.5 (1.7)	85.3 (100.0)
Mbalmayo	*Elaeis guineensis*	33.9	0.0	1.8	3.6	5.4	0.0	44.6
	Voacanga africana	3.6	0.0	3.6	1.8	3.6	0.0	12.5
	Hylodendron gabonense	1.8	0.0	0.0	3.6	5.4	0.0	10.7
	Scyphocephamiiun ochocoa	0.0	0.0	3.6	3.6	1.8	0.0	8.9
	Ricinodendron heudelotii	7.1	0.0	0.0	0.0	1.8	0.0	8.9
	Petersianthus macrocarpus	0.0	1.8	0.0	7.1	0.0	0.0	8.9
	Margaritaria discoides	0.0	0.0	1.8	1.8	5.4	0.0	8.9
	Albizia adianthifolia	3.6	0.0	3.6	1.8	0.0	0.0	8.9
	Terminalia superba	0.0	1.8	0.0	1.8	3.6	0.0	7.1
	Milicia exelsa	0.0	1.8	1.8	1.8	1.8	0.0	7 .1
	Distemonathus benthamianus	0.0	1.8	0.0	3.6	1.8	0.0	7.1
Total Mbalmayo: Stems/ha Relative density (%)		50.0 (37.3)	7.1 (5.3)	16.1 (12.0)	30.4 (22.7)	30.4 (22.7)	0.0 (0.0)	133.9 (100.0)
Yaoundé	*Celtis* spp	45.0	0.0	0.0	0.0	15.0	0.0	60.0
	Elaeis guineensis	40.0	0.0	0.0	0.0	10.0	0.0	50.0
	Tabernaemontana spp	20.0	0.0	0.0	0.0	15.0	0.0	35.0
	Spathodea campanulata	0.0	20.0	5.0	0.0	0.0	0.0	25.0
	Funtumia spp	15.0	0.0	5.0	5.0	0.0	0.0	25.0
	Alchornea floribunda	25.0	0.0	0.0	0.0	0.0	0.0	25.0
	Oncoba welwitschii	5.0	0.0	0.0	0.0	15.0	0.0	20.0
	Ficus mucuso	20.0	0.0	0.0	0.0	0.0	0.0	20.0
	Didelotia letouzeyi	10.0	5.0	5 0	0.0	0.0	0.0	20.0
	Dacryodes edulis	0.0	0.0	10.0	10.0	0.0	0.0	20.0
Total Yaoundé: Stems/ha Relative density (%)		180.0 (60.0)	25.0 (8.3)	25.0 (8.3)	15.0 (5.0)	55.0 (18.3)	0.0 (0.0)	300.0 (100.0)
Total: Stems/ha Relative density (%)		280.0 (53.9)	32.1 (6.2)	47.0 (9.0)	7.8 (13.8)	86.8 (16.7)	1.5 (0.3)	519.2 (100.0)

Table 2: Logistic regression of domestication of woody species based on socio-economic characteristics of villages and farmers

Parameters	B	S.E.	Wald	df	Sig.
Closest market (Vclomark)	0.015	0.004	14.1	1	0.000
Important market (Vimpormark)	-0.022	0.003	66.6	1	0.000
Market access (VAccess)	0.186	0.077	5.8	1	0.016
Financial capital (FC)	0.232	0.043	28.7	1	0.000
Natural capital (NC 1)	0.104	0.123	0.7	1	0.397
Natural capital (NC 2)	0.581	0.179	10.5	1	0.001
Natural capital (NC 3)	-0.361	0.124	8.5	1	0.004
Constant	-0.547	0.184	8.8	1	0.003

Table 3: Logistic regression of plant species domestication based on farmers' knowledge of their uses in *Cucumeropsis* agroforests

Variables	B	S.E.	Wald	df	Sig.
Food (TU1)	-1.675	0.115	213.806	1	0.000
Medicine (TU2)	-0.282	0.088	10.196	1	0.001
Timber for houses (TU3)	-0.202	0.101	4.037	1	0.045
Constant	1.262	0.109	134.857	1	0.000

Discussion

The domestication of woody species by farmers at the beginning of the cropping-fallow-forest conversion cycle is a reality. The *Cucumeropsis* agroforest fields contained plants of woody species in the order of 85 stems/ha at Ebolowa, 134 stems/ha at Mbalmayo and 300 stems/ha at Yaoundé (Table 1) and represented 108 woody species distributed over 57 families. In all the blocks the highest percentage of these plants are below 2 m in height, with 60% in Yaoundé, 59% in Ebolowa and 37% in Mbalmayo. One can assume that these plants regenerated from seed or vegetative regrowth during cultivation of the crops. However, the next largest stem density of a size category is for small (21-50 cm DBH) and medium-sized (51-100 cm DBH) trees, with 31% small trees in Ebolowa, 23% in each of small and medium-sized trees in Mbalmayo and 18% medium-sized trees in Yaoundé, and it can be assumed that most of these trees had been domesticated. There are variations between blocks for the total number of trees domesticated with 45.4% in Mbalmayo, 34.4% in Ebolowa and 23.3% in Yaoundé (Table 1). The variations indicate that the number of woody plants domesticated does not follow the resource use intensification gradient of the study area but that it is probably influenced by the biophysical characteristics of the woody species and the specific socio-economic characteristics of each block such as the distance to important markets and the perception of availability of natural capital (Table 2). The results also show that the stem size of woody species per type of use influence the decision to fell or to keep/maintain a specific plant (Chi-square=11.1, df=5, $p<0.05$). The results suggest that the larger the size of a woody species, the higher is the probability to be kept/maintained during the clearing of the forest (Table 3). This confirms the results of Carrière (1999) that large-sized trees are rather kept in the mixed food-crop and *Cucumeropsis* agroforests than the smaller-sized categories.

Three of the 10 categories of use of woody species (food, medicine, timber and material for house construction) are significant to capture the cognitive processes behind the domestication of woody species. However, the coefficient of the regression equation for these variables was negative (Table 3). This suggests that these are the parameters that one should address to increase the quantity and quality of woody species in the earlier stages of the cropping-fallow-forest conversion cycle. The technical aspects of domesticating woody species to rebuild forest resources are still underestimating the ability and the cognitive processes behind the natural-traditional domestication of woody species. Such traditional cognitive processes behind domesticating the quantity and quality of woody species are not linear but are based on the natural and financial capital of farmers (Table 2) and various others socio-economic factors such as the availability of labour (Mala 2009). The results suggest the need to define domestication of woody species that would reflect the processes taking place within the cropping-fallow-forest conversion cycle to maintain the woody species as a component of agricultural biodiversity (Charyulu 1999, FAO 1999a, 1999b, 2005). This definition should link woody plant diversity to the history, biophysical environment, culture, society and socio-economic dimensions of the landscape that underlie local management practices. The results show that the concept of domestication incorporates a range of variables or indicators of forest-agriculture sustainability, including different non-agricultural plant species of different size. This combination forms a multi-stratified landscape that is a source of resilience within the cropping-fallow-forest conversion cycle, with the diversity in quantity and quality of woody species shifting from *Cucumeropsis* and mixed food-crop agroforests, to cocoa agroforests, alternated with different stages of fallow (Carrière 1999). The number of plant species per size category of woody plants decreases from seedlings and resprouting stems to the large-sized trees confirming the high potential to accelerate forest regeneration and regrowth but also to provide goods and services (Dounias 1996, Carrière 1999, Ngobo 2002).

Conclusion

The domestication of woody species within *Cucumersopsis* agroforests takes place under complex cognitive processes. These processes are articulated around the farmers' knowledge of market access, distance to market, available financial and natural resources, and the biophysical characteristics and uses of the available woody species. The decrease in the number of woody species kept, from seedlings and sprouting stems to large-sized trees, create the conditions for plant species to regenerate and regrow based on this standing ecological memory. The management practices and ecological knowledge of farmers to combine both crops and non-agricultural woody species within the cropping-fallow-forest conversion cycle are the motor of agricultural and forest productivity, ecological processes and patterns (species richness). Technical processes alone are not sufficiently adequate to properly enhance the domestication of woody species in research and intervention processes at the relevant scale in sustainable agroforestry systems. The complexity of cognitive processes taking place in the context of high biodiversity under which local management of agricultural biodiversity knowledge operates should be better understood.

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MATCHING RESOURCE USE NEEDS WITH RESOURCE STATUS AND POPULATION DYNAMICS OF TARGET SPECIES IN TRANSKEI COASTAL FORESTS TO SUSTAIN RESOURCE USE, PORT ST JOHNS FOREST ESTATE, SOUTH AFRICA

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Abstract

The demand for different forest products for subsistence and/or commercial purposes in the Port St Johns Forest Estate along the Wild Coast of the Eastern Cape Province, South Africa, impacts on the natural forest ecosystem, the conservation status of targeted species and the sustainable harvesting of particular tree and non-tree species, whether legal or illegal. A pilot study conducted in four forest/village complexes each within three Forest Management Units (FMUs) looked at resource use in one household and the adjacent forest per selected forest/village complex and a resource inventory in that forest. The household study showed two important results: i) the main species for the main uses of wood (house construction, fences and firewood) which included some introduced species eg *Eucalyptus* and *Pinus* species; ii) a change from the traditional homes built of poles, laths and mud with thatched roofs, to cement bricks with corrugated iron roofs with pine roof construction, and the use of eucalypt poles for fences. The forest resource use study showed: i) utilization in six forests declined; remained the same in three; but increased in the remaining three; ii) various tree and shrub species were cut to provide laths and poles for hut construction, fence poles or craftwork but the harvesting patterns for the various species differed considerably; iii) most cut stems showed signs of vegetative regrowth (coppicing) and mere cutting is unlikely to make them disappear from the forests but make them unavailable for a short while after excessive harvesting. The inventory along two transects per selected forest, running from edge to edge through the forest interior, showed that i) the importance of targeted tree species below and above 5 cm DBH varies widely among the three FMUs and for the two size categories; ii) the stem diameter distributions of the species in different forests indicate their resource status and population dynamics, which in general show they have a good number of stems <5 cm DBH, with a sharp decline in number of stems in the larger size categories; iii) the two main targeted species, *Millettia grandis* and *Ptaeroxylon obliquum*, showed a strong sprouting after being cut. Results from the study have a number of important implications for the management of the natural forest resource base of the Port St Johns Forest Estate.

Background

Demand for different forest products for subsistence and/or commercial purposes in the Port St Johns Forest Estate (PSJFE) may impact on the natural forest ecosystem, the conservation status of targeted species and the sustainable harvesting of particular tree and non-tree species, whether legal or illegal. The Forestry Department (DWAF) requested that a study be done to obtain baseline data on the use of selected tree and other plant species, the levels at which they are used, what they are used for, where these species grow, how abundant they are, and what the status of the population of those species are, to establish sustainable harvesting levels for such species.

The pilot study was designed in three phases: 1) general reconnaissance assessment; 2) qualitative/quantitative resource use assessment in and around selected forest/village complexes and species response to harvest practices; and 3) resource inventory to assess the condition of the selected forests and population status of targeted tree species used for various forest products. This paper presents information on resource use (phase 2) and on forest condition and resource status (phase 3), and recommends guidelines for implementing sustainable resource use.

Study area

The study was conducted in the PSJFE in the Eastern Cape Province of South Africa. Three coastal FMUs were selected for the study because of the high concentration of forests (Figure 1). The limited time frame confined this pilot study to 12 forests/forest complexes of a total of about 80 forests/forest complexes, i.e. 15% of the forests. Each forest within the boundaries of a FMU was numbered on a 1:60,000 map of the PSJFE (with orthophoto backdrop of the area). Four forests were randomly selected from each selected FMU for the study:

Mainly Pondoland Scarp Forests (Von Maltitz *et al.* 2003): Mount Sullivan/Mount Thesiger FMU: Mt Thesiger, Nyandu, Sonkwe, Tobolweni

Transkei Coastal Forests (Von Maltitz *et al.* 2003): Gxwaleni FMU: Ingcanda, Hombeni, Matywaba, Sihlili; Bulawu FMU: Gogogo, Isidudu, Pahlakazi, Vitini.

Figure 1: Location of the 12 selected forests (small circles) within each coastal FMU (large squares) in the Port St Johns Forest Estate (Map source: DWAF, Pretoria).

Methodology

Qualitative/quantitative resource use: Households and Forest

Time constraints allowed for one week per FMU group of forests and one day per selected forest (with associated settlement).

Resource use within household

One household from a village complex associated with a forest was visited during the morning (08:00-12:00) to assess products used from the forest. A household was defined as the area occupied by one family managed by the head of the family, consisting of the houses, the home garden and the livestock enclosures. The following data were recorded:
<u>Household</u>: Family name; Name of village/settlement; Number of houses of different size and type (traditional round huts and modern style houses); Electricity supply (yes/no); Size of household by sex and age, and education level; Kind of enclosures, and the circumference of each (home garden, cattle/goat pen, etc).
<u>For houses</u>: Length (circumference) and height of walls; Species used for poles in wall of pole-mud walls, laths to keep poles together, and structure of roof (poles, laths, string for attaching thatch), doors, door frames, windows, window frames; For houses with wall structure exposed: horizontal distance of exposure (maximum 5 m long) in old houses, or four

sections of 5 m length in newly built houses. Each individual pole in each section was recorded by height, diameter at base, and species.

For enclosures: Length of enclosure (circumference) and height of each type of enclosure; In four sections of 5 m length each: height, basal diameter and species of each pole, and means of keeping poles together (wire or fibre or laths); Frequency by which individual enclosures are replaced, by type of structure.

Other uses of wood (species, dimensions, parts, purpose, frequency): Firewood; Sledges; Kitchen utensils; Wood carving; etc.

Resource use from forest

Assessment of resource use from the nearby forest was done in the afternoon (12:00 – 16:30). Resource use was observed along a random walk through the forest, in the company of someone from the village. The following data were collected: Name of forest and point of entry into forest (with GPS); Species and size of trees and understorey plants harvested harvested, and for what purpose (if obvious, such as timber, laths, bark); Responses of species to harvesting impacts; Time since harvesting (very recent to long time ago); General condition of forest: old gaps, recent gaps, disturbance of understorey, regeneration of target species, invader plants, etc. Gaps were classified as either old or recent; Presence of livestock (cattle, goats, etc), based on the actual presence, or signs of footprints or faeces. The presence of gaps, invader plants and livestock was rated as 0 = None; 1 = Sporadic to rare; 2 = Intermediate; 3 = Abundant. Canopy condition was scored as 1 = Canopy intact; 2 = Scattered small gaps; 3 = Large gaps, many emergent trees and general canopy lowered; 4 = Tree layer removed; 5 = Forest cleared (e.g. for cultivation).

Resource inventory

Selected transects in each forest

For each selected forest a number of lines were drawn on an orthophoto of the forest (1:10,000 scale) to cover the main environmental (altitudinal) gradients. Each potentially accessible transect line was numbered, as for Isidudu forest (Figure 2) and two transects randomly selected. Each selected transect started outside the forest margin and was sampled through the forest, down the slope, through the valley to the open area outside the forest on the other end of the line (Figure 3). Observations indicated that at least some of the species regenerate on the forest margin and in forest gaps.

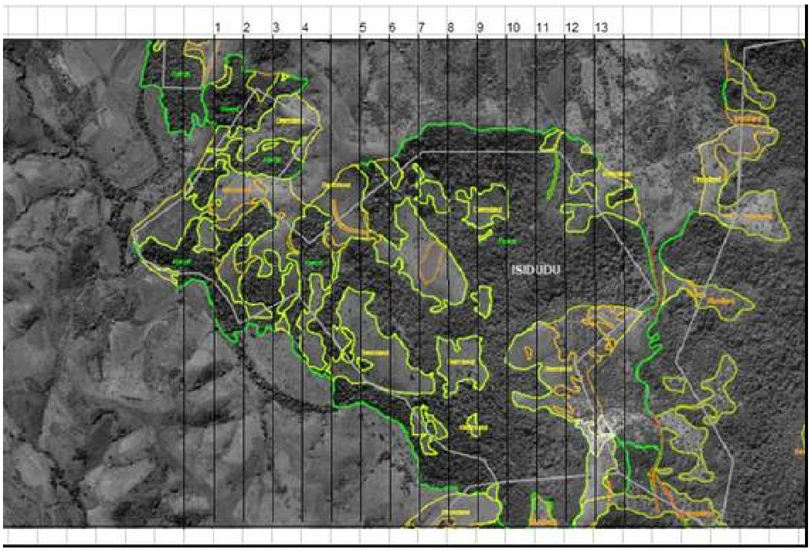

Figure 2: Potential transect lines marked on the map of Isidudu forest.

Sampling along a selected transect line

Circular plots of 11.3 m radius (400 m²) with sub-plots of 5.65 m radius (100 m²) were sampled along each transect line at points of homogenous stands (Figure 3). The site of tree regeneration on the forest margin was often too narrow to use a circular plot. In such cases a rectangular plot of the same area was used (Figure 3).

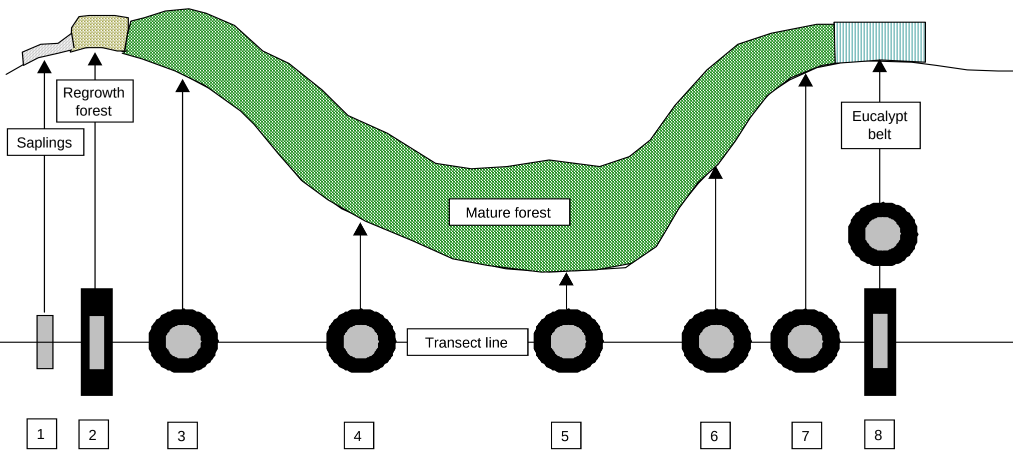

Figure 3: Profile of forest through a valley, indicating the placement of plots along the hypothetical transect line (Plot 1: sub-plot rectangle of 20 x 5 m for woody plants <5 cm DBH (no trees ≥5 cm DBH for main plot); Plot 2: rectangle of 40 m x 10 m for woody plants ≥5 cm DBH with sub-plot for woody plants <5 cm DBH; Plots 3 to 7: circular plots with main plot 11.3 m radius for trees ≥5 cm DBH, and sub-plot 5.65 m radius for woody plants <5 cm DBH; Plot 8: either rectangle or circular plot, depending on width of eucalypt belt.)

Recording of information on sample plots

<u>Site information</u>:

- Forest name, transect & plot number, aspect and slope;
- Grid reference, altitude, geology, geomorphology and substrate conditions;
- Forest canopy: height, smoothness, size and causes of gaps;
- Observed disturbances.

<u>Stand information</u>:

400 m^2 main plot: All stems ≥5 cm DBH by species and DBH (a harvested tree was indicated with an asterisk*). Each multiple stem ≥5 cm DBH on a tree was recorded by DBH and all stems 1.0-4.9 cm DBH by counts, with indication that they belong to the same tree.

- *100 m^2 sub-plot*: All stems 1.0-4.9 cm DBH by species and stem counts.

<u>Harvested trees</u> (recorded with stand information and noted with *):

- *Type of use*: Main stem cut; branch cut; bark removed; roots removed; etc;
- *Response*: Dead; sprouting on stem, at base or from roots; bark recovery: none, edge growth, sheet growth; etc;
- *Bark-harvested trees*: Estimated amount of bark harvested as %.

Calculation of importance values of species per FMU

Importance Value (IV) of a species, calculated for all forests sampled within FMU as (RF+RD+RBA)/3 for stems ≥5 cm DBH and (RF+RD)/2 for stems 1-5 cm DBH, where

RF = Relative frequency = number of plots (frequency) in which the species was present in a FMU, expressed as percentage of the sum of all frequencies of all species in the FMU;

RD = Relative density = number of stems of a species in a FMU, expressed as a percentage of all stems of all species in the FMU;

RBA = Relative basal area = total basal area (DBH expressed as horizontal stem surface area) of a species in a FMU, expressed as a percentage of total basal area of all stems of all species in the FMU.

Results and Discussion

Resource use by households

The study recorded a range of uses and the species used for each, including medicine, food, fibre and general utensils (see Cawe and Geldenhuys 2007 for details). This paper only covers wood use for construction of the houses and fences, and for firewood, i.e. by far the main use of forest resources.

Forty eight people lived as 4.4 persons per household (range 1 to 8), representing 24 males and 24 females of which 25 were children (14 males, 11 females) up to 18 years of age. Information on education level of people was not readily provided but 11 households had at least somebody, usually children, with some education (primary or secondary school education).

Household homes

The study showed important shifts in building style, away from the traditional thatched roof round pole-and-mud wall huts in all areas, which resulted in changes in resource use: 16 houses with thatched roofs, 21 with corrugated iron roofs; 19 round huts and 21 square houses; and 25 built with poles, laths and mud, and 15 with bricks. Only two households had no electricity (both close to the main road and Port St Johns). The traditional houses consume a lot of wood, including poles and laths for construction and firewood for cooking, warmth and social gatherings (Table 1). Wall dimensions were determined for 25 traditional pole-and-mud houses. Poles in the walls were counted in eight houses (hidden within mud in others). Horizontal laths used in the walls were counted in three houses. Poles in the roof construction were counted in eight houses. Laths used in the roof construction were counted in five houses. Lath dimensions were similar in both the roofs and walls. The number of laths was calculated based on the assumption of an overlap of 0.5 m in the laths.

Thirty species were used in house construction, with the main species (in order of importance; * indicate alien species):
Millettia grandis (12 study areas), *Ptaeroxylon obliquum* (11), **Eucalyptus* sp (7), **Cestrum laevigatum* (7) and scattered use of *Brachylaena discolor*, *Buxus macowanii* and *B. natalensis*, *Englerophytum natalense*, *Strychnos usambarensis*, **Pinus* sp, *Tricalysia capensis*, *Duvernoia adhatodioides*, *Combretum kraussi and Grewia occidentalis*.

Fences

Dimensions and pole use in home garden fences were determined at nine households with fences, and in cattle pen fences at four households (Table 1). Wire, laths and/or brush material were used to fill the spaces between poles. Twenty four species were used in fence construction. The main species are (in order of importance; * indicate alien species):
M. grandis, *P. obliquum*, **Eucalyptus* sp, *B. natalensis, T. capensis* and *D. adhatodioides*.

Firewood

Firewood pile dimensions were determined at five households (with two piles at one household; seven households had no firewood) (Table 1). Some households with no firewood collected up to two headloads per day. Twenty six species were used as firewood and the main species used are (in order of importance; * indicate alien species):
A. karroo and *Dalbergia* sp (both in 9 study areas), **C. laevigatum*, **Eucalyptus* sp, *B. natalensis, T. capensis*, *M. grandis*, *P. obliquum* and *D. adhatodioides*.

Table 1: Average wood use of 25 traditional round pole-and-mud wall huts with thatched roof in the Wild Coast area around Port St Johns

Usage	Dimensions	Poles	Laths
Walls	25 houses 20.8 m length (range 16 – 31 m) 2.1 m height (range 1.8 – 2.6 m)	8 houses 28.5 (1.4 poles/1 m wall length with range 0.8-2.3) with pole size 2.6 m x 6-8 cm	3 houses 720.7 (16.5 laths/1 m wall height (range 13.6 – 21.1) (1.5 m long (range 0.9 – 2.4 m) x 3.4 cm diameter (range 2.1 – 4.5 cm)
Roof	-	27.4 (1.3 poles/1 m wall length) 3.3 m long x 6 cm diameter	168.1 (4.9 laths/1 m pole length or 16.2 rows of laths) 1.5 m long (range 0.9 – 2.4 m) x 3.4 cm diameter (range 2.1 – 4.5 cm)
Garden fence	281 m (range 140 – 514 m) Area = 0.26 ha (range 0.12 – 0.80 ha)	213.6 (7.6 poles/10 m with range 5-10) 1.7 m long (range 1.3 – 2.4 m) x 8.1 cm diameter (range 3 – 13 cm)	-
Livestock fence	39.5 m	28.3 1.7 m long above ground (range 1.3 – 2.4 m) x 9.6 cm diameter (range 4 – 21 cm)	-
Firewood	2.7 m long (range 1.9 – 3.3 m) x 1.2 m wide (range 1.0 – 1.5 m) x 0.8 m high (range 0.5 – 1.4 m) = 3 m^3 (range 1.2 - 5.0 m^3 [latter pile included five headloads]) Ngogo forest: *Acacia karroo* pile of 2.7 m long, 1.7 m wide and 0.7 high = 3.2 m^3 Mbudu forest: four women each carried head load of 2.0 m long, 0.3 m wide and 0.3 m high = 4 x 0.2 m^3		

Resource use inside the forest

Stumps indicated the harvesting of various tree and shrub species, mainly to provide laths and poles for hut construction, fences or craftwork. A total of 56 species were harvested with a mean of 11.8 species (7-18 species) and 31.3 stems (17-47 stems) per forest. In Nyandu forest 47 stems of 18 species were cut. Other forests with large numbers of species harvested include Isidudu (44 stems of 16 species), Sihili (41 stems of 16 species) and Tobolweni (35 stems of 15 species). Sonkwe forest had only 17 stems of 7 species cut. *Millettia grandis* was the most intensively harvested species, accounting for 19.5% of all stems cut in the various forests. Twenty one species had 5 or more stems harvested, but the top six species are, with number of stems cut (intensity) in number of forests (frequency) between brackets: *M. grandis* (73, 12), *D. adhatodoides* (32, 4), *B. natalensis* (24, 6), *S. usambarensis* (21, 7), *Tricalysia lanceolata* (21, 6) and *P. obliquum* (21, 5).

The harvested stump diameter preferences for 11 most intensively harvested species, and a group of 15 other canopy species, differ considerably (Figure 4). In most cases (63.6% of species) stems of <20 cm stump diameter were cut but a much wider range of stem sizes of *M. grandis* and *P. obliquum* were cut. The larger cut stems reflect the size to which these two species can grow, and also the value of their poles used for craftwork (*M. grandis*) and as fence posts (*P. obliquum*). The modal diameter class was 20-30 cm for *M. grandis* and 5–10 cm for *P. obliquum*. The modal diameter class for *B. discolor* and *Cussonia sphaerocephala* was 20-30 cm but varies in the other species.

Response to cutting

The 11 most intensively utilized species coppiced to different degrees (numbers between brackets show number of stems found cut, and percentage of cut stems that coppiced, for the top species):
M. grandis (72 stems, 47.2%); *D. adhatodoides* (32 stems, 37.5%), *B. natalensis* (23 stems, 69%), *S. usambarensis* (21 stems, 95.3%), *T. lanceolata* (21 stems, 66.7%), *P. obliquum* (21 stems, 42.9%), *Teclea natalensis* (14 stems, 78.6%), *Acalypha glabrata* (15 stems, 73.3%) and *B. discolor* (13 stems, 69.2%). Three of the four most-harvested species (*M. grandis, D. adhatodoides* and *P. obliquum*) have a poor coppice rate (frequency of stems with coppices). However, they can coppice vigorously in gaps and open areas and mere cutting is unlikely to eliminate them from the forests.

Debarking

Twenty one species were debarked, mainly in Tobolweni (15 species), Nyandu (12 species) and Mbudu (11 species), but the main species are:
M. grandis (17 stems, 7 forests), *Apodytes dimidiata* (6 stems, 1 forest), *D. obovata* (6 stems, 4 forests), *Heywoodia lucens* (5 stems, 3 forests), *Margaritaria discoidea* (5 stems, 2 forests) and *Croton sylvaticus* (4 stems, 3 forests). The bark of most of these species is used medicinally, but the bark of *M. grandis* and *D. obovata* is used for fibre. *M. grandis* bark rope is often used to tie bundles of poles and laths taken from the forest.

History of resource harvesting

Assessments of recent and current use were combined into a single assessment (recent), using the higher score of the two. The difference in scores for recent and old forest use indicated whether resource use was increasing, constant or declining. In Sonkwe, Phahlakazi, Ingcanda, Tobolweni, Nyandu and Mt Thesiger use declined, in Mbudu, Isidudu and Matywabe it remained the same, but in Khunkula, Sihlili and Ngxongo it increased.

Most cut stumps were old except for *T. natalensis* and *B. discolor* (values between brackets indicate number of stems cut and percentage recently cut*)*:
M. grandis (74, 24.3%), *B. natalensis* (23, 39.1%), *T. lanceolata* (21, 38.1%), *P. obliquum* (21, 14.3%), *S. usambarensis* (21, 4.8%), *D. adhatodioides* (32, 0%), *A. glabrata* (15, 0%), *T. natalensis* (14, 57.1%), *B. discolor* (13, 53.8%), *C. sphaerocephala and E. natalense (both 10, 0%).*

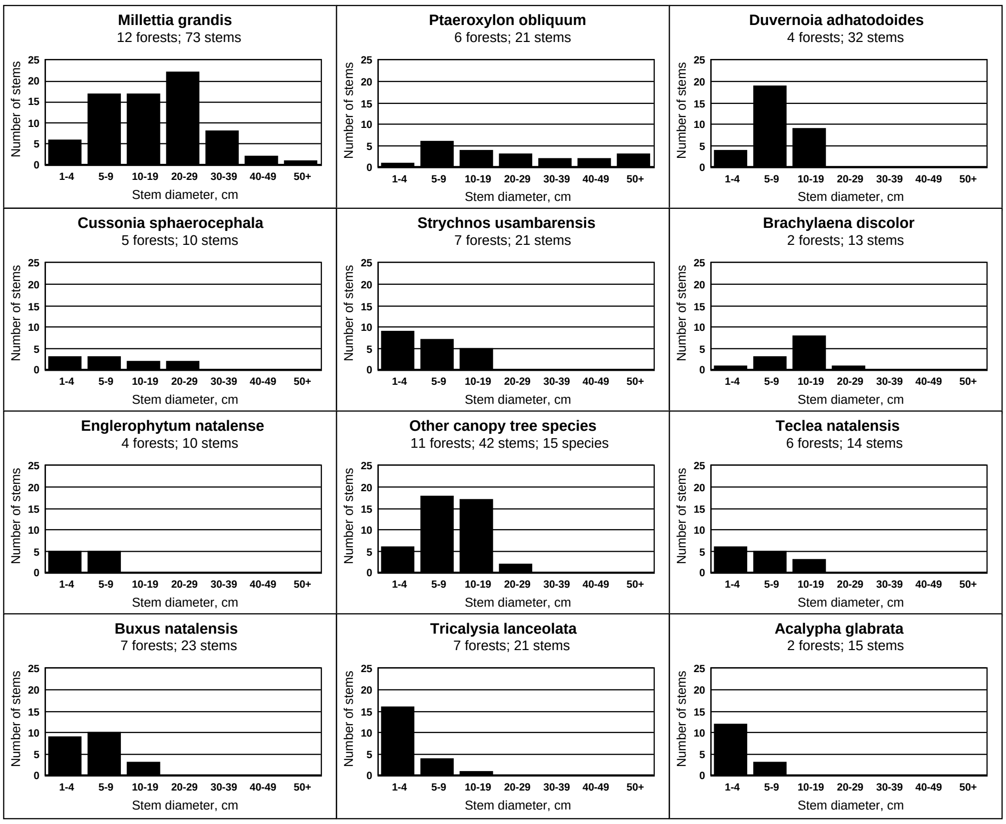

Figure 4: Stem diameter class distribution of the cut stems of the most intensively used species, and a group of 15 other canopy tree species. The y-axis scale is the same for all species for direct comparison of intensity of use.

Forest condition

Scores for old and recent gaps, canopy condition and invader plants were summed for each forest. A forest in the best condition scored 1 (no gaps or invader plants and canopy intact). A score ≥7 indicates serious problems and 14 would indicate an extremely poor forest condition. Mt Thesiger, Sonkwe, Nyandu and Tobolweni were in reasonably good condition (score <7), but the other forests were in poor condition; Ingcanda Forest being the worst. In general, forests had large gaps with many emergent trees and a generally lowered canopy (score of 3). Gaps, either recent or old, were fairly common (score of 2) or abundant except in Mbudu Forest where canopy lowering is probably recent. Invader plants are becoming common (a score of 2 in three forests), most likely because of the poor canopy condition.

Resource inventory

A total of 119 plots were sampled on 26 transects through the 12 selected forests. Eight plots in grassland or clearings along transects were not sampled. The complete results are contained in Cawe and Geldenhuys (2007).

The Importance Value (IV) of a species was calculated per FMU group of forests but is shown here for selected species calculated over all sampled forests in the PSJFE (Table 2). For example, the regeneration (dbh <5 cm) and trees (dbh >5 cm) of *M. grandis*, the most important tree species, is much better in the drier Bulawu and Gxwaleni forests than in the moister Mt Thesiger forests. *P. obliquum* regenerates best in Gxwaleni forests but poorly in the other forests. *Brachylaena discolor* regenerates very poorly in Bulawu and Gxwaleni forests and poorly in Mt Thesiger forests, but is basically a light-demanding species. The growing stock for stems ≥5 cm DBH in the different forests shows an overall 1079.1 stems/ha (range 770-1606 stems/ha in Bulawu forests, 930-1315 stems/ha in Gxwaleni forests, and 1068-1220 stems/ha in Mt Thesiger forests) and overall basal area is a relatively low 23.67 m^2/ha (range 14-25 m^2/ha in Bulawu forests, 12-24 m^2/ha in Gxwaleni forests, and 18-43 m^2/ha in moister Mt Thesiger forests) (Table 2). Stem density of species in different stem diameter categories provide insights into the population dynamics and resource status of a species (Table 2). In general there is a good density of stems <5 cm DBH but a sharp decline in the larger tree sizes.

An analysis of the stems per ha in each sampled plot along a transect through a forest, in the stem diameter categories of <5; 5-9.9; 10-19.9; 20+ cm DBH, showed under what conditions a species regenerates, grows taller and matures (not shown here, but see example for *M. grandis* in Figure 5 for one area, and Cawe and Geldenhuys 2007 for the different species). *M. grandis* occurs in all sampled forests (Table 2), but is more abundant in Bulawu and Gxwaleni forests. Regeneration (stems <5 cm DBH) is abundant on the forest edge, and in old forest gaps, but absent or with a few stems in closed canopy forest. Only few trees >10 cm DBH occur in closed forest. There is abundant regeneration and this needs to be managed to provide in the resource use needs. *B. discolor* occurs scattered as small trees (5-9.9 cm DBH) or intermediate trees (10-19.9 cm DBH) and occasional larger trees (>20 cm DBH) (not shown in Table 2). Regeneration is generally almost absent, but relatively abundant in Sonkwe forest. Trees are more abundant in the Mt Thesiger area, and rare in Bulawu and Gxwaleni forests. Sustainable use for poles of this species needs attention. *C. kraussii* occurs scattered in Bulawu and Gxwaleni forests, with more abundant regeneration and small trees in parts of Mt Thesiger forests. Patches of regeneration occurred outside sampled plots along the forest margins and larger forest gaps in some areas. The ability of the cut stump to resprout vigorously offers the potential to use this species better for laths and small poles. *D. adhatodioides* occurs relatively infrequent with occasional good regeneration in Bulawu forests, and parts of Mt Thesiger and Gxwaleni forests, with abundant regeneration along the forest margin in places. Sustainable use needs attention in view of its relatively abundant resource use. *P. obliquum* has a poor presence in the forests in relation to its abundant pole use. Abundant regeneration in the proximity of larger trees was observed outside the forest margin, in forest gaps, in parts of degraded forests, and even under eucalypt belts along the forest margin. Vigorous sprouting of many cut stumps in the open presents a management option. Sustainable resource use of this species needs urgent attention.

Table 2: Importance value and mean stem density per ha over all sampled forests of selected species (with ≥10 stems/ha for either category <5 cm or >5 cm DBH).

Species	Importance Value by DBH classes over all forests		Mean stems/ha by tree diameter (cm)				Stems 5+ cm DBH in different forests			
			Regene-ration	Small trees	Medium trees	Large trees	Mean	Min	Max	Number of forests
	<5 cm	≥5 cm	<5	5-9	10-29	30+				
Millettia grandis	24.38	24.89	194.6	32.9	40.8	5.0	78.6	12.5	412.5	12
Englerophytum natalense	22.17	19.25	224.3	50.0	24.3	0.9	75.2	2.8	212.5	9
Philenoptera sutherlandii	10.26	17.73	75.7	18.9	25.5	12.6	57.0	2.5	177.5	6
Dalbergia obovata	6.20	22.70	20.7	39.9	9.7	-	49.5	10.0	127.5	12
Tricalysia lanceolata	17.25	11.80	281.1	43.5	5.2	0.2	48.9	10.0	362.5	8
Teclea natalensis	18.47	19.73	82.0	28.4	18.0	1.1	47.5	2.5	130.0	12
Duvernoia adhatodoides	11.62	13.71	103.6	32.7	13.5	-	46.2	2.5	120.0	10
Cussonia sphaerocephala	3.74	20.33	8.1	17.1	18.0	1.8	36.9	12.5	115.0	11
Chaetachme aristata	9.84	13.90	50.5	23.0	9.7	0.5	33.1	10.0	97.5	12
Strychnos usambarensis	11.82	11.21	61.3	13.1	13.1	1.6	27.7	2.5	80.0	9
Tricalysia capensis	14.36	9.57	160.4	20.7	6.8	-	27.5	2.5	110.0	7
Drypetes gerrardii	12.11	13.78	51.4	11.7	9.2	3.8	24.8	2.5	65.0	10
Heywoodia lucens	2.81	9.65	6.3	4.1	9.2	8.3	21.6	5.0	100.0	6
Combretum kraussii	5.30	7.23	20.7	12.8	7.4	1.1	21.4	2.5	112.5	9
Strychnos henningsii	7.62	12.56	25.2	7.0	9.9	1.4	18.2	2.5	35.0	12
Dalbergia armata	4.06	7.80	27.9	12.2	3.2		15.3	2.5	91.7	10
Buxus natalensis	38.16	8.19	647.7	10.4	0.2		10.6	2.5	52.5	11
Ptaeroxylon obliquum	8.96	5.21	106.3	7.7	1.1	0.2	9.0	2.5	75.0	5
**Cestrum laevigatum*	5.84	8.34	40.5	7.4	1.1	0.2	8.8	25.0	45.0	3
Mean stems (all forests, all species)			3030.6	630.6	363.7	63.1	1057.4			
Maximum stems			4810.0	957.5	502.5	117.5	1315.0			
Minimum stems			1870.0	442.5	212.5	20.0	770.0			
Mean basal area m^2/ha (all forests, all species)			-	2.45	7.89	13.00	23.34			
Maximum basal area			-	3.46	11.43	30.56	42.55			
Minimum basal area			-	1.74	4.61	3.17	12.08			
Total species involved			109	116	95	48	125			

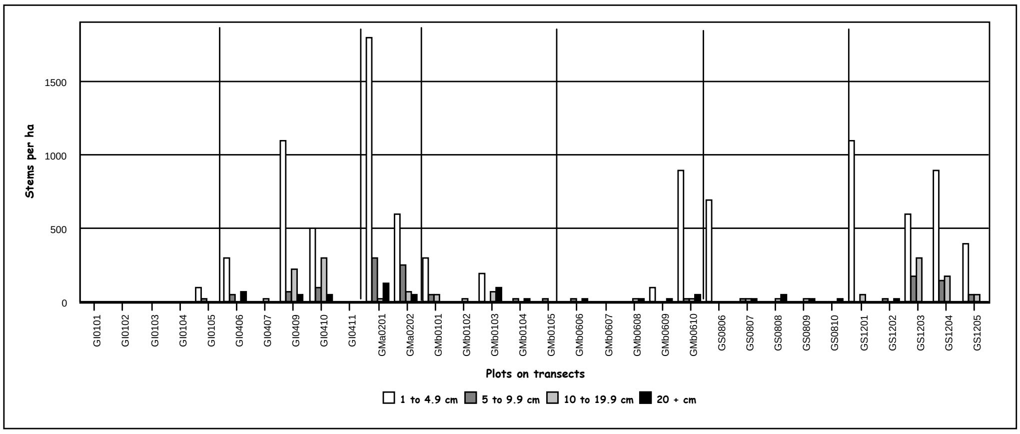

Figure 5: Population status of *Millettia grandis* in plots along transects through different Gxwaleni forests. Each transect is separated by vertical dotted lines.

Ninety eight (71.5%) of the 137 woody species recorded in the survey were multi-stemmed; a capacity important for the continued survival of these species when harvested. More detailed observations of the sprouting behaviour of *P. obliquum and M. grandis* in severely degraded forests and on the forest margin showed that cut small trees developed several to many sprouts on the cut stem. This response suggests a possible way to manage the stumps during the harvesting of poles and laths to ensure the survival of the species under intense use for poles.

Discussion

This pilot study, with severe time and financial constraints, provided useful baseline data for developing sustainable harvesting practices for the target species, but the information is not suitable to determine sustainable harvesting levels, for which growth or production rates would be needed.

The household study showed the many species people harvest for poles and laths for construction, for fencing and for fuel wood, in what dimensions, but that a smaller number of species (including alien invader plant species) are intensively used. The forest walk provided particularly useful insights on how the species are harvested for different products and how they respond to the different practices. The design of the brief forest inventory provided for most of the species their distribution in different forests, population structure (abundance or density, stem diameter distribution) and regeneration status (density and frequency of seedlings, saplings and small poles). This provided essential information on the population dynamics of species that are necessary to implement sustainable resource use. A study of more forests will either confirm the patterns observed during this study or add other perspectives on resource use variation or a better understanding of the characteristics and dynamics of the targeted species. The household study had severe time constraints and in future at least three households per village should be assessed to verify the observed trends from this study. Two forest walks are needed per forest, based on zonation of the forest by distance from a village (close by and further away).

The household study indicated important changes in resource use, which should form part of future development planning in the area and actions towards sustainable resource (creating alternative resources). Alternative house construction material are being used, such as corrugated iron roofs, the use of mud or cement bricks, the use of alien tree species (pines and eucalypts) in the roof construction and in the walls, and in fences (after chemical treatment against rot), and smaller less durable material from *C. laevigatum* as poles, laths and even firewood (good to start a fire). Contrary to expectation, corrugated iron roofs and cement bricks in modern square houses were found in most households in all FMUs and not only near main roads and the town. Most households have electricity but they still use wood as a source of energy. Several households do not have livestock pens. The plantations of alien tree species in the area, substituting much of the timber and small poles that would otherwise be obtained from the natural forests, play a crucial role in the conservation of many of the natural forests.

The forests vary in their composition of the most important species, and in forest condition, but the variation could be ascribed to the physical substrate, location within the landscape, various degrees of resource use (historical and current), and status of recovery. Many forests are in poor condition with many large gaps and presence of invasive alien species (some are useful substitute resources), particularly those that experienced clearing for a short period during the early 1990's. The declining harvesting of woody species for poles and laths for building traditional huts, which require much wood, towards more modern brick buildings with corrugated iron roofs, will facilitate forest recovery.

For some species the intact forest provides a better habitat. But particularly the intensively used species, such as *M. grandis* and *P. obliquum*, requires more open conditions for good regeneration. In general, the stem diameter distributions (population status) of most species show a good balance between abundant regeneration and small stems with some more mature stems (sometimes the levels are relatively low). Such information, together with the information on species response to harvesting practices (sprouting and multi-stemmedness), provide a useful guide to develop sustainable resource management strategies for maintaining the forest distribution, structure and overall species composition but also the population dynamics and regeneration status of the species targeted for use.

Most species targeted for resource use show some degree of multi-stemmedness. All species used for their wood coppice when cut, but the rate of coppicing varies among species. Development of silvicultural management for such species would require that we know why some cut stems of a species sprout and others not. Is it related to size of a stem, season of cutting or height level of cutting? Over-harvesting may cause unavailability of such a species for use until they reach again a suitable size to be harvested. *M. grandis* is the most intensively utilized species for poles, fibre and crafts. *P. obliquum* is highly favoured for construction and poles due to its resistance to decay. Both species regrow vigorously through coppices. Coppice management is a tool to sustain the harvesting of laths and poles without threatening the survival of such species, and could be developed through participatory forest management with the local resource users. For example, resource users could be guided on selective cutting of small stems of stumps with several coppice shoots, to initially provide laths, and later small poles, but eventually trees.

Recommendations

Results from the study and the discussions above have a number of important implications for the management of the natural forest resource base of the Port St Johns Forest Estate. These include:

- Better management of forest resource use (other than policing of illegal resource use), as part of better resource management.
- Integrated management between natural forest resource use, plantation management, agricultural development, and provision of services that impact on daily livelihoods (housing, electricity, etc). For example, the changes in house construction can lead to forest recovery from former intensive use and degradation.
- Indiscriminate clearing of alien invader plants, particularly those that have good local use, will have serious implications for the forests. Such species do provide alternative resources and contribute to forest recovery (nursing establishment of more shade-tolerant natural forest species).
- Specific attempts need to be implemented, through participatory forest management, to encourage the management (stand manipulation, coppice management or other approaches) of the good regenerating stands of target species, particularly along the forest margin and in forest clearings. The abundance of natural regeneration makes it unnecessary to plant these species.

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Multiple resource use for diverse needs:

THE IMPACT OF POLICY ON RESOURCE USE IN MOZAMBIQUE: A CASE STUDY OF PINDANGANGA

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Abstract

The impact of alternative forest management regimes and sectorial and extra-sectorial policies on the well-being of stakeholders and on woodland conservation was studied in miombo woodlands in Pindanganga, central Mozambique. A dynamic model MIOMBOSIM, based on game theory, was developed. The analysis was based on a simulation model of human population and forest dynamics, costs of private sector, household consumption, commercial outputs and input prices (timber, charcoal, non-timber forest products or NTFPs, and domestic animals), using data from field surveys and the literature. The effects over time of changes in agricultural and NTFP prices were simulated. The modelling approach allowed for evaluation of management regimes, taking into account often conflicting stakeholder interests. This study showed that improving stakeholder well-being and resource conservation can be achieved with sound forest management practices. The cooperative management option (community based natural resource management) is potentially beneficial to local communities if properly implemented and can improve the condition of rural livelihoods and the woodland resource. Regulated forest management regimes, incorporating social concerns or incorporating social and environmental concerns, are potentially more beneficial to the household sector than the open access regime. An increase in sales by 100% or a 25% increase in market prices of NTFPs can lead to an increase in the per capita benefits of the household sector. An increase in agricultural product prices by 25%, without any other incentive structure in place, can lead to agricultural expansion at the study site. A combination of these two policy instruments under *ceteris paribus* conditions can improve the well-being of the rural communities depending on the management regime in place, but this increase is not enough to lift the household benefits above the poverty line of US$1 per person per day. The economic and conservation performances of the management regimes can change depending on the policy instrument applied.

Introduction

In the last years of the 20th century there was a clear move away from centralised and state-driven forest and woodland management towards decentralised and mainly community-based regimes in the southern Africa region (Matose and Wily 1996). In the course of this shift, the social formation of the community as well as the institutions and mechanisms which support its functioning as a management entity, are being defined in new and significant ways. Southern African countries have some historical similarities in their regimes of management of natural resources. During the colonial and post-independence eras, control of natural resources was centralised under the national government. In the 1980s a new approach of decentralisation and involvement of other stakeholders rapidly emerged and most countries of the southern African region embarked upon and adopted a new philosophy of natural resource management approach called Community-Based Natural Resource Management (CBNRM). The new approach attempts to share the social and political power over natural resources more broadly, combining conservation and development and reflecting a wider process of socio-political and economic change than had previously occurred in those countries in the past (Wainwright and Wehrmeyer 1998, Hulme and Murphree 2001).

The Mozambican government has been effecting institutional changes over the past two decades in the search for adequate policies and strategies for the management of its natural resources. In 1997 the government approved a new Land Policy, followed by Environment Law (1997). National Forestry and Wildlife Policy (1999) and the Decree Law of Administrative Decentralisation (Decree Law No. 15/2000) to guide the management of the natural resources (Nhantumbo *et al.* 2001, Wily and Mbaya 2001). The new Mozambican National Forestry and Wildlife Law (1999) empowers local communities to own and participate in the management of natural resources through CBNRM initiatives. It establishes a process of participatory management of resources in which a management council (conselho de gestão) is created that includes members of the community, local government, private operators and other associations (Article 31, no. 1). To date the State intended to manage the natural resources as joint ventures with the private sector and the local communities. The National Environmental Law does not explicitly recognise the contribution of local communities towards the management of natural resources, but serves as a basis for designing regulations intended to minimise negative environmental impacts resulting from development activities and/or irrational use of natural resources (Nhantumbo *et al.* 2001).

The first CBNRM project in Mozambique was launched in 1994 in the community of Bawa, in Tete Province, located on the border with Zimbabwe and was known as 'Tchuma-Tchato' (Wily and Mbaya 2001). The relative success of this programme encouraged the rapid spread of new projects over the country. For example, four years after the establishment of the Tchuma-Tchato project, about 40 projects were being implemented in Mozambique by different government institutions and local and international NGOs through the financial support of international donors (Anstey 2001).

The general objective of this study was to assess the socio-economic and environmental impacts of the use of miombo woodland resources and to identify the most appropriate management regime in a way that satisfied the achievement of the goals of the stakeholders in Pindanganga. This study had the following specific objectives: (i) Improve the game theory model developed by Sumaila *et al.* (2003) that integrates the major uses of miombo woodlands, their interaction and dynamics; (ii) identify the most appropriate management regime and evaluate its socio- economic and environmental impacts; and (iii) test different policy instruments to improve the understanding of the interaction between stakeholders and the influence of different factors in management regimes.

This study was motivated by the fact that the game theory model developed by Sumaila *et al.* (2003) did not take into consideration the following: household benefits, non-timber forest products (NTFPs), human population dynamics, the allowable cut established in the management plans, the effects of transaction costs on the cooperative management regime, charcoal production efficiency variation, greater off-miombo employment opportunities or tree diameter class segregation. To date, it is unknown what the socio-economic and environmental impacts would be if these aspects were taken into consideration, or what would happen if either new agricultural incentives were put in place or the commercial sales or prices of NTFPs were increased.

Materials and Methods

Study area

Pindanganga is located in Gondola District in central Mozambique, which is one of the major suppliers of timber, construction material (poles and thatching grass) and charcoal within Manica Province to the provincial capital, Chimoio city. It is relatively rich in both forest and wildlife natural resources. The forest area covers 36,512 ha of miombo woodland at a stocking rate of 37 m^3/ha, under a community-based forest management programme. The climate in the study area is cool and wet, with a mean annual temperature of 21.5 ^{0}C. The mean maximum temperature is 26.6 ^{0}C and the mean minimum is 16 ^{0}C. The cooler months are May-August and the hotter months are September-April. The mean annual precipitation is about 1,080 mm, concentrated in January and February, with a dry season during May-September (MINED 1986).

The rural communities in Pindanganga lived under civil war from 1980 to 1994. As a result, unforeseen large population concentrations developed around most of the large settlements, within relatively safe corridors. High levels of damage of the woodland cover took place because of harvesting of wood for fuel, timber, building materials and through clearing for agriculture. However, since 1994 the communities have returned to a more normal lifestyle. The typical mean farm size of a household is 3.5 ha and mean family size is six persons. The human population at the study site is 2,331 inhabitants (INE 2001).

The dynamic game theory model

In the conceptual model two groups of stakeholders are identified: the private/commercial sector and the local community/household sector, both of whom are assumed to be under the control of a regulator (the governance). Power of governance can be located at the central/local/village level or with any other authority. It is assumed to have as objective the maximisation of society benefits, which include direct economic benefits, social benefits and environmental protection from the use of miombo resources on a sustainable basis. Community interests in miombo woodlands are assumed to be the benefits that it can derive from wood and NTFPs harvested for consumption and sale. Private sector interests are motivated by the profit derived from logging activities. A summary of the three different versions of the model is presented below, based on some assumptions on the relationship between the user groups and the regulator. Decision-making by the household and commercial sectors about the use of miombo woodlands is defined in the theoretical games. It is assumed that a fixed area (N_t) is available to the communities, of which N_a is under agricultural cultivation and N_m is forested miombo woodlands.

The decision process in the commercial sector involves a determination of the amount of timber to harvest annually (H_c) from Nt ha of miombo resources available to maximize the annual net benefits. The household sector is interested in maximising utility of time (maximising benefits). Firstly, it decides on the amount of forest area available to be converted into agriculture, in order to maximise utility over time. Secondly, it decides how much of the miombo area is going to be cleared for agriculture (H_a) and how much is available for harvesting wood products (H_m) and NTFPs (thatching grass and honey). Lastly, it decides how much of the remaining standing miombo area will be allocated to pole harvesting (H_{po}) and charcoal making (H_{ch}).

Three principal game theory models were applied to study the use of miombo woodland resources, namely a command model, a cooperative model (joint management) and a non-cooperative model (separate management). Each type is briefly presented below.

Command model

This model assumes that the regulator (e.g. a central or local government) can dictate the behaviour of the two sectors directly (decisions are centralised) through the allowable cut of sites, established in the management plans. The society-wide net benefits are maximised through the choice of the amount of labour to be used by the commercial and the household sectors in each year over the time horizon of the analysis. The amount of labour employed defines the volume of wood products to be harvested by each sector. The volume of forest products defined in the management plans is the decision variable that the government uses in managing these resources.

The maximisation of the total equivalent annual net discounted benefits (B_t) is represented in equation 1 and it is subject to the usual ecological, household constrains (equations 2 and 4) and non-negativity.

$$\underbrace{Max}_{L_h, L_c} \sum_{t=1}^{T} [B_t] \rho_{t-1} D \qquad (1)$$

In the above equation:

$$B_t = \left[B_c\left(H_{a,t}\right) + B_h\left(H_{a,t}\right) + B_s\left(\theta_c H_{a,t}, \theta_h H_{a,t}\right) - \theta B_e\left(H^c_{a,t}, H^h_{a,t}\right)\right]$$

$$\rho_{t-1} = \frac{1}{(1+r)^{t-1}}, \rho_0 = 1, t = 1,...,T.$$

$$D = \frac{r(1+r)^t}{(1+r)^t - 1}$$

where

ρ = discount factor

r = discount rate

D = factor to convert the net present value of the benefits to an annual value over the harvesting period.

Depending on the values assigned to parameters θc, θh and θ, different scenarios of the command model can be investigated. Three scenarios were considered, namely the scenario in which the regulator is directly concerned with profits, social and environmental benefits but favouring the household sector (θ_c=0, θ_h=1, and θ=1); the scenario in which both profits and environmental benefits are considered (θ_c=0, θ_h=0, and θ=1); and the scenario in which both profits and social benefits favouring the household sector are considered (θ_c=0, θ_h=1, and θ=0).

The maximisation of benefits denoted by equation (1) is subject to the usual ecological constraints (equations 2 and 3), household constraints (equation 4) and non-negativity. The stock dynamics of miombo woodland are represented by equation (2), where the volume of study miombo per diameter class in this period ($N_{a,t}$) is determined by the volume in the previous class (N_{a-1}, t-1); the survival rate(s) is assumed to be constant for all diameter classes; the volume in a given year (regeneration); and the amount of woodland resources used in this period by the commercial and household users respectively. N_{a-0} is the initial standing volume of miombo at the start of the game, and E represents the Mean Annual Increment (MAI) of miombo to maintain the allowable cut. Equation (3) describes the growth per diameter class over time of the miombo. The parameters ε, Φ and γ are ecological, they can be used to vary the quality of the miombo stand (Frost 1996).

$$
\begin{aligned}
&N_{1,t} \leq R_t \\
&N_{2,t} \leq sN_{1,(t-1)} + N_{1,(t-1)} - H^h_{1,(t-1)} \\
&N_{3,t} \leq sN_{2,(t-1)} + N_{2,(t-1)} - H^c_{2,(t-1)} - H^h_{2,(t-1)} \\
&N_{4,t} \leq sN_{3,(t-1)} + N_{3,(t-1)} - H^c_{3,t-1} \\
&N_{4,t} = E, \forall_t \geq 1; N_{a,0} \text{ given.} \qquad (2)
\end{aligned}
$$

where

R_t = any natural regeneration that takes place;

$N_{a,t}$ = volume in a class diameter *a* in a given year *t* (m^3).

$$g_{a,t} = \frac{\varepsilon}{1+\phi\gamma^t} \qquad (3.)$$

From now on the subscripts *a* (a = 1,.., A) and *t* (t = 1,.., T) will be used to represent tree diameter classes and harvesting periods (cutting cycle) respectively. Note that A and T denote the last diameter class and last harvesting period respectively. The subscripts *c* and *h* are used to represent private/commercial and household sectors respectively. The harvesting activities for the household sector are taking place in the second and third diameter classes while for the commercial sector they are taking place on the third and fourth diameter classes.

$$L_h = L_m - L_a - L_n - L_{off} \qquad (4)$$

Where L_h is equal to total labour available by the household; L_a = labour required to cultivate land currently under agriculture; L_n = labour required for converting land to agriculture; and L_{off} is required labour for off-farm/off-miombo activities.

Cooperative model

Under the cooperative model (participatory management of the natural forest resources) it is assumed that the two users (household and commercial sector) have incentives to cooperate through joint maximisation of their benefits, which are expressed as equivalent annual income (EAI) as shown below. This relationship is subject to the usual ecological and household constraints (equations 2 and 4 described earlier) and non-negativity.

$$\underbrace{Max}_{L_h, L_c} \sum_{t=1}^{T} \left\{ \left[\alpha\rho_{h,t-1} B^h_{a,t} + (1-\alpha)\rho_{e,t-1} B^c_{a,t} \right] - T_c \right\} D \;, 0 \leq \alpha \leq 1 \;, \qquad (5)$$

T_c is the transaction cost of management of miombo woodland in a participatory way. The value assigned to the parameter α reflects the relative weight given to each sector under cooperative management. In this research the parameter α was assigned the value 0.5

according to Mlay *et al.* (2003). This usually depends on the bargaining power of the user (Munro 1979).

According to Mlay *et al.* (2003), the decision of the householder and commercial sector to jointly manage miombo woodlands will depend on the additional net benefits gained relative to net benefits forgone by not cooperating. The relative weight assigned to each sector in the cooperative management regime is reflected by the preference parameter whose value varies from 0 (giving all weight to the household sector) to 1 (giving all weight to the commercial sector). Taking into account that the harvesting practice of the commercial sector is selective while the harvesting practice of the household sector is non-selective, if the intangible benefits through cooperation are taken into account, incentive for cooperation by the commercial sector under lower values of the preference parameter is feasible and thus a cooperation management regime giving equal weights to the two sectors (0.5) will be used as reasonable to reflect the level of cooperation.

Non-cooperative model

In the non-cooperative model each of the different user groups or stakeholders (commercial sector and household) is assumed to harvest independently without taking into account the interest of other stakeholders. This model will be used to mimic an open access management regime, currently the dominant management regime under which miombo woodlands are being used in Mozambique (DNFFB 2003). The constrained maximisation problem for the household sector is presented in equation 6:

$$\underbrace{Max}_{Lh}\sum_{a=2}^{3}\sum_{t=1}^{T}(\rho_{c,t-1}B_{a,t}^{h})D \qquad (6)$$

This relationship is subject to the usual ecological and household constraints (equations 2 and 4 described earlier) and non-negativity.

Similarly, the non-cooperative management problem facing the commercial sector can be stated as follows:

$$\underbrace{Max}_{L_h,L_c}\sum_{a=3}^{4}\sum_{t=1}^{T}(\rho_{c,t-1}B_{a,t}^{c})D \qquad (7)$$

This equation is subject to the ecological and household constraints (equations 2 and 4 described earlier) and non-negativity.

In the non-cooperative model, in addition to all the θs being zero, the first term in the stock adjustment equation is set equal to zero.

The three models can be solved by introducing modified Lagrange multipliers and applying non-smooth convex optimisation (Flåm 1993). Simulation of the models is based on the numerical approach applied in Sumaila (1995, 1997) using the systems dynamic simulation package known as Powersim, developed by ModellData AS in Bergen, Norway .

In the three models, rural households are assumed to harvest wood products for energy (firewood and charcoal), building poles, thatching grass and honey. Firewood is harvested by the households mainly for their own consumption, while charcoal is harvested for commercial purposes. The number of charcoal bags (H_{bg}) produced from harvested miombo depends on the average timber density of miombo trees (equal to 858 kg/m^3 according to Bunster 1995), the charcoal production efficiency; and the average mass of a charcoal bag (m). Timber density for each tree species is indicated in Appendix A. This functional relationship is expressed in equation (8). The gross income from miombo activities is expressed in equation (9).

$$H_{bg} = \frac{H\partial\theta}{m} \qquad (8)$$

$$I_{h,t}^{m} = P_p\left(\sum_{a=2}^{3} H_{a,t}^{poles}\right) + \sum_{a=2}^{3} H_{a,t}^{ch} P_{ch}\left(\frac{\theta_1 - \theta}{\theta}\right) \qquad (9)$$

Where

P_p = Average roadside market price of poles (US$/m^3)

a = Tree diameter class.

H_a^{poles} = Total volume of poles harvested at diameter classes two and three in a year (m^3)

P_{ch} = Mean roadside market price of a charcoal bag (US$/bag)

θ_1 = New charcoal production efficiency (%)

∂ = Mean timber density of miombo trees

The allocation of the total volume of harvested wood between poles ($H_{po(a,t)}$) and energy ($H_{ch(a,t)}$) depends on the relative market prices of poles and charcoal as well as diameter classes. It is given by equations (10) and (11) respectively. The market demand for poles is lower than for charcoal, although pole prices are higher and take into account the effect of relative prices. The amount of poles harvested is constrained to the maximum average amount of poles sold in the past years (500 m^3 per year) in order to constrain the optimal amount of poles allocated by the model. The amount of charcoal produced annually is restricted by the mean Annual Allowable Cut (MAAC) established by the management plans. This figure was established after asking the interviewed householders and forest technicians about the harvest levels of poles.

$$H_t^{poles} = \frac{P_p \sum_{a=2}^{3} H_{(a,m)}}{\left(P_p + P_{ch}\right)} \leq 500 \qquad (10)$$

$$H_t^{charcoal} = \frac{P_p \sum_{a=2}^{3} H_{(a,m)}}{\left(P_p + P_{ch}\right)} \leq MAAC \qquad (11)$$

The amount of miombo harvested is a function of the volume of standing miombo ($N_{(a,t)}$) per timber class (a = 2 and 3) and labour allocated for this activity (L_m). A Cobb-Douglass function used by Sumaila *et al.* (2003) was adjusted to include diameter segregation and is expressed in equation (12).

$$H_{h,t}^{m} = \sum_{a=2}^{3} q_h \left(1 + i_h\right)^{t-1} N_{a,t}^{\mu} L_m^{\psi} \qquad (12)$$

Where

q_h = household relative harvesting capacity parameter for removing miombo is assumed to be constant for all diameter classes;

i_h = average growth rate of rural population (human population dynamics);

μ, and ψ are partial elasticities of production (they vary between zero and one). Each is assumed to be 0.5 in the model (Mlay *et al.* 2003).

The amount of miombo harvested is limited to a maximum allowable cut established in the management plans of the study sites, which was calculated based on the Mean Annual Increment (MAI) of miombo forest at the study sites.

Model data requirements and data collection

All coefficients used for the model were derived from the survey results. Data on population, area under forest cover, miombo employment and growth, commercial harvesting costs and discount factors were obtained from secondary sources. The human population growth in the study sites during the first 20 years of the simulation period is equal to 1.2%; for the next 10 years is equal to 1.5% and for the last 10 years is equal to 1.0% (INE 2001)

Field work

The study site was selected to capture the following features: presence of miombo woodlands; the degree of access to transport and markets; presence of commercial logging; and presence of activities of exploration of forest products (wood and NTFPs) for sale by households. The target population was defined as households who use miombo woodlands for agriculture and/or for extraction of wood and NTFPs for household consumption and sale. In this study the sample unit was a household. For data collection, the sampling method involved a random selection of households from listings prepared by village leaders in accordance with the definition of the target population. According to FAO (1990), if the total number of households is larger than 1000, the minimum sample should be 50 households. The total sample size for the study is 54 households. They were selected from villages or zones in Pindanganga, out of 1,858 listed households. Since conditions were considered to be more or less uniform, inter-village variation was assumed minimal and hence there was no need for stratified or multi-stage sampling.

To accomplish this research a combination of methods was used to generate the required information. The data were collected from both primary and secondary sources. A structured questionnaire, checklists for formal interviews and informal discussions and participant observations were the methods used to gather information from primary sources. The questionnaire was used to collect data from sampled households in face-to-face interviews. It investigated aspects of household consumption of wood products and NTFPs, activities, labour distribution by sex and age, management of miombo trees, and selling activities. The checklists were used for focused discussion with key stakeholders including relevant district officers and village government leaders and local foresters. The survey was carried out during September to November in 2002 and 2003, a period of 12 weeks in each year.

The data related to crop yields and wood and NTFPs prices were collected at the Provincial and District Directorate of Agriculture and Fisheries. An appraisal in various urban markets and at rural roadsides gave the latest market prices of construction material (poles, bamboo and grass), fuel wood (charcoal and firewood), logs and honey coming from the study areas. The farmers surveyed did not collect the information about their own crop yields because farmers often had difficulty even recalling within-year information on resource use when the activities had been conducted several months preceding the date of interview.

In the survey, the transaction cost was determined from the objectives and working experience of the Pindanganga community-based management programme. For this programme, the information collected related to the composition of local committee members, number of meetings per month/year, the human and financial resources used and the number of people involved in patrolling and monitoring the miombo woodlands as well as enforcing the transaction.

Charcoal efficiency was measured based on a random sample of 23 earth kilns. To estimate the charcoal yield, the following measurements were taken: the number of trees harvested; the length of the logs and branches prepared to go to the kiln; the diameter at mid point of the length of all logs prepared to go to the kiln; and the numbers and mass of the charcoal bags produced.

The subsistence income for the community is estimated based on the total number of households in the community, the typical household size and composition by age and sex, consumption basket of food and non-food items, the minimum per capita caloric requirements established and the local market prices. The calories for the typical household were converted into quantities of products and the monetary values were assigned using local market prices.

Calibration and validation of the model

The calibration and validation of the model in this research was performed using the harvesting capacity parameter and by evaluating the magnitude of benefits, resource use and conservation with the stakeholders. The harvesting capacity parameter in the basic models was arbitrarily set according to Mlay *et al.* (2003). The modelling results were discussed in November and December 2003 with the MOFLOR manager, the Harvesting Timber Association for Manica Province, the technicians of the provincial Directorate of Forest and Wildlife at Manica Province and the local committee members in Pindanganga.

Results

Based on discussions with the stakeholders, the parameters for the model were finally set as indicated in Table 1.

Table 1: Data requirements for the simulation model for Pindanganga

Data type	Units	Pindanganga
Amount of thatching grass sold	Bundles/yr	1,000
Average basal area of miombo woodland	m^2/ha	6.9
Average farm size	ha	3.4
Charcoal production efficiency	Percentage	13.7
Chicken price	US$/unit	0.55
Chicken quantity sold by whole community	Unit/year	23,046
Discount factor	-	[0.909; 0.89]
Existing agricultural land	ha	6,317
Forest area	ha	36,512
Goat price	US$/unit	6.1
Goat quantity sold by whole community	Unit/year	4,754
Harvesting cost by commercial sector	US$/$m^3$	2.5
Honey quantity (price)	Litres (US$/litre)	10,000 (0.51)
Number of families per site	Persons	1,858
Off-miombo labour	Percentage	0.008
Pig price	US$/unit	9.2
Pig quantity sold by whole community	Unit/year	1,153
Price of grass	US$/kg	0.01
Price of charcoal	US$/$m^3$	1.7
Price of poles	US$/$m^3$	2.05
Price of standing miombo	US$/$m^3$	11.5
Regeneration (survival rate)	%	0.012 (0.92)
Agricultural revenue per hectare	US$/ha	126
Subsistence income for community	US$	677,470
Transaction cost (fixed cost)	US$/ha	2.26
Total person-days/year in community	Person days/yr	1,657,283
Wage rate	US$ per year	405.6

Basic simulation results

Data used for the basic simulations were taken directly from the fieldwork report and questionnaires or calculated from there. The impact of management regimes on the stakeholders' benefits is presented in Table 2. The difference in benefits between the two sectors reflects the difference in market values of the products harvested and harvesting capacity.

The commercial sector derives more of the benefits under the non-cooperative management regime from harvesting wood products compared to the household sector. Mlay *et al.* (2003) found the non-cooperative management regime to be not the best option for the commercial sector. These stakeholders can become involved in the cooperative management regime if the total benefits (tangible and intangible benefits) and the penalties for non cooperation exceed the additional benefits emanating from the non-cooperative management regime.

The household sector derives potentially more total household benefits from the regulated management regime with social concerns, followed by non-cooperative regime and cooperative management regime (Table 2).

Table 2: Equivalent annual net discounted benefits (EANDB) for private and household sectors from miombo woodland activities in Pindanganga.

Management Regime	Private sector EANDB[a] (US$ per annum)	Household sector EANDB (US$ per annum)	Household EANDB (US$ per capita per day)
Non-cooperative	(1) 443,519	(2) 107,469	0.03
Cooperative	(4) 391,381	(3) 94,252	0.03
Environmental	(5) 230,371	(5) 37,507	0.01
Social	(2) 433,173	(1) 107,761	0.03
Social and environmental	(3) 428,266	(4) 76,086	0.02

[a]*The figures in parentheses represent the ranking of the management regime on the basis of EANDB's within each sector*

The regulated option for environmental reasons leaves all stakeholders with the lowest benefits. This makes sense because of the emphasis put by the regulator on environmental concern; in this way more of the woodland resources are bound to be preserved, thereby resulting in fewer benefits. If the objective is to maximise stakeholder benefits on a sustainable basis, the highest equivalent annual net discounted benefits are achieved under centralised management favouring the social aspects and non-cooperative management regimes (Table 2). Equivalent annual net discounted benefits reduced to US$ 267,878 per annum when the objective is resource conservation.

For the households, the command regimes incorporating social concerns, both non-cooperative and cooperative, are the best options in terms of per capita household benefits from miombo wood products, NTFPs and agriculture. The command environmental, command social and environmental management regime options are the least attractive. The per capita benefits are the extra net income after the minimum subsistence requirements are met. They were accounted for in the model and for all management regimes represent less than 3% of US$1 per day (97% below the poverty line).

The trends in average volumes harvested annually to provide maximum discounted net benefits under each management arrangement for the stakeholders, correspond to the benefits derived from those products (Table 3). In comparison with the non-cooperative model, which represents the current practice, least volume is harvested under the command regime incorporating environmental benefits. For the household sector, the highest volume of wood products is harvested under the command social regime, which is only slightly more than under the non-cooperative regime, with decreasing volumes under the cooperative regime, then command regime incorporating both social and environmental benefits and then the environmental regime, in that order. The timber harvesting volumes for the commercial sector are limited to a maximum of 6,000 m^3 per year, in accordance with the management plan of the study site. The highest allowed volume is reached for all management regimes, except the command regime incorporating environment benefits. For the commercial sector, the average annual harvest under the regulated regime for environmental reasons is about 60% of the harvest under the open access regime.

The best outcome with respect to ecological health of the woodland is achieved under the command environment regime, followed by the command regime incorporating social and environmental benefits; the command regime incorporating social benefits; the cooperative regime; and lastly the non-cooperative regime (status quo), in that order (Table 3, column 3). The focus on environmental concerns means that a larger area of woodland cover has to be maintained to meet peoples' needs, while protecting the environment. Deforestation is highest under the non-cooperative or open access management regimes (at the end of rotation only about 11% of the initial woodland area will remain) (Table 3, column 2). As expected, the regulated system incorporating only environmental concerns leads to least deforestation, but it is the option economically least attractive to both the household and commercial sectors. The average annual woodland area converted to agriculture is highest under the cooperative and command regime incorporating social benefits, followed by the non-cooperative regime, then the command regime incorporating social and environmental benefits and lastly the command regime incorporating environmental benefits only.

Table 3: Volumes harvested and amount of charcoal bags produced in Pindanganga

Management Option[a]	Converted land (ha)[b]	Standing miombo (ha)	Number of charcoal bags	Harvested volume (m^3)		
				Commercial	Household	Charcoal
NC	(3) 236	(5) 3,891	(2) 25,546	6,000	11,666	8,329
COOP	(1) 250	(3) 4,118	(3) 24,000	6,000	11,403	7,825
CM-E	(5) 72	(1) 6,070	(5) 7,833	3,577	3,577	2,554
CM-S	(2) 238	(4) 4,031	(1) 25,706	6,000	11,739	8,381
CM-SE	(4) 253	(2) 4,331	(4) 19,511	6,000	10,068	6,361

[a]. NC = Non-cooperative, COOP = Cooperative, CM-E = Command environment, CM-S = Command social, CM-SE = Command social and environment.

[b] The figures in parentheses represent the ranking of the management regime

Impact of sectoral policy on the well-being of stakeholders, resource use and conservation under alternative management regimes

A general increase in the current commercial sales or market prices of NTFPs could be brought about by, for example, improvement in road infrastructure, new markets closer to the local communities, or removal of explicit government taxes on NTFPs. To assess the impact of such an increase, the Pindanganga model is simulated with an arbitrary increase of 100% on the current selling amount of NTFPs (scenario I) and an increase by 100% on the market selling prices of NTFPs (scenario II).

The relative results on the impact of increasing commercial sales amount or prices of NTFPs (honey, chickens, pigs, goat and thatching grass) on annual discounted net benefits from miombo activities are presented in Table 4. These values were obtained by comparisons made in relation to the basic simulation results within each management regime (values in brackets), and in addition the non-cooperative model results were used as reference results for assessing the other management regimes.

An increase in the commercial sales of NTFPs (scenario I) did lead to changes in the ranking of the management regime within each sector, while an increase in market prices of NTFPs (scenario II) did not lead to a change in the ranking. Raising the commercial sales of NTFPs or market prices by 100% reduced annual discounted net benefits for the commercial sector under all management options compared to the non-cooperative regime. The largest reduction was observed under the command model with environmental concerns, where the discounted net benefits relative to the base scenario were reduced by 27%. These results conform to *a priori* expectations, since selling NTFPs contributed to the household economic benefits derived from miombo forest for the householder sector. This scenario was in favour of the household sector, meaning that in addition to the restriction on harvesting implied by the environmental concern, the commercial sector is indirectly penalised by the social consideration favouring the household sector.

The household annual discounted net benefits from the sale of wood products from miombo activities showed a decrease across all alternative management regimes and the total sale of wood and non-wood products per capita per day increased compared with the basic runs. The command regime, accounting only for environmental benefits, was the least beneficial with discounted net benefits being decreased by 47.2% and 0.64% relative to the base scenario. Net benefits attained their highest value under the social and environmental management option. The observed increase in household benefits per capita per day from miombo activities was caused by an increase in harvesting of NTFPs and a reduction in land area converted to agriculture.

Table 4: The relative effect (%) of increases by 100% in commercial sales of NTFPs (I) and market sale prices of NTFPs (II) on discounted net benefits from miombo activities under alternative regimes in Pindanganga.

Management Regime	Commercial annual benefits[a]		Household annual benefits		Total annual benefits		Benefits per capita per day	
	I	II	I	II	I	II	I	II
Non-cooperative	100.0 (0.2)	100.0 (-0.6)	100.0 (-1.0)	100.0 (-0.2)	100.0 (0.0)	100.0 (-0.5)	100.0 (3.6)	100.0 (4.7)
Cooperative	88.0 (-11.8)	0.0 (0.0)	94.0 (-6.9)	109.1 (0.7)	89.2 (-10.8)	89.6 (-10.9)	94.4 (-2.2)	93.5 (5.8)
Environmental	51.8 (-48.1)	52.2 (-0.2)	35.2 (-65.2)	34.9 (-0.2)	48.6 (-51.4)	48.8 (-51.5)	41.3 (-57.2)	40.9 (12.3)
Social	97.4 (-2.4)	98.3 (0.1)	100.7 (-0.4)	99.7 (0.7)	98.0 (-2.0)	98.6 (-1.9)	100.7 (4.3)	99.7 (4.3)
Social and environmental	97.3 (-2.4)	96.8 (-0.4)	96.7 (-4.3)	78.6 (-10.9)	97.2 (-2.8)	93.2 (-7.2)	97.2 (0.7)	80.4 (17.0)

[a]*The figures in parentheses represent the percentage of change at the end of simulation comparing with the basic scenario.*

Using the non-cooperative model as a reference (the current management practice) the command model incorporating environmental benefits was the least beneficial, while the command with social and environmental concerns and the cooperative models were the most beneficial. The increase by 100% in commercial sales and prices of NTFPs could lead to an increase in household per capita benefits with 3% to 8% but it is not enough to reach the poverty line (US$1 per person per day). This showed that forest policies concerned with NTFPs by themselves in Pindanganga do not address the poverty of the local communities. In terms of per capita benefits, raising market prices of NTFPs had a similar effect as the effect of increasing the amount of NTFPs sold.

The average volume of miombo logs harvested by the commercial sector did not change under any of the management options, except for the command regime with environmental concerns (Table 5), which was a result of a harvesting restriction imposed by the management plan. The largest decline in harvesting was observed under the command model incorporating environmental benefits. Comparing the alternative management options with current practice (the non-cooperative model), the largest harvest volume decline was observed under the command model incorporating social and environmental benefits. However, the volume harvested was least sensitive to increase the selling amount and prices of NTFPs under the command model with social concerns.

The impact of increasing the commercial sales or prices of NTFPs in mitigating deforestation was most pronounced, as expected, under the command model incorporating environmental benefit. This management option showed the highest percentage of the area of standing miombo woodlands at the end of the simulation. Increasing commercial sales and prices were least effective in mitigating deforestation under the non-cooperative model. These results seem to suggest that the management options that will minimise conflicts between multiple objectives (command social environment and cooperative models) were the most beneficial.

Table 5: Relative effect (%) of a 100% increase in commercial sales (I) and a 100% price increase of NTFPs (II) on average annual volume of miombo wood products harvested under alternative management options in Pindanganga.

Management Regime[a]	Converted land[b], ha	Standing Miombo, ha	Amount of charcoal bags		Harvested Volume (m^3)					
					Commercial		Household		Charcoal	
	I	II	I	II	I	II	I	II	I	II
NC	100.0 (-0.4)	100.0 (0.4)	100.0 (-0.3)	100.0 (0.7)	100.0 (0.0)	100.0 (0.0)	100.0 (-0.6)	100.0 (0.4)	100.0 (-0.6)	100.0 (0.4)
COOP	108.9 (8.5)	108.0 (2.5)	105.3 (4.9)	104.2 (-0.9)	100.0 (0.0)	100.0 (0.0)	100.7 (0.1)	99.7 (2.3)	96.8 (-3.8)	95.9 (2.3)
CM-E	30.6 (-69.5)	30.4 (-0.5)	156.7 (56.1)	155.1 (0.1)	59.6 (-40.5)	59.5 (-0.1)	30.8 (-69.4)	30.5 (-0.1)	30.8 (-69.4)	30.5 (-0.1)
CM-S	100.9 (0.4)	100.0 (-0.2)	104.2 (3.8)	103.0 (0.1)	100.0 (0.0)	100.0 (0.0)	101.1 (0.5)	100.1 (-0.2)	101.1 (0.5)	100.0 (-0.2)
CM-SE	93.2 (-7.2)	91.1 (-14.6)	108.3 (8.0)	108.4 (-2.0)	100.0 (0.0)	100.0 (0.0)	93.3 (-7.3)	91.2 (6.0)	93.3 (-7.3)	91.2 (19.8)

[a] *NC = Non-cooperative, COOP = Cooperative, CM-E = Command environment, CM-S = Command social, CM-SE = Command social and environment.*

[b] *The figures in parentheses represent the percentage of change at the end of simulation comparing with the basic scenario.*

Impact of extra-sectoral policies on the well-being of stakeholders, resource use and conservation under alternative management regimes

The extra-sectoral policies considered here are concerned with agricultural performance and off-miombo employment opportunities. Agricultural policy changes are largely due to the strong link that exists between subsistence agriculture and miombo woodlands. Agriculture is one of the main causes of deforestation in Mozambique (Saket 2001). Policy changes related to areas outside the miombo are often due to expectations that use of products from the miombo will sustain the communities (Kaimowitz and Angelsen 1996).

This section analyses the impact of agricultural performance (technology changes in agriculture leading to 25% price increases) on stakeholder benefits and deforestation in miombo activities (Tables 6 & 7). An increase in agricultural revenue by 25% has reduced the benefits of the commercial sector (Table 6), when comparing increased household benefits for the cooperative and non-cooperative management regimes and reduced area of standing miombo at the steady state, when compared to the base scenario. The response to a price increase for forest conversion to agriculture is more pronounced under the command model incorporating environmental benefits. The model's prediction conforms to Barbier's (2000) observation that in low input agriculture, an increase in output prices will promote the area expansion instead of intensification at least in the short term.

Table 6: Relative effect (%) of an increase by 25% in agricultural prices on discounted net benefits from miombo activities under alternative regimes in Pindanganga.

Management Regime	Commercial annual benefits[a]	Household annual benefits	Total annual benefits	Benefits per capita per day
Non-cooperative	100.0 (-0.1)	100.0 (17.2)	100.0 (3.3)	100.0 (16.2)
Cooperative	88.2 (-0.1)	96.0 (21.8)	89.9 (4.3)	96.0 (20.6)
Environmental	74.6 (43.4)	49.1 (65.0)	68.9 (46.5)	51.4 (56.6)
Social	97.7 (-0.1)	102.1 (19.3)	98.7 (3.8)	101.9 (18.3)
Social and environmental	98.0 (1.4)	102.4 (69.6)	99.0 (11.7)	102.5 (65.5)

[a] *The figures in parentheses represent the percentage of change at the end of simulation comparing with the basic scenario.*

Table 7: Relative effect (%) of an increase by 25% in agricultural output prices on charcoal production and volumes harvested by the stakeholders under alternative management options in Pindanganga.

Management Regime	Number of charcoal bags[a]	Converted land, ha	Standing miombo, ha	Harvested Volume (m^3)		
				Commercial	Household	Charcoal
Non-cooperative	100.0 (-3.9)	100.0 (4.2)	100.0 (-2.2)	100.0 (0.0)	100.0 (-1.3)	100.0 (-3.9)
Cooperative	98.2 (0.4)	108.5 (6.9)	107.1 (-1.0)	100.0 (0.0)	101.7 (2.7)	98.2 (0.4)
Environmental	44.6 (39.7)	44.7 (52.0)	96.7 (-39.4)	85.5 (43.4)	44.6 (43.5)	44.6 (39.7)
Social	101.9 (-2.7)	102.0 (5.7)	107.1 (1.1)	100.0 (0.0)	101.9 (-0.1)	101.9 (-2.7)
Social and environment	99.5 (25.2)	99.6 (-3.2)	107.7 (-5.4)	100.0 (0.0)	99.5 (13.8)	99.5 (25.2)

[a] *The figures in parentheses represent the percentage of change at the end of simulation comparing with the basic scenario*

Interaction between sectoral and extra-sectoral policies

The relative impact of the interaction between extra-sectoral and sectoral policies through a simultaneous increase in NTFP market sale prices and agricultural output prices by 25% on the benefits to stakeholders and woodland resources did not change the ranking of the management regimes within each sector compared with the base scenario when prices of NTFPs increased (Tables 8 & 9). The ranking was only changed when commercial sales or agricultural output prices were increased.

The impact of a simultaneous increase in market prices of NTFPs and agricultural output prices by 25% under *ceteris paribus* affected the commercial sector indirectly through labour supply. It affected directly the household sector which performed both activities. The annual household discounted net benefits from wood products increased for all management regimes in relation to the base scenario, except for the environmental regime. The household net benefits per capita per day from wood, NTFPs and agriculture increased for all management regimes in relation to the base scenario, except for the environmental regime. In the case of the commercial sector, the annual discounted net benefits increased, except for the command with environmental concerns regime and the cooperative regime.

The maximum harvested volume for the commercial sector was not affected by these policy changes and was expected as a consequence of the restriction incorporated in the model for the allowed cut volume of commercial timber (in accordance with the management plan). The total volume harvested by the household had increased compared to the base scenario, except for the environmental regime.

Table 8: Relative effect (%) of the combined increase by 25% of NTFP market sale prices and agricultural output prices on discounted net benefits from miombo activities under alternative regimes in Pindanganga.

Management Regime	Commercial annual benefits[a]	Household annual benefits	Total annual benefits	Benefits per capita per day
Non-cooperative	100.0 (-0.6)	100.0 (16.5)	100.0 (2.7)	100.0 (16.9)
Cooperative	88.8 (0.0)	96.4 (12.3)	90.5 (4.4)	96.6 (22.2)
Environmental	74.9 (43.4)	49.4 (-42.4)	69.3 (46.4)	52.0 (59.4)
Social	98.9 (0.6)	102.4 (19.3)	99.7 (4.3)	102.2 (19.4)
Social and environmental	98.3 (1.2)	102.3 (19.2)	99.2 (11.3)	102.2 (66.0)

[a] *The figures in parentheses represent the percentage of change at the end of simulation compared with the non cooperative management alternative under the basic scenario.*

With regard to the impact of policy changes on the woodland resource, it was observed that the standing woodland decreased in relation to the base scenario, except for the command regime with social concerns. This reduction was due to the significant impact of the agricultural price increase and to the relatively lower weight of NTFP prices compared with agricultural products (maize and sorghum) and wood products (timber, charcoal and poles). Land conversion to agriculture (Table 9) resulting from the increase in agricultural output prices, increased as expected. The increase in net benefits from wood products to the household sector resulted from the wood obtained in the process of land conversion to agriculture. Cropper *et al.* (1997) and Panayotou and Sungsuwan (1994) found similar results in two separate studies on deforestation in Thailand. Deininger and Minten (1996) in Mexico found also a significant positive relationship between deforestation and agriculture revenue increase.

Table 9: Relative effect (%) of the combined increase in market prices of NTFPs and agricultural output prices by 25% on resource use under alternative management options in Pindanganga

Management regime	Converted Land, ha	Forest area, ha	Number of charcoal bags	Harvested Volume (m^3)		
				Commercial	Household	Charcoal
NC	100.0 (3.8)	100.0 (-3.4)	100.0 (-4.3)	100.0 (0.0)	100.0 (-1.7)	100.0 (-4.3)
COOP.	109.0 (6.9)	108.5 (-1.0)	98.6 (0.5)	100.0 (0.0)	102.1 (2.7)	98.6 (0.5)
CM-E	44.9 (52.0)	98.0 (-39.3)	44.8 (39.8)	85.5 (43.4)	44.8 (43.6)	44.8 (39.8)
CM-S	102.0 (5.2)	108.4 (1.0)	102.2 (-2.8)	100.0 (0.0)	102.2 (-0.2)	102.2 (-2.8)
CM-SE	99.2 (-3.9)	109.5 (-5.0)	99.1 (24.2)	100.0 (0.0)	99.1 (12.9)	99.1 (24.2)

[a] *The figures in parentheses represent the percentage of change at the end of simulation comparing with the basic scenario*

Discussion

Four different models of management of miombo woodlands in the southern Africa region were identified. These were: (i) a dynamic game theory model for miombo woodlands (Sumaila and Kowero 2001), (ii) a goal programming model for miombo woodlands (Nhantumbo and Kowero 2001); (iii) the miombo ecosystem and land transformation model – MELT (Desanker 2001); and (iv) a simulation model of miombo woodland dynamics under different management regimes in Zimbabwe (Gambiza *et al.* 2000).

The dynamic game theory model developed in this research differs from the model developed by Sumaila *et al.* (2003) by taking into account the following aspects:

- the dynamics of both the human population and agricultural and forestry prices;
- the demand for poles is compared with firewood and charcoal;
- the demand from the commercial sector is restricted according to the allowed harvest cut established in the community management plan;
- the effect of transaction costs on the cooperative management regime, which affects the harvesting levels of the two sectors, charcoal production efficiency, harvesting technology efficiency and the dynamics of non-miombo activities over time, highlights the conflict between householder and commercial sectors through variation in diameter classes of tree species used for logs, charcoal, firewood and poles, and the model accounts for the benefits from the NTFPs.

The mechanism of diameter class segregation included in the model allows us to constrain the timber harvested by the commercial sector, according to the Forestry and Wildlife Policy which states that the trees can be harvested only if they have a diameter at breast height greater than 30 cm.

Mlay *et al.* (2003) found that the cooperative management regime is the second best management option in terms of private benefits and total benefits for the two sectors in Dondo, Nhamatanda and Gondola-Manica districts. In this research, the cooperative option is ranked as the third option (and therefore less attractive), due to the inclusion of the transaction costs in the analysis.

Implications of alternative management arrangements

The alternatives analysed for managing miombo woodland resources reflect either on-going practices or new practices in their early stages of introduction. From experience, centrally regulated regimes in Mozambique have not been effective in redressing deforestation, land degradation and conservation. Although the government has the obligation to defend society-wide interests, experience in natural resource conservation and use shows that the policies adopted and instruments used for their implementation have been ineffective. Because the social and economic benefits implied by the regulation are not felt at community level, there has been an incentive for non-compliance, which in turn is facilitated by lack of institutional and financial capacity for enforcement (Mlay *et al.* 2003).

In the implementation of CBNRM, the principal aim is biodiversity conservation. The involvement of the community is viewed as strategic to minimise the problem of natural resource degradation, given that the classic and centralised system of natural resource management in Mozambique has shown itself inefficient in promoting and guaranteeing sustainability. This approach involves other stakeholders, in particular rural communities (Serra 2001).

Regulated management regimes which take into account social needs or both social and environmental needs are potentially more beneficial to the household sector than open access regimes. This suggests that if these benefits were to flow to the local communities, non-compliance to sustainable forest management activities could be minimised. This can be guaranteed under decentralised management with local community participation but only with clear definition of a benefit-sharing arrangement. The cooperative management regime, which already has a legal support for property right protection, needs to be promoted in association with policies and regulations that bring incentives to increase the benefits from activities related with NTFPs. These include honey production, keeping domestic animals, and the sale of thatching grass.

The results show that improvement in well-being and resource conservation can be achieved with sound management practices. Regulated management regimes incorporating social or social and environmental benefits provide higher benefits to the household sector than the open access regime. This means that the well-being of the rural communities and woodland conservation can potentially be improved if these benefits were felt at the community level. Mlay *et al.* (2003) showed similar results for Central Mozambique, while Kachule *et al.* (2001) found the same for Malawi.

The results of this research indicate that the levels of deforestation are greater under open access regimes. Kaimowitz and Angelsen (1998) found similar results using analytical models. The cooperative management regime, taking into account the transaction costs, shows that both the local communities and the commercial sectors can gain under this arrangement. The benefits for stakeholders found in this study are less than the benefits found by Mlay *et al.* (2003). This can be explained by inclusion in this model of transaction costs, diameter class segregation and population dynamics over the rotation period. In the case of Mozambique, where the Forest and Wildlife Law permits communities to enter into partnership with the private sector in its exploration of natural resources, the results show that such cooperation is potentially beneficial to local communities if properly implemented.

Sectoral policies in the form of commercial sales and prices of NTFPs manifest their impact on the woodland resource mainly through the household sector activities in the form of an increase in household benefits from harvesting wood and non-wood products. The amount of wood products harvested has reduced slightly.

Extra-sectoral policies, particularly those directed to promote agricultural production, can have a positive or negative effect on forest development. Angelsen *et al.* (1996), in their study of 19 Tanzanian regions, have found a significant increase in cropped area with increases in agricultural prices. Kaimowitz and Angelsen (1998) stated that agricultural price increases, without significantly altering the demand for labour or capital, increase the amount of woodland cleared by each household. Our results show that modest price increases in agriculture promote agricultural production through land expansion. Reduction in land clearing for agriculture is achieved only if improvement in agricultural production technology leads to a large increase in productivity. Another important issue to note is that the impact of these policies on the woodland resources and the welfare of stakeholders is influenced by the management regime in place.

The impact of the management regime and policy intervention on the welfare of stakeholders and on the ecology of the woodland resources will depend on the natural resource endowment and the initial socio-economic conditions on the ground. Policy changes in the household or commercial sector are likely to affect the state of affairs in other sectors. While the general direction of policy or institutional change can be predicted, the actual impact will reflect the initial conditions which are site specific. In addition, the results show that there is no management regime capable of satisfying all goals of the stakeholders, meaning that some trade-off between goals is necessary. This means that a clear definition of priorities is necessary.

Conclusion

This study showed that an improvement in well-being of rural communities and resource conservation can be achieved with sound management practices. The cooperative management option or CBNRM is potentially beneficial to local communities if properly implemented and can improve the rural livelihoods and the woodland resource condition. Sectorial policies targeting NTFPs can lead to an increase in the per capita benefits to the household sector by 1% to 5%. Extra sectorial policies promoting an increase in harvest prices without any other incentive leads to agricultural expansion. A combination of these two policy instruments under *ceteris paribus* can improve the well-being of the rural communities by 10% to 25%, but cannot reach the poverty line (US$1 per capita per day). The study is deterministic and thus cannot be expected to give a perfect picture of the study area. Nevertheless, the results of this study provide forest managers alternative scenarios, which they can use in their selection of appropriate resource management practices

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TOWARDS THE IMPROVEMENT OF POLICY AND STRATEGY DEVELOPMENT FOR THE SUSTAINABLE MANAGEMENT ON NON-TIMBER FOREST PRODUCTS: SWAZILAND- A CASE STUDY

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Abstract

Non-timber forest products (NTFPs) are a major component of rural household economies in the four ecological zones of Swaziland. This study highlighted inadequacies in existing national, regional and international policies/ strategies and legislation to manage NTFPs, and data on use patterns and use values in 18 categories of NTFPs. Community consultations, user surveys and basic economic analyses showed lack of traditional management systems and variation in edible and medicinal NTFP use between communities and households within the ecological zones. Resource surveys showed the negative impact of uncontrolled commercial harvesting on the valuable standing NTFP stock especially on preferred species. Thus, the study developed a theoretical framework for policy reform towards sustainable NTFP management in Swaziland.

Introduction

The Swaziland population (±1 million) live in a total land area of 17,364 km^2 (FAO-WFP 2008) and use diverse non-timber forest products (NTFPs) as a major component in their rural household economy. It is mainly a rural and subsistence society, with a dual land tenure system consisting of Swazi Nation Land (SNL) held in trust by the King and allocated to households by chiefs, and Title Deed Land (TDL) that is freehold. It is a lower middle-income country whose income distribution is skewed, with an estimated 20% of the population accounting for more than 50% of national income. An estimated 43% of the population live in extreme poverty and 76% of the poor live in rural areas (FAO-WFP 2008). The country has four agro-ecological zones: Lubombo Plateau; Lowveld; Middleveld; Highveld. The climate is sub-tropical, characterised by wide ranges in total annual rainfall, periods of droughts that particularly affects the Middleveld and Lowveld (Dlamini 2007).

The total value generated by a forest consists of wood and non-wood goods and services (Buttoud 2000, Gluck 2000). Goods and services of the forest resource can be classified into four broad categories: direct use benefits/values; indirect use benefits/values; and intermediate use services which can be divided into option values and existence values (McKenney and Sarker 1994, Clarke *et al.* 1996, Buttoud 2000, DANCED 2000a, Shackleton *et al.* 2000, Hassan 2001, Hassan *et al.* 2002, Shackleton 2002, Chipeta and Kowero 2004, Clarke and Grundy 2004, Shackleton and Shackleton 2004). Direct use benefits include timber for construction and furniture, wood for crafts and household tools, fire wood, construction poles, wild fruits and other foods and other benefits. Indirect use benefits include pollination services, livestock grazing, recreation/aesthetic services (eco-tourism), religious functions and other benefits. Intermediate use services comprise carbon sequestration, watershed and soil protection, biodiversity reserves, habitat for wild fauna and flora (breeding and nursery functions) and other services.

In the past, the focus in forest management was on commercial timber, regarded as the primary forest product (Peters *et al.* 1989, Chopra 1993, Godoy *et al.* 1993, McKenney and Sarker 1994, DANCED 2000b, Wong *et al.* 2001, Hassan *et al.* 2002). However, it is becoming clear that economically, environmentally, culturally and socially, non-timber forest goods and services are equally important (Falconer 1992, Gunatilake *et al.* 1993, Chamberlain *et al.* 1998, Langoya and Long 1998, Robles-Diaz-De-Leon and Kangas 1999, Chapeskie 1999, Shackleton *et al.* 2000, Dovie *et al.* 2001, Hassan *et al.* 2002, FAO 2003, Clarke and Grundy 2004, Geldenhuys 2004, Lawes *et al.* 2004, Shackleton and Shackleton 2004, 2005, Olsen 2005). In Swaziland commercial harvesting of timber from natural forests and woodlands was confined to timber for farm structures (DANCED 2000b, Hassan *et al.* 2002).

It is easy to define and measure timber outputs from the forest, but it is difficult to define and quantify many NTFPs (Balick and Mendelson 1992, McKenney and Sarker 1994, Shackleton *et al.* 2000, Gram 2001, FAO 2001, 2003). NTFPs are classified in many different ways, for example by end use and plant part used (Chandrasekharan 1995, Cook 1995, Temu 1995). However, an internationally accepted standard classification is yet to be developed. A tentative classification system for ease of data collection by researchers for the regional outlook of NWFPs in Africa from various international classification systems was inconclusive (FAO 2001). The categorisation of NTFPs is important for resource assessment and economic valuation purposes (FAO 2001, Hassan *et al.* 2002).

The pressure on natural forests and woodlands in Swaziland and most parts of the world requires a clear picture of the products and services used by different users for efficient policies and sustainable forest resource management planning. This study of NTFPs is a first step towards such an integrated approach towards a policy and strategy for sustainable management of natural forests and woodlands in Swaziland. The overall objective of this study was to determine the socio-economic use, direct use values and management of natural forests and woodlands for edible and medicinal NTFPs in the four ecological zones of rural Swaziland as basis for an improved policy and strategy towards sustainable management of NTFPs (Dlamini 2007). The purpose of this paper is to present the results of (i) the hierarchical review process of NTFP relevant policies and legislation; (ii) the review of earlier national NTFP studies and to develop NTFP categories for Swaziland based on different sources of information on NTFPs; (iii) the quantity and value of NTFPs used in the four ecological zones through community consultations, user surveys and economic valuation, and (iv) the quantity and value of NTFP resources through resource surveys and their economic valuation.

Materials and Methods

Policy review

A hierarchical method comprising four steps: preliminary selection of relevant policies and legislation; first assessment on NTFP relevance of all selected policies and legislation; second assessment of selected NTFP relevant policies and legislation; review and detailed analysis of short-listed policies and legislation. This approach was modified from methods used in several other studies (see Dlamini 2007). A model of 21 criteria was designed to analyse and rank national and international policies (Dlamini 2007).

Status of NTFPs

Earlier national studies on NTFPs, and national, regional and international sources of information were reviewed. Subject matter specialists were consulted in face to face interviews to ascertain and establish NTFP categories that exist in Swaziland and to further rank various plant species in order of importance and multiple use (see Dlamini 2007 for details).

Site selection for community consultations, and for user and resource surveys

Sites were selected on the basis of three criteria:

1. Coverage of a broad spectrum of forest and woodland types in the four ecological zoes of Swaziland;
2. Selected villages should be part of communities that live adjacent to natural forests and woodlands and harvest and utilize NTFPs from those neighbouring woody vegetation systems.
3. The selected natural forests and woodlands should be shortlisted from the list of nominated forests developed during community consultations.
   The following study sites and villages were selected in each ecological zone:
   Highveld: Hhelehhele North (Mlumati & Hhelehhele); Middleveld:Grand Valley or KaKholwane (Emoti & Kundodemnyama); Lubombo: KaShewula (Jamehlungwini & Mangwenya); Lowveld: Siphofaneni (Hlutse & Madvuma)

Community consultations

In each selected study site, two villages were selected with assistance from the District Forestry Officer and Agriculture Extension Officers according to the site selection criteria above. In each village, forty community representatives were selected comprising twenty men and twenty women, with two community leaders as observers. Data were collected through group discussions, individual interviews and the review of the National Forest Policy to determine group and individual perceptions on biodiversity threats, NTFPs and related policies (Dlamini 2007).

User surveys and economic valuation

A sampling approach was followed with two villages per site and 17 households per village to assess what NTFPs people harvest from the natural forests/woodlands. Household profiles were developed for each village through questionnaires. Individual questionnaires were completed to cover the different products harvested by species, products and quantities for domestic and/or commercial use, the time spent on resource use, the practices followed and costs-benefits (values) of the different species and products (Dlamini 2007). Farm-gate prices were collected monthly over the entire survey period from local sources. Annual value extracted per household = Annual quantities extracted (either for domestic use or trade) x mean farm-gate price.

Resource surveys and economic valuation

Key informant interviews with 28 subject matter specialists, 40 traditional healers and 136 local collectors to gather local knowledge on the species and their habitat, ecology, response to harvesting, uses, etc. Resource surveys were undertaken in one natural forest/woodland from each ecological zone. In each forest/woodland a nested sampling approach was used for the resource inventory (see Dlamini 2007 for details), with 10 main 50 m x 50 m sample plots per study site, subdivided as shown in Figure 1. The main plots were used to record for each tree the species, diameter at breast height (DBH), and height, and unit price, total value and other comments. Small trees, bushes and shrubs on the four sub-plots of 25 m x 25 m were counted by species, size, and unit price, total value and other comments. Information on understory individuals (mushrooms, berries, vegetables, herbs and other) were collected by species name on the 16 sub-plots of 12.5 m x 12.5 m. The economic valuation model was based on Peters *et al.* (1989), Balick and Mendelson (1992) and Godoy *et al.* (1993, 2000) where: Trees/Shrubs: Total value = number of trees X annual yield per tree X unit price; Under-storey: Total value = number of individuals X annual production X unit price.

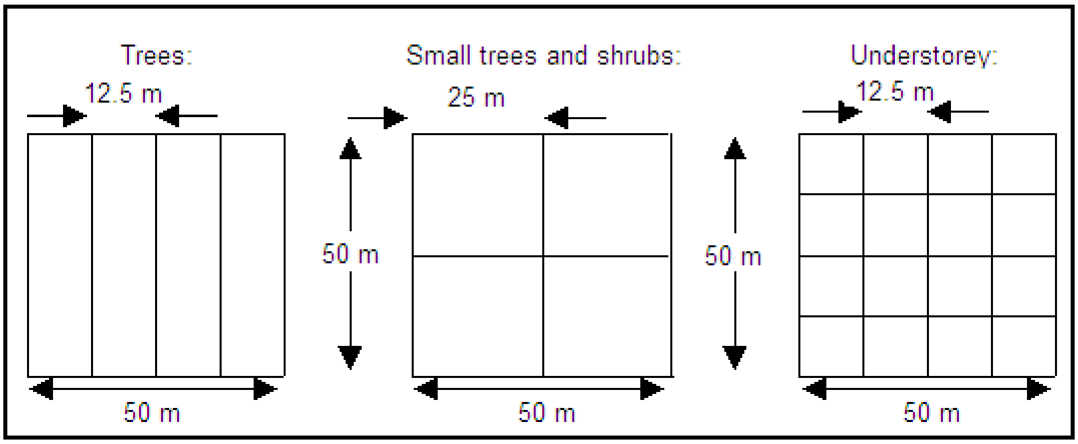

Figure 1: An illustration of the design of main plots and two levels of sub-plots for the resource surveys.

Results

Policy review and implications

The inventory of policies and legislation potentially relevant to natural resource management gave nine national policies/strategies, 15 Acts and 11 international principles. The screening process indicated that existing national and international policies and legislation addressed NTFPs differently; some adequately and some inadequately. Some national policies contain elements of NTFPs and deal with them directly, but some deals with them indirectly; some do not contain elements of NTFPs yet deal with them indirectly. Only policies and legislation with 2 points and are dealing or covering more than one category of NTFPs were selected for the final analysis. The scores for those national and international legal documents included in the final analysis (Table1) show that they address NTFPs to varying degrees. The international conventions scored the highest points because they cover a broad spectrum of important and key issues on the development and sustainable management of NTFPs. The lower scores of the national legal documents and confirm the view that they are outdated. They are also orientated to promote preservation, not sustainable use, and therefore difficult to implement. Preservation of natural environmental resources hinders their development and sustainable use. Some of the new national programmes are in line with international principles of sustainable use and management of NTFPs.

NTFP categories and major NTFP species in Swaziland

A list of 18 major use categories of NTFPs in Swaziland was compiled from the literature (Table 2), which are in line with international grouping of NTFPs. A species list was compiled of the most preferred and commonly used plants used in Swaziland (Compton 1976, Dlamini 1981, 1999, Ogle 1982, Mander 1998, Cassidy *et al.* 2000, Braun *et al.* 2004. The list included the following number of species by uses: medicine (338), food (208), hand crafts (53), cultural rituals (52), household items (39), ornamentals (17), tannins and dyes (13), fuel wood (9), fodder and grazing (9), and thatching (8). A matrix of the NTFP plant species was developed based on 14 direct use benefits to rank the species in order of importance on the basis of number of uses over 14 direct use categories: Edible leaves; Edible fruits and berries; Other edible portions; Medicinal products; Wattle and tannin; Fuel wood; Building material; Floral products; Landscape; Crafts and household; Fodder and grazing; Tannin and dyes; Thatching plants; Cultural plants. The top 12 most versatile species in terms of diversity of use were as follows (* indicates introduced species):

Species with 6 uses: *Sclerocarya birrea*

Species with 4 uses: *Bauhinia galpinii, Berchemia zeyheri; Dichrostachys cinerea, Euclea crispa, Syzygium cordatum*

Table 1: Detailed breakdown of the scores and ranking against NTFP issues and elements for the selected legal documents

Legal documents	Scores* by Issues and elements of NTFPs**																					Grand Score	Rank
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		
(a) International protocols, conventions and strategies																							
Convention on Biodiversity	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	42	1
SADC Forestry Protocol	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	41	2
UNCED Agenda 21	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	40	3
Millennium Development Goals	2	2	2	2	2	2	1	1	1	2	2	2	2	2	1	2	2	2	2	2	2	38	4
Environmental Initiative of New Partnership for Africa Development (NEPAD)	2	2	2	2	2	2	1	1	1	2	2	2	2	2	1	2	2	2	2	2	2	38	4
SADC policy and strategy for Environment and Sustainable Development	2	2	2	2	2	2	1	1	1	2	2	2	2	2	1	2	2	2	2	2	2	38	4
World Bank Forest Strategy/ Policy and Forest Certification	2	2	2	2	2	2	1	1	1	2	2	2	2	2	1	2	2	2	1	2	2	37	5
Convention in International Trade of Endangered Species of Flora and Fauna	1	1	2	2	1	1	2	2	2	2	2	2	2	1	2	2	2	0	1	1	1	33	6
(b) National policies and legislation																							
National biodiversity strategy & action plan	0	0	1	2	1	1	2	1	1	2	2	2	2	2	2	2	2	1	2	1	1	30	1
Criteria and indicators for sustainable forest management	1	0	2	2	1	1	0	0	1	2	2	2	2	2	2	2	2	0	2	2	2	30	1
National environment policy	0	1	1	2	1	1	0	1	1	2	2	2	2	2	2	2	2	1	2	1	1	29	2
National forest policy	1	1	1	2	1	1	0	0	1	2	2	2	2	2	2	2	2	0	2	1	1	28	3
Game act	1	1	0	2	0	0	2	0	0	2	2	1	1	0	2	2	2	0	0	1	0	19	4
Plant control act	0	0	0	1	0	0	2	0	2	1	1	0	0	2	0	0	0	0	1	0	0	10	5
Forest preservation act	0	0	0	1	0	0	0	1	1	0	0	1	1	1	0	1	1	1	0	0	0	9	6
National trust commission act	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	1	0	8	7

***Scores:** Issues and elements of NTFPs addressed: 2 = adequately; 1 = inadequately; 0 = not addressed

****The 21 Issues and elements of NTFPs:** 1 Stakeholders involvement; 2 Economic incentives; 3 Existing gaps; 4 Broad spectrum; 5 Decentralisation; 6 Sustainable Management; 7 Schedules of species; 8 Red data list; 9 Flora Protection; 10 Strategies for sustainable management; 11 Commercialization and domestication; 12 Implementability; 13 Status of policy; 14 Impact of Alien Invasive species; 15 Ethnobotanical Surveys; 16 Trade Chains; 17 Valuation of NTFPs; 18 Integrated Forest Management; 19 Scientific understanding; 20 Training; 21 Collaboration

Table 2: Use categories of NTFPs in Swaziland (goods and services)

Use Category	Comments
Direct Use	
1. Forest foods & drinks	Edible fruits, leaves, roots, buds, herbs, other edible portions that contribute to improving food security and nutritional status
2. Forest medicines	Leaves, bark, fruits, roots, other
3. Thatching material	Different grasses used as roofing material
4. Plant tannin & Dyes	Plant dyes from bark and other parts, including vegetable tannin materials
5. Household items & fibre products	Items made from indigenous forests found in households; include kitchen utensils, mats, sweepers, other
6. Handicrafts & fibre products	Everyday utensils, some also used in traditional ceremonies. Weapons such as knob sticks. Traded items made for tourists
7. Animals & animal products	Ivory, trophies, bones, feathers, butterflies, live animals and birds and bushmeat, etc
8. Fuel wood & charcoal	A major source of energy to both rural and urban households traded in large amounts throughout the country.
9. Other NTFPs	Spices, insect products, natural plant pigments, essential oils, incense wood, latex, plant gums, waxes etc.
Indirect Use	
10. Cultural ceremonies & rituals	Plants used in local and national ceremonies. Use of bird feathers in traditional gear, Plants and animals used as indicators, e.g. red chested cuckoo calling in the ploughing season.
11. Landscaping and ornamentals	Shade, windbreaks, garden plants, hedges, aesthetics. Improves the scenery.
12. Fodder & grazing	Trees, shrubs, grasses, and others that provide for livestock fodder
13. Floral greenery	Ferns, wild flowers, herbs, other
Intermediate Use Services	
14. Tourism and recreation	Forests and trees provide habitats for animals and plants that attract foreign visitors and generate income. Useful in Biodiversity conservation.
15. Soil fertility & soil conservation	Plant parts such as roots, leaves, fruits, bark, other, that contribute to soil stabilization and maintaining soil fertility
16. Pollination services	Various insects; bees, beetles and other that contribute to crop production; including birds and bats.
17. Hydrological cycle & water conservation	Natural forests and woodlands play a crucial role in the water cycle and in water holding and circulation
18. Other environmental services	Services such as oxygen production, acid rain deposition, carbon sequestration.

Species with 3 uses: *Acacia dealbata*; Acacia karroo, Brachylaena discolor, Ficus sur, Phoenix reclinata, Ziziphus mucronata.*

Community consultations

Information on various species used for NTFPs in the study areas obtained through the community consultation meetings show much variation between the study areas for the different product groups (Table 3). The graphical representation (Figure 2) shows the differences in perceptions of men versus women in the use of different types of resources.

User surveys and economic valuation

The mean quantities and values of edible and medicinal goods harvested per household per year in the four study areas show much variation (Table 4). There is a very high extraction rate of edible NTFPs at Siphofaneni area, suggesting households in this area make good use of the available wild edible NTFPs in their surrounding natural woodlands. Similarly the households of Grand Valley area rely heavily on the available natural medicines in their surrounding woodlands.

Table 3: Number of preferred and threatened species reported during community consultations (including repetitions for different categories) in the different study sites, based on the perceptions of the respondents

Product group	Grand Valley	Hhelehhele North	Shewula	Siphofaneni	Total NTFP species	Mean no. responses (out of 40)*	Standard deviation
Edible plant species	38	16	16	20	180	25.1 ab	1.9
Threatened edible plant species	2	1	5	9	34	25.6 ab	0.7
Medicinal plant species	20	20	13	9	124	28.1 a	1.3
Threatened medicinal plant species	7	5	5	0	34	21.6 b	1.4
Edible animal species	4	0	5	7	32	13.4 c	1.3
Threatened edible animal species	0	0	0	4	8	26.5 a	1.8
Top priority species	5	7	10	15	74	27.4 a	1.2

** Means with same letter indicates no differences and different letters indicate differences*

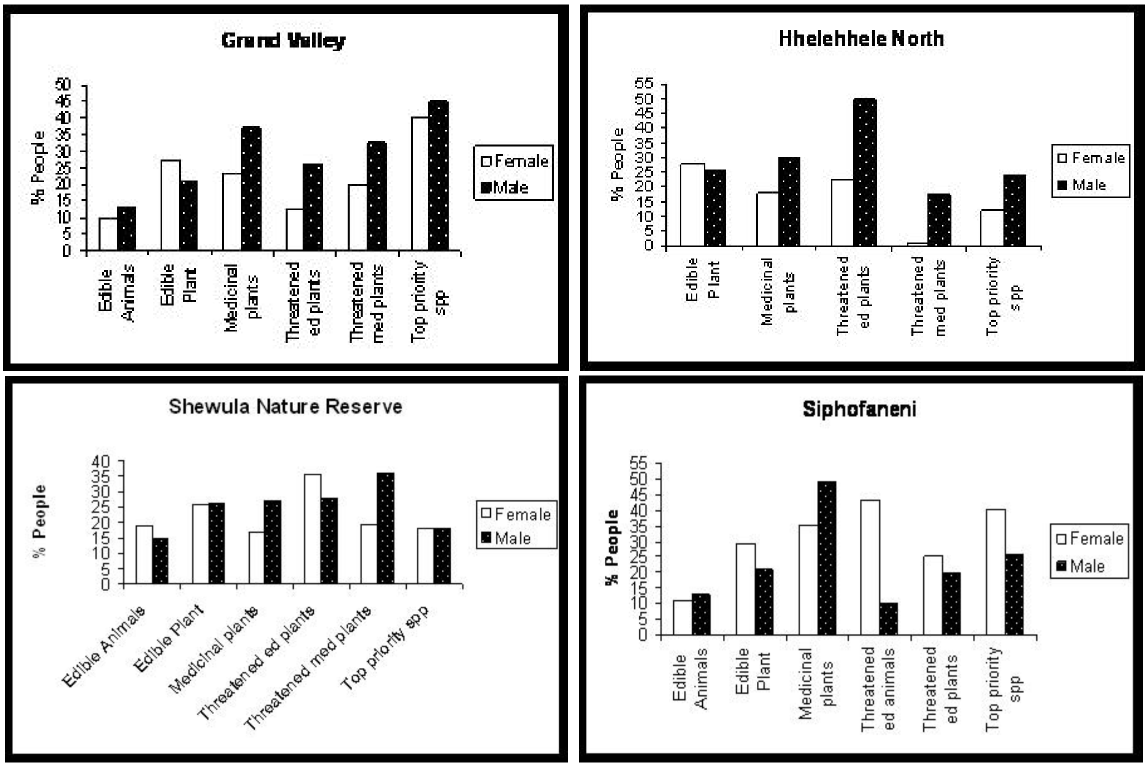

Figure 2: Graphical representation of the percentage responses of community representatives (male and female separately) for the various product groups at the four study areas

Table 4: Mean annual quantities (kg) and values (US$) per household in the four study areas in the ecological zones of Swaziland

NTFPs	Hhelehhele North		Grand Valley		Shewula		Siphofaneni	
Number of observations (N) and mean* annual quantities (kg)								
	N	Kg	N	Kg	N	Kg	N	Kg
Edible	193	115.8b	239	410.4b	96	166.4b	217	2144.9a
Medicinal	99	2.8b	148	5.3a	103	1.6c	102	1.6c
Number of observations (N) and mean* annual values (US$)								
	N	US$	N	US$	N	US$	N	US$
Edible	193	53.9b	239	534.0ab	96	80.9b	217	995.6a
Medicinal	99	65.6b	148	122.1 a	103	37.0c	102	37.4c

*Means with same letters are not statistically significantly different, Exchange rate: 1US$ is equivalent to R6.50 as at 2004 (Times of Swaziland, 2nd March 2004)

The study assessed resource use over six classes of harvesting duration for edible NTFPs (in weeks) and nine classes for harvesting duration medicinal NTFPs (in months). The highest extraction rate for edible NTFPs occurred over eight weeks, and for medicinal NTFPs over 5 months (Table 5). Some species are harvested any time of the year (for medicine), but it should be noted that these are not harvested continuously but fall within the given harvesting durations as well.

Table 5: Mean annual quantities and mean annual values per household over the respective harvesting durations

Variable*	(a) Harvesting duration in weeks: Edibles							
	4	8	12	16	20	24		
N	29	256	255	157	45	3		
Kg	15.9	1804.3	106.9	644.9	239.3	64		
US$	7.4	834.8	54.3	808.1	155.3	78.8		
	(b) Harvesting duration in months: Medicinal							
	1	2	3	4	5	6	7	8	9
N	133	116	99	63	23	10	4	1	3
Kg	0.9	1.5	2.3	7.4	14.1	3	3	4	4
US$	22.3	36.3	54	171.4	325.8	69.2	70.7	93.2	103.8

* N = Number of observations; Kg = volume of harvest; US$ = value of harvest

A study by Hassan *et al.* (2002) amongst the rural communities (urban populations showed a low dependence on direct harvesting from natural forests and woodlands) provided an economic valuation of forest products for seven major NTFPs groups (Table 6). The contribution of natural forests and woodlands in flow benefits, including the highlighted NTFPs, was equivalent to 2.2% of the total GDP, 20% of agricultural GDP and 439% of the contribution of forestry reported in the national accounts for 2000 (Hassan *et al.* 2002). It should be noted that this excludes indirect use benefits and intermediate services of the natural forests and woodlands.

The top 10 most harvested species in each of edible and medicinal NTFPs were selected based on harvesting frequency and quantities over the four study sites (Table 7). *Sclerocarya birrea* was the most highly ranked species in the user surveys (as was found in the matrix of common NTFPs above which showed it to be the most multi-purpose species in Swaziland with six uses).

Table 6: Total value of NTFP groups harvested for various purposes by ecological zone (US$ millions/year) (adapted from Hassan *et al.* (2002)

NTFPs group	**Highveld**	**Middleveld**	**Lowveld**	**Lubombo**	**Total**
Fuel wood	10.98	8.27	7.20	3.15	29.6
Thatch	0.36	0.46	0.47	0.03	1.33
Edibles	0.07	0.04	0.10	0.01	0.24
Medicines	0.01	0.09	0.03	-	0.10
Craft wood	0.01	0.04	-	-	0.06
Weaving grass	0.27	0.15	0.07	-	0.50
Fodder	0.30	0.33	0.20	0.06	0.99

Table 7: Top 10 most commonly harvested species in each of the categories of edible and medicinal NTFPs across the study sites

Species (* = introduced species)	Mass (kg) harvested/yr	Species	Mass (kg) harvested/yr
Edibles		Medicinal	
Sclerocarya birrea	755	*Aloe saponaria*	24.6
Strychnos spinosa	204	*Momordica onvolucrata*	12.0
Strychnos madagascariensis	186	*Momordica claematidia*	12.0
Aloe saponaria	180	*Tubernaemontana elegans*	8.5
Caterpillars	180	*Schotia brachypetala*	7.6
*Psidium guajava**	170	*Kigelia africana*	6.5
Umbhindolo (SiSwati name)	160	*Siphonochilus aethopicus*	5.6
Pollichia campestris	128	*Pittosporum viridiflorum*	3.5
Syzygium cordatum	124	*Rotheca hirsuta*	3.4
Englerophytum natalense	123	*Peltophorum africanum*	2.9
The prioritised multi-purpose species harvested for both edible and medicinal purposes			
Sclerocarya birrea; Psidium guajava; Momordica involucrata; Momordica clematidea; Aloe saponaria; Berchemia zeyheri*			

Resource surveys and economic valuation

The number of species recorded for the different ecological varied slightly between the zone but the differences were not statistical significant (Table 8). However, Umtfumunye natural forest and woodland in the Middleveld had a much higher number of species, for both edible and medicinal NTFPs. The Shewula Nature Reserve in the Lubombo Plateau had the highest number of multi-purpose plant species. Hlutse in the Lowveld had the lowest number of species. Overall the findings of the study indicate that the natural forests and woodlands selected for the resource surveys are denuded or heavily depleted of the preferred tree species of edible and medicinal NTFPs. As a result there were far too few tree species per sampling plot and it is not possible to establish relative frequencies of tree species based on DBH and height. This assessment could therefore only deal with the number of individuals per species. The differences between zones were, however, highly significant for inventory value, yields and unit prices (Table 8).

The general assessment is that the condition of the natural forests and woodlands in the selected study sites is poor. Some key species of edible and medicinal NTFPs have been noted as being lost from the sampled areas (Table 9). Patches of bare land were most noticeable in all the sampling plots in all study sites.

Table 8: Summary of the inventory and economic valuation in sampled forests/woodlands in the four ecological zones.

Study Area	**Hhelehhele North**	**Shewula**	**Siphofaneni**	**Grand Valley**
Ecological zone	Highveld	Lubombo Plateau	Lowveld	Middleveld
Name of Forest	Lufafa	Shewula Reserve	Hlutse	Untfumunye
Number of species	18	18	12	34
Growth form	**Number of stems per 10 plots (0.25 ha) by growth form**			
Trees	21	31	35	62
Shrubs	11	12	11	26
Understory	2	10	3	12
Other	7	5	2	60
Total	41	58	51	160
Categories	**Number of individuals (Number of species)**			
Edible plants	22 (7)	13 (8)	15 (6)	62 (15)
Medicinal plants	16 (11)	24 (11)	23 (6)	88 (26)
Multipurpose plants	3 (3)	21 (3)	13 (4)	10 (7)
Variable	**Stand values***			
Stems/ha per species	20.1	36.1	23.5	20.2
Value: US$/ha	230.8	785.2	852.0	510.0
Unit price: US$/species	7.6	12.0	11.5	14.6
Yield: kg/ha/yr	20.9	31.5	43.1	17.8

* Exchange rate: 1US$ is equivalent to R6.50 as at 2004 (Times of Swaziland, 2nd March2004).

Table 9: List of missing common/key species (based on available local literature and community consultations) in the inventory results across study sites

Edible species:	**Medicinal Species:**
Psalliota campestris	*Pittosporum viridiflorum*
Aloe maculata	*Drimia delagoensis*
Syzygium cordatum	*Schotia brachypetala*
Ficus sur	*Manilkara species*
Cephalanthus natalensis	*Harpephyllum caffrum*
Lannea discolor	*Encephalartos species*
Vangueria infausta	*Senecio rhyncholaenus*
Lantana rugosa	*Pterocarpus angolensis*
Berchemia zeyheri	*Maesa lanceolata*

Discussion

This study has shown that NTFPs have significant direct socio-economic use values and benefits at local and national level in Swaziland. Inadequate policy recognition in general leads to the underestimation of the role of NTFPs in sustaining rural economies (Dovie 2003).

But policy makers are not clear on what government, the private sector, or local communities can do to preserve an optimum level of forest biodiversity (Bhattarai and Hammig 1998). As an intervention, it is therefore necessary to ensure their sustainable use and management through proper management systems that should be provided for in the national and international policies and legislation relevant to the NTFP sector.

The existing national policies and legislation, including the national criteria and indicators for sustainable forest management, contain elements and issues of NTFPs but to a lesser extent compared to the existing international policies and legislation. This has made it difficult to develop NTFPs at the local and national levels, despite their ecological, environmental, social, cultural, spiritual, and economic roles in the country. The lack of a broader stakeholder participation and involvement, including resource users, particularly rural communities, in policy and legislation formulation processes is one of the reasons for the weak and ineffective policies. In this study a new 4-step hierarchical approach to policy and legislation review and analysis was developed and presented. The assessment of a total of 16 national and international policies and legislation based on 21 criteria provides a basis for the improvement of future natural resources management policies and legislation.

An analysis of previous studies in Swaziland showed a profound lack of information on the status of NTFPs. There is a great need for qualitative and quantitative statistics on the status of the full range of NTFPs (goods and services) in Swaziland. Shackleton and Shackleton (2004) raised similar needs from a study in South Africa because of the emergency net function and insurance which NTFPs provide during times of misfortune (drought, diseases, economic recessions, etc). Omission of the total true economic value of the direct and indirect use benefits and intermediate use services of NTFPs in Swaziland can lead to the government agreeing to land conversion from natural woody systems to other land use options (e.g. agriculture). A national resource and environmental accounting is necessary to safeguard decision makers in the selection and approval of development projects.

The updated main categories of NTFPs (goods and services) presented in this study, in line with other regional and international studies, provides a useful tool in the classification of NTFPs. The matrix displaying multi-purpose properties of species of commonly used NTFPs in Swaziland and the associated ranking of top priority NTFP species is a good basis for species selection for local and national level domestication and commercialization initiatives. This provide for the formulation and development of a standard procedure for economic valuation of NTFPs (Dlamini 2007) and an improvement of studies done in Swaziland by DANCED (2000b) and Hassan *et al.* (2002).

Local communities lack knowledge of the existing policies and legislation that safeguard the sustainable use of NTFPs in the adjacent natural forests and woodlands. They stated that there are no existing traditional local-level NTFP management systems. This is confirmed by the ongoing overexploitation and unsustainable use of NTFPs leading to the current accelerated rate of forest degradation and deforestation. Uncontrolled trade in NTFPs by non-resident collectors in South Africa is considered as one of the inevitable threats to forest biodiversity

(Dovie 2003). This reaffirms that the existing policies and legislation are weak, ineffective and not implementable. Proper and innovative policies and legislation need to be put in place to cope with the current challenges. The positive side is that local communities have identified potential threats to forest biodiversity and are willing to participate in the conservation and sustainable use of the adjacent natural forests and woodlands. They already have initiatives towards selection of top priority species for domestication and commercialisation. The institutional, cultural, socio-economic, ecological/environmental and policy issues raised by local communities provide a crucial and essential element and opportunity for the formulation and development of guidelines for local-level sustainable management and development of NTFPs.

This study captured a wide range in NTFP utilization. The method used in the economic valuation of NTFPs is an improvement of that suggested by Godoy *et al.* (1993, 2000) and FAO 2001). It considered assessing the use of NTFPs at the village doorstep and before the doorstep, which resulted in higher quantities and values per household compared to previous studies. The user surveys showed the variation, between and within the specified villages across the four ecological zones of Swaziland, in the actual annual quantities harvested and direct use values per household of selected edible and medicinal NTFPs. Some households extract fewer edible NTFPs compared to other households, particularly those in the Shewula area, Lubombo plateau, with reliable food aid programmes. Some households extracted fewer medicinal NTFPs, such as in the Siphofaneni area in the Lowveld with easy access to modern medicines. Households with many unemployed members rely more heavily on NTFPs for medicines, food and rural household income than those with employed members. For example, reliance on NTFPs is low in the Shewula area with more employed household members. The reliance on NTFPs with over 70% of the population of Swaziland being unemployed is a major subsidy to the Swaziland Government (see also Shackleton and Shackleton 2004). Governments should take a leading role in the formulation, design, development and implementation of local and national level projects and programmes for the sustainable management and development of NTFPs. The annual direct use values per household of this study are comparable to those reported by from the Soliga households in India (Hedge *et al.* 1996) and for South African rural households (High and Shackleton 2000, Shackleton *et al.* 2002).

The NTFP resource assessment and economic valuation in this study is a genesis of NTFP inventory and valuation in Swaziland. The sampling method yielded higher inventory values compared to the NTFP inventories in the Amazonian rainforests (Peters *et al.* 1989), in the tropical forests (Balick and Mendelson 1992) and in Maryland (Robles-Diaz-De-Leon and Kangas 1999). Besides differences in forest types and species composition, one reason could be that this study used smaller sample plots of 50 m x 50 m (smaller than the conventional 1 ha), and included all the plant growth forms (trees, small trees, shrubs and understory). Most other studies target mainly trees and exclude shrubs and understorey plants.

The information on species distribution and estimated standing value of the selected NTFPs showed their economic value. The values are relatively high despite the fast disappearance and extinction of top priority species. The increased demand for NTFPs may result in uncontrolled over exploitation of NTFPs, leading to accelerated forest degradation and deforestation, and possible future disappearance and extinction of important NTFP species. Shackleton and Shackleton (2000) showed that extraction rates of several secondary forest resources are sustainable but not for more important or preferred ones like fuel wood, construction wood and medicinal plants. An action programme for the rehabilitation of degraded forests and jungles is highly necessary, and should form part of the new National Forest Action Programme to combat this potential environmental catastrophe.

Conclusion

Three broad issues and a set of recommendations for the sustainable management of NTFPs need to be considered:

1. Decision makers, forest managers and resource users lack of information on beneficial NTFPs for individual, community, and national well-being, and the economic, ecological and social characteristics of NTFPs and their uses. Government efforts to research, compile and disseminate information and statistics to key stakeholders on NTFP resources and their socio-economic and ecological values should be strengthened. Government and development agencies should support education and public awareness programmes for NTFP conservation and sustainable use.

2. The lack of protected rights to access and benefit from NTFP resources can adversely affect their conservation and sustainable use and discourage investment in the resource. Government, with assistance from concerned agencies and organizations, should i) develop and implement policies and legislation to provide secure access and benefits for the people whose livelihoods are dependent on or supplemented by NTFPs; and ii) ensure that stakeholders, particularly collectors, growers and traders are provided incentives to sustainably manage NTFP resources.

3. Individuals, communities and institutions generally lack the technical, financial, political and social capacity to influence policies and generate information necessary to manage and monitor NTFP resources effectively. Government, with assistance from concerned agencies and organizations, should support programmes and projects to build individual, institutional and community-based capacity to manage NTFPs through active participation of stakeholders. Government and research agencies should give priority to research and the development and dissemination of management practices, integrated into multi-purpose forest and agro-forestry resource management.

Theoretical framework for the sustainable management of NTFPs

The adoption of a new theoretical framework (Figure 3) is recommended for the sustainable management of NTFPs at the local, national, regional and international levels, divided into eleven strategies, i.e. the blocks in Figure 3 (Dlamini 2007):

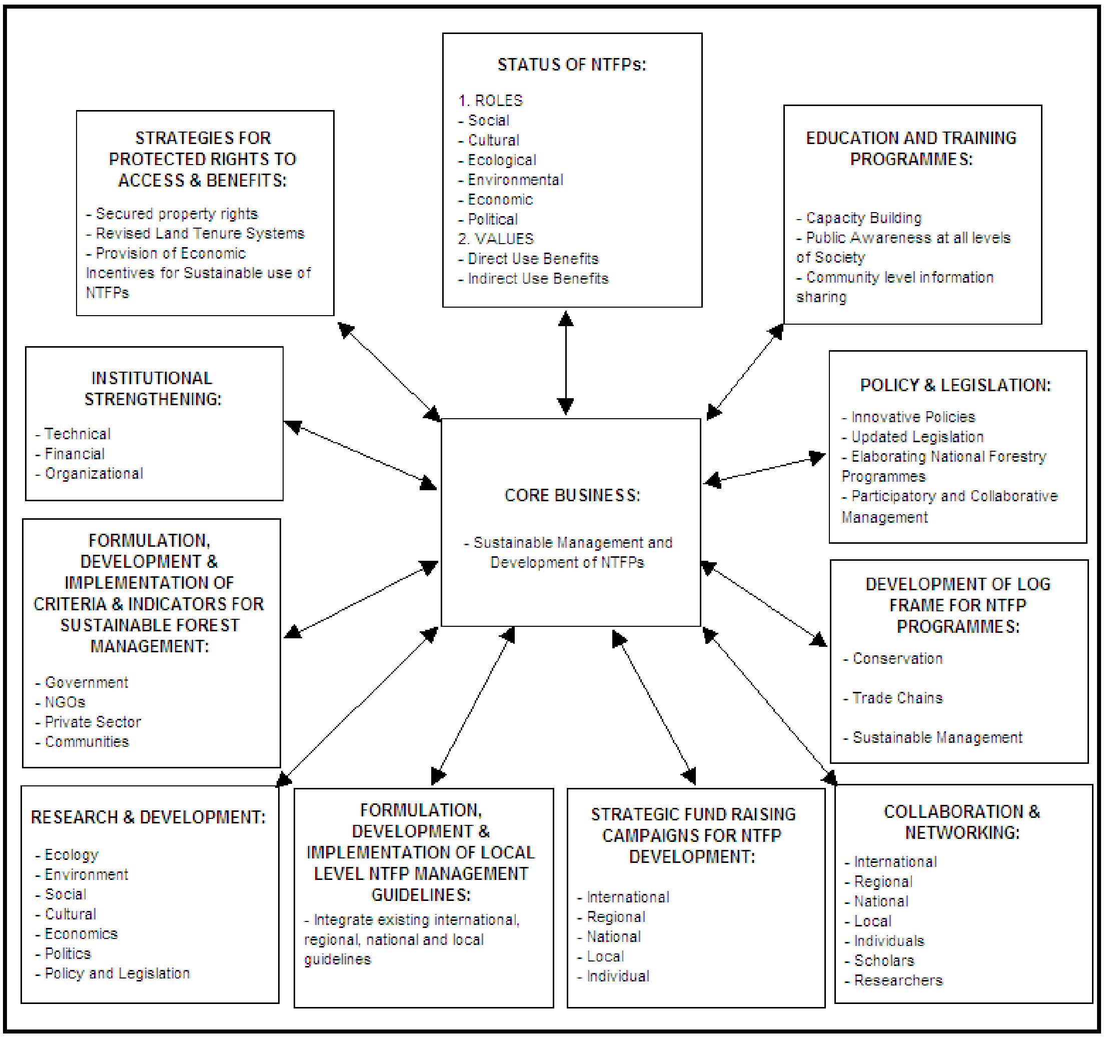

Figure 3: Schematic presentation of the key elements in the sustainable management and development of NTFPs (adapted from Dlamini 2007).

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NATURAL RESOURCES FROM COMMUNITY FORESTS: ARE SOCIO-ECONOMIC BENEFITS SUSTAINABLE FOR THE COMMUNITIES?

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Abstract

The Cameroon forestry law of 1994, which provides for the allocation of community forests (CF), among other things, gives rural communities access rights to the forest resources around their villages. This process is going through a lot of difficulties: local population empowerment, forest governance, adapting technical aspects to rural communities, difficult return on investment in real conditions (without external support), etc. Despite these difficulties, some communities (alone or with partners or projects) have had the opportunities and the willingness to implement “success stories” which are part of the already rich book of the Cameroonian community forestry. In two villages, logging of the CF has generated annual various revenues: community revenues (€3,500 and €4,800) and individual revenues (wages) (€9,500 and €11,600), depending on the level of external support to the community. Analysis shows that an economic model (€24/year/person in predominantly timber region) seems to be confirmed by the two cases (€26/year/person (2005) and €20/year/person (2007) chosen for this paper. These “low” profits could be largely improved by improving social, environmental, technical and economical sustainability. SNV and its partners develop supports to the main actors (rural communities, government, small and local private companies, CSO) in order to (i) take traditional arrangements into account (ii) reinforce the community forest management entities (iii) consider with high attention the forest allocation phase (iv) group the CF (“union of CF”) (v) allow the SMP to become a management sustainable tool (vi) take the other products (especially NTFP) into account.

What is community forestry?

The Cameroon forestry law of 1994 provides for the involvement of new actors in the management of forest and wildlife resources. The setting up of community forests (CF) guarantees rural communities access rights to the forest resources of their villages (Box 1). On the basis of a management agreement signed with the State (including a simple management plan, SMP), villagers have the opportunity to manage and harvest the products from their community forests and to consider opportunities for development (MINEF 1998, Brown *et al.* 2002). The objectives of community forestry are (i) to create jobs and generate income in rural areas, (ii) to improve the living conditions of the people, and (iii) to ensure the sustainable management of the environment while meeting the basic needs of rural communities. The aim is to reduce the basic triple constraint, namely (i) limited rural community access to forest resources, (ii) inadequate handling by communities of their own development, and (iii) almost non-existent income at the local level (Cuny and Tobith 2006).

Box 1

A Community forest is "a forest forming part of the non-permanent forest estate, which is covered by a management agreement between a village community and the Forestry Administration. Management of such a forest - which should not exceed 5,000 ha – is the responsibility of the village community concerned, with the help or technical assistance of the Forestry Administration". Source: Article 3(11) of Decree 95/531/PM of 23 August 1995.

Role of SNV in community forestry

The Netherlands Development Organization (SNV) has a long experience in community forestry (CF) in Cameroon. Firstly, through the project for Support to Sustainable Development in the Lomié/Dja region (SDDL), and secondly, the Capacity Building Programme (CBP, 2002–2005, co-financed by the British Department for International Development [DfID] and SNV) aiming at involving civil society organizations in the sustainable management of forests in order to fight poverty in Cameroon. CF enables the forest dwellers, one of the poorest segments of society, to increase their control over the generation and reinvestment of revenue based on legal production and commercialisation of high quality timber for fair prices (Klein *et al.* 2001). Since 2005, SNV Cameroon supports the community forestry process at meso level (NGO support to communities) and at macro level in order to improve the rules, taking into account all experiences (support to the sub-directory Community Forests of the Ministry of the Environment and Forestry [MINFOF]). Since 2007, SNV supports all actors (Civil Society Organizations [CSOs], private individuals/companies, government, etc.) specifically involved in reinforcement of the capacity of communities by grouping their CFs for an economy of scale, exchange of experiences, achieving better quality and quantity of products and better prices, etc. The SNV approach aims to reduce the main constraints related to CF management and wood commercialisation, to stimulate the use of legal timber from CFs by urban woodworkers and to increase the revenue of both forest dwellers and urban woodworkers.

ARE POPULATION NEEDS SATISFIED?

Timber from community forests

Management of CFs can "theoretically" yield revenues. A theoretical analysis of the costs and benefits of CF using an economic model (Vabi *et al.* 2002) showed significant variation in benefits derived by rural communities in three different regions (per year and per person): (i) predominantly timber where income is estimated at €24/annum, (ii) partly timber where income is estimated at €4.5/annum, (iii) predominantly non-timber forest products (NTFPs) where income is estimated at €4.2/annum. Another study (Klein *et al.* 2001) showed that a community that exploits its forest alone can obtain €95/m³ of sawn timber per annum (Eastern Province).

The SMP is a strategic document which defines and schedules the activities to be carried out in the CF within a given time and space. It is designed to serve as a viable instrument for forest resource management. The cost of preparing the CF application file of the Kongo village (supported by SNV) is estimated at €545, i.e. about €0.18/ha. The cost of preparing the SMP for the Kongo CF was €2,305, i.e. about €0.75/ha (excluding technical assistance provided by the project) (Assembe Mvondo 2006, Cuny *et al.* 2006).

After all these costs, in the small-scale framework foreseen by the law, logging requires the use of mobile saws (Lucas Mill-type) and the manual transportation of sawn timber by villagers (which sometimes causes health problems). Logging was done by villagers in contract with local private companies, without support from the project. Total revenue for the village and its inhabitants, over five years, was €65,300 (annual average: €13,000), i.e. €60/m³ and €26/year/person. Social/community benefits represented 27% of the total and direct income to individuals represented 73% (Cuny and Tobith 2006). Despite management difficulties and misappropriation of funds, the exploitation of the Kongo community forest led to significant socio-economic development of the village and generated substantial income for several families.

The case of Medjoh CF is different because of project support. Expenditure during the initial stages of development of this CF, before arriving at the logging phase, amounted to approximately €12,500 (€2.5/ha). Timber for the local market (kosipo or *Entandrophragma candollei*; dabema or *Piptadeniastrum africanum*) was sold at €60/m³. After deduction of the human resource costs related to harvesting, the community benefit was €13/m³. If the costs of loading and transporting the timber for sale on the local market, the community would have lost money, but the timber transport costs were paid for by a private international forestry company. Timber (iroko or *Melicia excelsa*) was sold at a higher price to local buyers (€170/m³). After withdrawal of the human resource costs related to the harvesting, the benefits were €68/m³. The reduction in the benefits is important when the running costs are taken into account (€31/m³) (Julve *et al.* 2007). Specifically, SCNIC, a small local private company supported by SNV) has supported the community in negotiating an international contract directly with "The Best Wood Company" (based in The Netherlands): the result has been a sale of 16 m³ of sawn timber with a net benefit of €110/m³ (twice as a sale through intermediaries).

In the Medjoh CF, if villagers could exploit 200 m³ (planned for the annual harvesting cycle, with 80% for the local market and 20% for the international market), the annual community and individual revenues would be respectively €4,800 and €11,600. The overall annual revenue would be €16,400 (€20/year/person).

In conclusion, the economic model of Vabi *et a.l* (2002), with €24/year/person in a predominantly timber region, seems to be good when compared to the Kongo revenue of €26/year/person (in 2005) and the Medjoh revenue of €20/year/person (in 2007).

Other products from community forests

The multi-resources inventory included NTFPs and particularly the fauna, but the plan made no provision for hunting of animals of for commercial harvesting of other NTFPs. Thus, the harvesting of fauna and NTFPs remains individualistic and domestic. Women harvest NTFPs to satisfy family needs for food (vegetables, condiments, oils, etc.), health care (strong use of medicinal plants) and other daily and domestic needs (packing, etc). Few specialized studies report on the valuation of NTFPs from CFs. The local community of the COPAL CF use many NTFPs (Akoa Akoa 2007). The economic study focused on four NTFPs: the community annually sells Njanssang (*Ricinodendron heudoletii*) and wrapping leaves of Maranthaceae for up to €15,200 and €7620 respectively; Andock (*Irvingia gabonensis*) and Gnetum (*Gnetum africanum*) each yield €1,000. Average revenue is theoretically estimated at €2.75/person/day.

This example shows that NTFPs can be a good opportunity for different components of the community (women, young people, etc.) to generate revenue with the valuation of these products. Compared with timber, NTFPs (and other products) are often considered as of low value (this could be false in forests low in timber sources), despite their diversity and multiple use. Their use varies considerably through time and space, and their sales can fluctuate strongly according market demand. NTFPs can provide sources of income which can overlap or can be in conflict. For example, fruit, bark and wood of the same species can provide different products for different uses.

Women organizations generally market wild mango (fruit and nuts of *Irvingia gabonensis*) and products of Maranthaceae which are favoured NTFPs in Cameroon, to generate some income.

Is sustainability achieved?

Social sustainability

The idea to create a CF is rarely the result of the willingness of the communities but it often comes from external actors with much interest in the process. This situation makes social mobilization difficult, with inadequate social organization and low representation of women and the youth in the offices of the management entities (SNV 2005). The process therefore is often taken over by some actors (most often the elite and businessmen), making ownership by local communities with limited capacity and resources difficult (Auzel *et al.* 2001). Thus the quality of the SMP varies according to the structures that prepare them. It is generally not done in a participatory manner (hence limited sharing of benefits by communities thereby not allowing good forest harvesting activities).

There are many organizational constraints. Communities do not manage the income derived from the harvesting of community forests adequately (misappropriation of funds) and this often leads to conflicts. It can happen that the timber buyers corrupt the forest managers in order to get the timber at a low price and/or no payment. There is a huge communication gap between those responsible for managing the forest and the rest of the community which, in the short-term, can cause conflict. The sharing of information, considered as a power, is difficult in the villages. The executive office (elected in the general assembly) loses its power as soon as the forest begins to create wealth to the advantage of other powers (clans, elitist, individualistic, tribal, etc.). In another way, the manual transportation of sawn timber on the head by villagers is a tedious, dangerous and costly exercise, especially when products are far from storage areas and derived from dense wood. Lastly, the process is often long, complex and difficult. For example, in the Medjoh CF, the conciliation meeting took place in 2000 (beginning of the process) and made it possible to define the limits of the forest; the SMP has been approved in 2005 and the harvesting started in October 2006.

Environmental sustainability

The harvesting from the CF has generally been fraught with many problems. Before 2003, about 40% of forests underwent industrial-type harvesting (MINEF-DfID 2004). Decentralized offices of MINFOF rarely monitor the process with the consequence that community forest management procedures are often incorrectly applied. Ecological sustainability can be endangered by over-exploitation and exclusive focus on timber species. Thus, the harvested volume of valuable species is often higher than the natural potential of the forest. This imbalance does not respect the SMP which can involve a suspension of the management agreement. It is often the case that annually the logger covers the whole forest in search of trees, which should have been harvested once in ten or even twenty years. Moreover, in the Kongo village, two species (sapelli or *Entandrophragma cylindricum*; moabi or *Baillonella toxisperma* account for 75% of the total volume as a result of selective felling (often without respecting the SMP).

Technical sustainability

The multi-resource inventory requires technical expertise (trained prospectors, data-processing), material (compasses, GPS, GIS) and financial means (€1.2/ha). Its preparation is very expensive and requires high level technical skills but calculations of yield regulation have value only for forests of a minimum area of 20,000 ha (Durieu *et al.* 2004). MINFOF do not have sufficient means to control sustainable resource use and the main part of the CF planning is confined to drawing a map of equal areas for annual harvests (Vermeulen *et al.* 1997). Finally, the inventory is rarely used as a tool of decision-making to aid development of the SMP (Julve *et al.* 2007).

Input supplies (fuel, lubricants, spare parts, etc) and maintenance of equipment are some of the major difficulties faced by communities to harvest and manage their forests (Nguenang 2003). Control (or information on irregularities) of community forest harvesting by the rural population is also difficult (limited power).

Economical sustainability

Communities encounter major problems in marketing their forest products due to the absence of a marketing culture, lack of skills and logistics. Investment is large at the beginning of the process: inventory of the forest resources, SMP preparation, costly Lucas Mill-type mobile saws (too expensive for communities) and the purchase of a bill of loading to MINFOF (transportation of timber forest products).

Other constraints limit the profits of villagers: (i) Low price cheating by wood buyers and middlemen (prices imposed; not negotiated) (ii) Contracts often oriented towards the interests of the timber company or wood buyers, often too vague, and rarely respected. For example, in Kongo the communities receive €39/m^3 for *Entndrophragma utile* whereas its Free On Board (FOB) value is €214/m^3. Moreover, operations of timber grading are often against the population interests and some buyers do not pay for timber delivered by communities.

In these conditions, return on investment (ROI) is very difficult and situations of dependence are developing (in particular with private forest companies as in Medjoh), but are not viable in the long term. CF should not depend on the willingness of the external actors but must aim at an internal efficiency in order to be able to achieve its goals within its own means (sale of products). In addition, the official formal market (within which the CFs should operate) cannot be in competition with the parallel illegal timber market chain frequently called "wild sawing", an activity conducted because of the legal constraints and, which do to corruption, create prices which are impossible to compete with.

Lastly, government now requires an Environmental Impact Assessment (EIA) which poses a new administrative burden for the community. The cost of the CF management process increases because of the EIA price of €11.000 which reduces the possibility of poverty alleviation.

Ways to improve the process towards sustainability

The many difficulties and constraints mentioned above make it difficult to reach sustainable management of CFs, especially in the framework of logging. SNV (with other actors) is involved in different processes to facilitate a better implementation of CF practices.

Consideration of traditional arrangements

It is often difficult to achieve actual representation in some villages at the side of the road (composed of many non-local groups), and in others with Pygmies or migratory herders (who are often excluded). Traditional village organizations are often not considered when NGOs prepare the implementation of the legal CF management entity. However, villagers have traditional systems of organization, such as the “gula” (system of traditional council meetings), that maintains the balance of power in the village and therefore have strong social legitimacy and a good representation. In the east of Cameroon, the “boumkwa” (community of wise villagers) could also be considered. The specific decision-making systems of the Pygmies (the “yé”) involve several groups (including women) who first discuss issues separately and then come together in a “plenary”. On the basis of these traditional systems of management, including sanctions (where they still exist), the organizational capacity of the legal CF management entity (association or Common Initiative Group [CIG]) can be strengthened. The traditional authority may see new structures such as the CIG as a rival entity (competing for power and money) and conflicts between these two types of power may develop. Developing a partnership between the NGO and the traditional leadership may help to prevent such potential conflicts (Cuny 2004).

Reinforcement of the legal community forest management entity

The management entities (ME) have to improve (i) the representation and social legitimacy of their leaders, (ii) their governance (better respect for articles of association and the rules), (iii) their capacity to negotiate transparent contracts with actors (harvesting or marketing), in relation to the SMP (to avoid over-harvesting of their forest resources), (iv) transparency in their management of accounts (better income management capacity), and (v) their acceptance of a strong control by the village community.

Acceptance of the forest allocation phase

It is necessary to ensure ongoing sensitization of community members at the start and throughout the CF management process to enable the whole population to understand the developments and to assure control over the technical activities and management of revenue. In communities lacking stable leadership structures (southern Cameroon), social development aimed at ensuring community empowerment may take time towards adoption of a "community spirit". Throughout the development process there should be buy-in from all actors to develop a sense of ownership of the concept, particularly by women and minorities who are often excluded of the process. This phase is important because it lays the foundation for the community participation approach and unites people around a common goal. This would limit groups with divergent objectives and interests to eventually endanger the whole exercise.

Grouping of community forests

SNV (and other actors like World Wide Fund for Nature [WWF] and Nature+) supports the concept of grouping of the CFs to form a "Union of CFs" because of (i) experience sharing and support between the CFs ("we are together"), (ii) the possibility of using the logging equipment jointly (with precise rules), (iii) marketing of products of quantity/quality according to the market demand, (iv) potential to diversify production (NTFPs, fisheries, etc.), (v) the possibility through combined action, of lobbying/advocating/negotiation with the government (particularly against administrative bureaucracy and illegal harvesting), and (vi) seeking funds together. However, such a union of CFs should not constrain the autonomy of each CF. Lastly, the contract procedure, described above, could be supported by grouping CFs to create an economy of scale and increase the diversity of species used. The union of CFs should develop an "entrepreneurial spirit" and unity: for example, ten associations can each year offer more than 5,000 m^3 and a large volume of quality species to timber harvesters within a specific contractual framework that protects the interests of each community and, in the long-term, aims at certifying timber intended for export.

Use the simple management plan as a tool to achieve sustainable management

The SMP has to become a sustainable management tool, despite the fact that it is a new concept for the communities, it is not very applicable to small scale operations, and MINFOF does not ensure effective follow-up (because of lack of interest and means). CF develops amongst part of the community a concern for conservation which is translated into concrete reality by population supervision and reduction of illegal small-scale logging. Harvesting (in collaboration with small private operators) can be a mining operation (a threat to forest biodiversity) if it is focussed on a very limited number of species of high value on the timber market. It is therefore essential to distinguish between management (community approach) and exploitation-marketing (private or cooperative approach). This involves strengthening the contracting capacity/ability of a community (it is the community that "decides"...). SNV through its operating teams is carrying out actions in this way. Grassroots' organizations (CIGs and unions) backed by NGOs, need assistance in negotiating contracts and ensuring respect for their execution. The functioning of grassroots' organizations must be assessed by the people themselves and improved upon on the basis of the internal working of the community without losing sight of the fact that the management of a CF is a community project.

Timber should not be the only resource

Numerous other opportunities can be integrated into the CF management beyond the current focus on timber: NTFPs, ecotourism, subsistence hunting, small-scale fishing, extraction of sand, stones or ores, reforestation, handicraft, fuel wood, charcoal, farming (commercial / subsistence crops), etc. All these opportunities would allow the SMP to become polyvalent and thereby involve all the components of the society. NTFP valuation in a CF could be made with (i) the study on the situation of the various NTFPs (statute, pressure), (ii) the development of plans of specific management for certain NTFPs, (iii) the creation of village nurseries, (iv) the development of the harvesting and marketing of certain NTFPs, and (v) the security of the product value chains. However, for the NTFP industry to enter the Cameroonian mainstream industrial culture, it is critical to attempt the integration of the timber industry with the NTFP industry to benefit both sectors. There are four possible types of interaction between the NTFP and timber industries: independent resource use, competition for resources, complementary resource use and symbiotic resource use. The latter two seem the most adapted to the context of Cameroonian CFs and experiences in these two approaches could be incorporated into such integrated and collaborative management within the community forests.

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SNV is a Netherlands Development Organization. It is present in 32 countries including 17 in Africa. It has been operating in Cameroon since 1963 and provides support, counseling and guidance to civil society organizations, local communities, decentralized services of the State and the private sector. Through its main areas of action (community forestry, NTFPs, pastoralism / livestock, water, health), SNV seeks to accomplish two main goals: job creation / income generation, access to basic services, without losing sight of social differences

between minorities and the other components of the society. SNV ensures that activities carried out in all its areas of action have a positive effect on gender relations.

Acronyms

CF	Community Forestry / Forest(s)	MINEF	Ministry of the Environment and Forestry
CIAD	International Support Centre for Sustainable Development	MINFOF	Ministry of Forestry and Wildlife
CIG	Common Initiative Group	NGO	Non-Governmental Organization
COPAL	Coopérative des Paysans et Agriculteurs de la Lékié	NTFP	Non-Timber Forest Product
CSO	Civil Society Organization	ROI	Return on Investment
DfID	Department for International Development	SCNIC	
EIA	Environmental Impact Assessment	SDDL	Support to Sustainable Development in the Lomié/Dja region
FOB	Free On Board	SMP	Simple Management Plan
GIS	Geographic Information System	SNV	Netherlands Development Organization
GPS	Global Positioning System	WWF	World Wide Fund for Nature

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HOUSEHOLD VULNERABILITY AND THE SAFETY-NET FUNCTION OF NTFPs IN THE EASTERN CAPE AND LIMPOPO PROVINCES, SOUTH AFRICA

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Abstract

Many rural households live in and depend on forests, deriving multiple benefits from the goods and services provided. These extend beyond the direct-use and associated cost saving, and include an important safety-net function. NTFPs as a rural safety-net offer both consumption- and income-smoothing options. Despite the increasing awareness of the potential role played by NTFPs in helping households cope with vulnerability, the empirical evidence of this function, its prevalence and how it manifests is still sparse. In light of these gaps in the understanding and appreciation of the potential safety-net role of NTFPs, this study examines the safety-net function within two rural villages in South Africa thereby contributing towards an understanding of this role. Rural households in both villages are vulnerable to a range of risks, shocks and trends. Annual expenses (including school fees), increasing living costs, social expenses and expenses associated with illness/injury were experienced by more than 60% of households over a two year period. Households turn to a range of coping strategies in response to these crises, however certain responses were found to be more common irrespective of the shock in question. Those used more prevalently both in terms of proportion of households and the range of crises for which they were employed, include the use and sale of NTFPs (70 %) and kinship (85 %). The use of NTFPs as a rural safety-net was found to manifest through both the use and sale of various products (with certain products being favoured particularly fuel wood) with increased use being the more dominant manifestation. Understanding households' own strategies for combating poverty and vulnerability is important for the effective targeting of public safety-nets.

Introduction

The livelihoods of rural households throughout the developing world are inherently fragile, exposed to shocks, trends and seasonal fluctuations over which households have limited or no control (DFID 1999). Shocks include human, crop and livestock health shocks and economic shocks. These are generally unpredictable in nature, can destroy assets or compel people to precipitately dispose of assets as a means to cope. Trends are more predictable and do not necessarily impact negatively on households. These include population, resource, technological, economic and governance trends. Seasonality is described as an enduring source of hardship and includes the seasonality of process, production, health and employment opportunities (DFID 1999). Rural households adopt a range of livelihood strategies, draw from diverse income sources and invest in an assortment of assets in an endeavour to achieve their livelihood outcomes and provide a buffer to risk (Niehof 2004, Bryceson and Fonseca 2006). These livelihood strategies include off-farm and land-based strategies, including the use and sale of non-timber forest products (NTFPs).

Coping strategies are characterised by a household's resilience to shocks and ability to return to a former livelihood status by relying on diverse incomes, food sources, skills and kinship networks (De Waal and Whiteside 2003). Recently NTFPs have been considered for their role in minimising crises-related impacts on rural households and as a possible means to assist households to move out of poverty (Angelsen and Wunder 2003, Belcher *et al.* 2005). NTFPs are used to meet basic needs, are sold to generate cash and serve an important gap-filling or safety-net function (Khare *el al*. 2000, Shackleton *et al.* 2002). A household's degree of vulnerability and the NTFPs used as a safety-net are determined by the nature, probability and intensity of the shock as well as the household's ability to cope with such shocks in terms of alternative income sources and insurance mechanisms (Angelsen and Wunder 2003, McSweeney 2003). The need for empirical data on the value and strength of the safety-net function of NTFPs as well as how the safety-net function manifests is still necessary (Shackleton and Shackleton 2004, Belcher *et al.* 2005). There is a lack of characterisation and common understanding of what constitutes a safety-net, as offered by access to and use of NTFPs. Furthermore, research has often focussed on tropical forests with less focus on resources from other ecosystems including savannas and woodlands. Consequently there is the need to examine the concept and nature of rural safety-nets in the South African situation with a particular focus on the role of NTFPs. For the purposes of this study the safety-net function of NTFPs has been classified as the increased use of NTFPs, the use of different NTFPs or the sale of NTFPs by households in response to times of need.

Study area

Two study sites were chosen, both within former homelands (as designated under South Africa's apartheid government). The village Dyala lies in the Kat River valley of the Eastern Cape Province. Dixie is in the Bushbuckridge Municipality of the Limpopo province. According to Gelb (2003) the Limpopo and Eastern Cape provinces are the two poorest in the country.

Biophysical environment

Dyala experiences warm, wet summers and cold winters. Mean annual rainfall is 997 mm. The surrounding area is a mosaic of grasslands and forest patches, including commercial timber plantations and natural evergreen forest. Classified as Amathole Montane Grassland

(Mucina and Rutherford 2006), highveld sour grasses are common although where heavy grazing occurs, the indigenous pioneer *Acacia karroo* has spread. Non-perennial and perennial streams ensure a water supply.

Dixie experiences dry, frost-free winters and warm, wet summers (Swart 1996). The mean annual rainfall is approximately 600 mm although erratic rainfall, frequent droughts, poor soils and limited land make cultivation difficult and crop failure common (Shackleton and Shackleton 2000). Dixie falls within the "Granite Lowveld" vegetation type (Mucina and Rutherford 2006).

Socio-economic environment

Former homeland areas throughout South Africa have similar characteristics in terms of poor service provision, low levels of development, high unemployment and a reliance on diverse livelihood strategies. Both Dyala and Dixie have limited infrastructure with no electricity, potable water or sewage reticulation. People rely primarily on river- and rainwater while fuel wood and paraffin constitute the primary forms of energy. Both communities rely on nearby regional centres for more diverse services.

General economic activity in the surrounding areas is low with high unemployment. For Dyala residents, there are limited opportunities in the forestry sector, small-scale tourism ventures and as seasonal farm labourers. In Dixie, tourism and the informal economy are the major employers. Participatory Rural Appraisal (PRA) exercises indicated a high dependence on government welfare grants. Land-based strategies include arable agriculture, animal husbandry and NTFP use.

Land in the Kat River valley is a mix of private and communal/state land ownership. The Dyala community has open access to land, including natural forest, except for the surrounding forestry department timber plantations where access is controlled by permit. Land-use in Dixie is a mix of residential plots, arable fields, communal grazing areas and up-market private conservation areas. The community has residential, grazing and cropping rights to the farm on which Dixie was established in 1963. Despite much of the area being marginal for agriculture, households are involved in subsistence arable agriculture and animal husbandry (Shackleton and Shackleton 2000).

Materials and Methods

Structured and semi-structured household interviews were employed. These addressed households' livelihood strategies (including the use and sale of NTFPs), households' vulnerability context over a two year period and households' response to crises, taking all coping strategies into account but focussing in particular on the safety-net function of NTFPs

(Paumgarten 2006). One hundred households were sampled: fifty households in each village. The data were analysed: for nominal categorical data a Pearson's Chi-Squared Test was used to determine significant associations between variables whilst numerical values were analysed using a t-test for independent samples (where the data was normally distributed) or the non-parametric Mann-Whitney U Test if the data failed tests for normality and homogeneity.

Results

Household vulnerability

All the sampled households were exposed to at least one crisis, either anticipated or unanticipated, during the two year period (Table 1).

Common crises, experienced by more than 50% of households, were illness/injury, increased living costs, and annual, social and agricultural expenses. The crises were experienced by households in both villages with significant differences existing in five cases: social expenses, loss of/damage to property, death/funeral expenses (Dixie), agricultural expenses and crop loss/damage (Dyala) (Table 2).

The use and sale of NTFPs

In both villages all the sampled households reported using NTFPs suggesting that as a safety-net, this option is available to all. Before considering the safety-net function of NTFPs, the more regular use was considered. All the sampled households reported using NTFPs, while 22% were involved in the sale. Households in Dixie were using and selling a significantly greater number of resources than in Dyala (Table 3).

With respect to the different NTFPs, there were significant differences in the proportions of households consuming in the case of thirteen. Those NTFPs where no significant inter-village differences existed included fuel wood, wild fruits, medicinal plants, honey and thatch grass. With respect to those NTFPs where significant differences did exist, in all but two cases a greater proportion of households in Dixie were using the resources. The exceptions were wild mushrooms and grass hand-brushes (Table 4).

Table 1: Descriptions of identified anticipated and unanticipated crises

Crisis	Description
1. Anticipated crises	
Annual expenses	• Associated with school fees and related costs.
Social expenses	• Associated with social events including Christmas, Easter and traditional ceremonies.
Agricultural expenses	• Expenses associated with arable agriculture.
Seasonal crop shortfalls	• Crop shortages from seasonal fluctuations in planting and production.
2. Unanticipated crises	
Livestock diseases/death	• Expenses associated with the treatment of livestock diseases and loss.
Crop loss/damage	• Resulting from pests, heavy rains, diseases, poor seed, etc. • Included total crop failure.
Loss of/damage to property	• Resulting from fire, weather, theft and rats.
Illness/injury	• Associated with medical costs. • Associated with effects on household labour and/or income.
Death/funeral expenses	• Costs (food, cash and livestock) associated with the funeral of household members or extended family.
Loss of income	• Resulting from the retrenchment, injury, suspension (usually temporary), resignation, retirement or death of the income earner or government-grant receiver. • Resulting from the retraction of a government grant. • Loss of income after the completion of temporary employment.
Increased living costs	• Includes the increasing cost of food and household items. • Group discussions indicated an increased reliance on NTFPs.

Table 2: Proportion of households (%) that experienced crises over a two year period

Crisis	Mean	Dyala	Dixie	X^2	Significance
Annual expenses	72	74	70	0.2	>0.05
Social expenses	67	50	84	13.1	<0.05
Agricultural expenses	52	64	40	5.8	<0.05
Seasonal crop shortfalls	45	50	40	1.0	>0.05
Livestock diseases/death	38	42	34	0.7	>0.05
Crop loss/damage	43	54	32	4.9	<0.05
Loss of/damage to property	50	32	68	12.9	<0.05
Illness/injury	66	66	66	0.0	-
Death/funeral expenses	39	28	50	5.1	<0.05
Loss of income	30	28	32	0.2	>0.05
Increased living costs	78	78	78	0.0	-

Table 3: Mean number of resources used per household

	Dyala	Dixie	T/Z	Significance
Mean number of resources used per household	7.2±0.2	10.2±0.2	*-10.6*	<0.05
Mean number of resources sold per household	0.1±0.1	0.6±0.2	*-2.1*	<0.05

Table 4: Proportion of households (%) using different NTFPs

NTFP	Dyala	Dixie	Mean	X^2	Significance
Fuel wood	96.0	100.0	98.0	2.0	>0.05
Sand/soil/clay/termite mounds	92.0	100.0	96.0	4.2	<0.05
Wild edible herbs	80.0	100.0	90.0	11.1	<0.05
Wild edible fruits	88.0	84.0	86.0	0.3	>0.05
Medicinal plants	68.0	88.0	78.0	5.8	>0.05
Wooden utensils	52.0	94.0	73.0	22.4	<0.05
Twig hand-brushes	46.0	96.0	71.0	30.4	<0.05
Grass hand-brushes	92.0	28.0	60.0	42.7	<0.05
Fencing poles	42.0	70.0	56.0	7.9	<0.05
Weaving reeds	0.0	94.0	47.0	88.7	<0.05
Bushmeat	10.0	50.0	30.0	19.1	<0.05
Fish	0.0	52.0	26.0	35.1	<0.05
Wild honey	22.0	22.0	22.0	0.0	>0.05
Insects	0.0	38.0	19.0	23.5	<0.05
Housing poles	2.0	28.0	15.0	13.3	<0.05
Thatch grass	14.0	16.0	15.0	0.1	>0.05
Mushrooms	12.0	0.0	6.0	6.2	<0.05
Seeds	0.0	8.0	4.0	4.2	<0.05

Fewer NTFPs were sold namely, fuel wood, sand, herbs, wooden utensils, grass hand-brushes, bushmeat, weaving reeds and seed jewellery. Of those households selling NTFPs, 72.7% had started to sell within the preceding five years while 90.9% stated they would continue to sell unless they found employment or got too old/sick to collect. Households gave a variety of reasons for engaging in the sale of NTFPs with the primary reasons being for the purchase of food/household goods and in response to demand (Figure 1).

Safety-net function of NTFPs

All of the households had experienced at least one of the identified crises. NTFPs were used as a safety-net in response to the complete range of crises (Figure 2) with significant inter-village differences for annual expenses and seasonal crop shortfalls. Seventy percent of households reported the use of NTFPs as a safety-net. This excludes those households that reported relying on NTFPs in response to increasing living costs. If these households are included then 82% of households expressed a reliance on NTFPs as a safety-net, making NTFPs the second most common strategy after kinship. Excluding this percentage, Paumgarten (2006) found kinship (85%), reduced spending (74%), changed diet and budgeting (72%), NTFPs (70%), selling livestock (44%) and stokvels (41%) to be common coping strategies although other strategies were identified.

Of the households that relied on NTFPs in response to crises, 40% used medicinal plants, 30% fresh herbs, 25.7% fuel wood, 17.1% dried herbs, 11.4% fruits, 8.6% construction materials and 7.1% bushmeat while 10% sold fuel wood and 8.6% sold other NTFPs (Figure 3). While some NTFPs were more crisis-specific, others were used in response to a variety of crises (Figure 4). For example, building materials were used exclusively for repairing damaged houses. Medicinal plants were the most common NTFP, used for human and livestock diseases/injuries but not in response to other crises. Fuel wood was used in response to eleven of the twelve identified crises, but predominantly for those crises affecting household income (e.g. increased living costs) or for anticipated crises (e.g. annual expenses). Fuel wood was sold in response to nine crises, again predominantly in response to crises affecting income (e.g. retrenchment and inflation) but also to raise money for anticipated expenses such as social ceremonies. Respondents explained that fuel wood was the most reliable NTFP in terms of sale as there is always local demand. Wild foods were used in response to ten crises. As with fuel wood, this was as a cost-saving substitute. Wild foods were used by households in response to crises that affected household income (e.g. retrenchment and inflation), diet (i.e. crop loss and seasonal crop shortfalls) as well as anticipated expenses such as annual expenses. Other NTFPs, including bushmeat, wooden utensils and grass hand-brushes, were sold in response to eight of the crises.

In addition to the selected crises, households were asked to detail times when their household had either: (i) used more NTFPs than normal (36%); (ii) used NTFPs not normally used (10%); (iii) sold more NTFPs than normal (8%) and (iv) sold NTFPs not normally sold (8%).

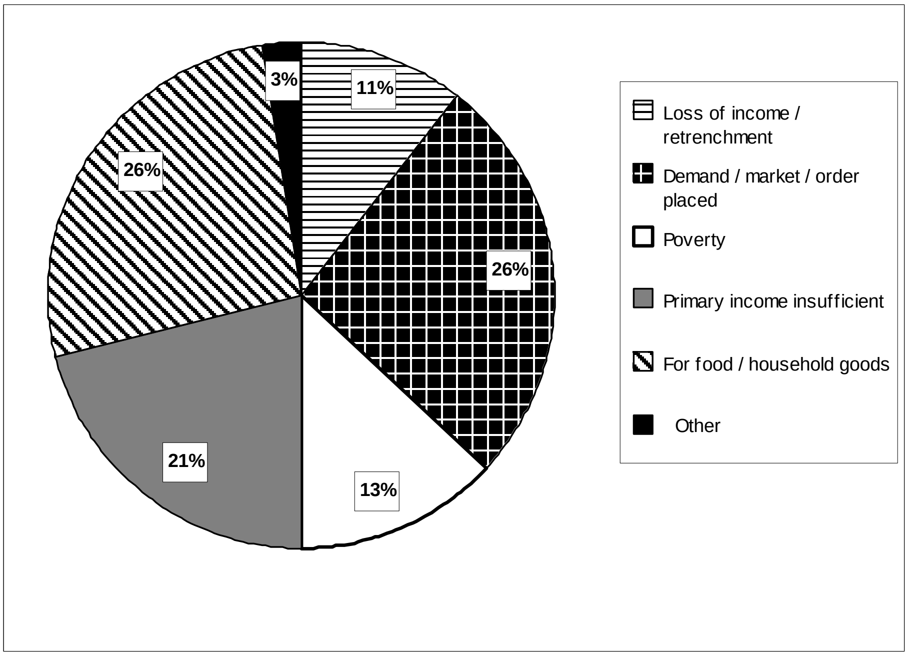

Figure 1: Reasons households sold NTFPs over the two year period

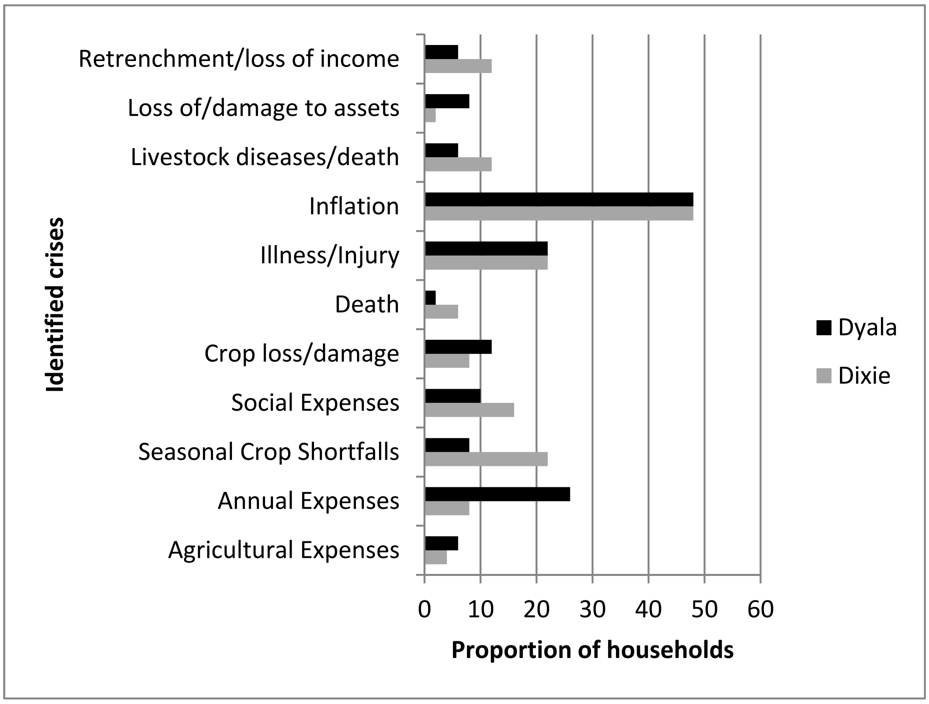

Figure 2: Proportion of all households (%) using NTFPs in response to identified crises

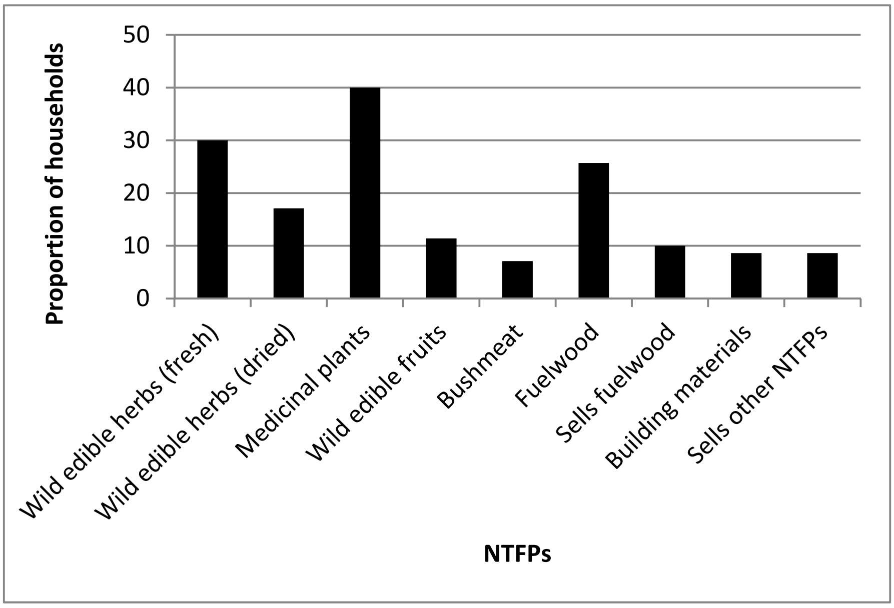

Figure 3: Particular NTFPs used by households in response to crises

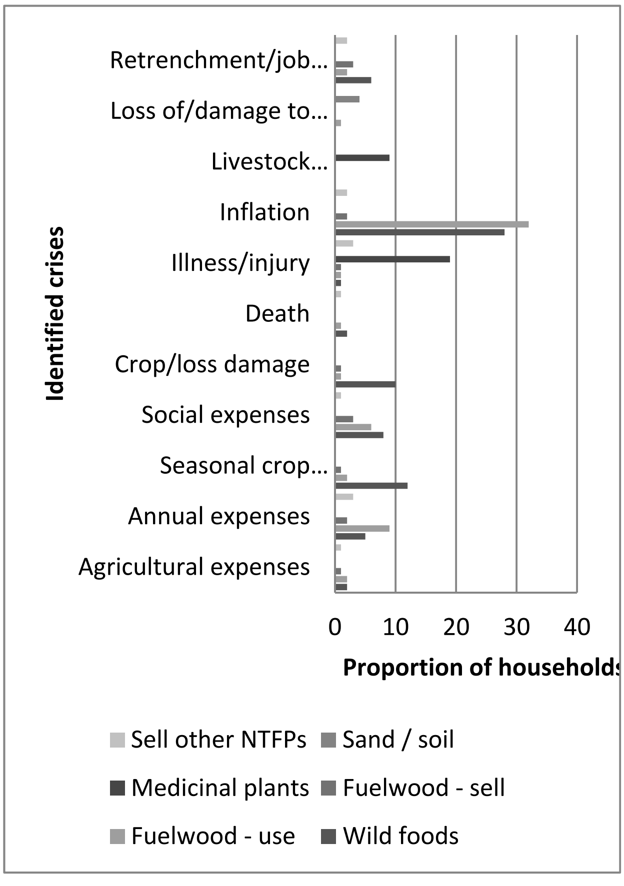

Figure 4: Particular NTFPs used in response to specific crises

Discussion

Households in this study associated vulnerability with unanticipated shocks, anticipated periods of hardship as well as with trends such as the increasing cost of living. Other commentators have identified a similar range of crises suggesting these are a common feature of rural livelihoods (Pattanayak and Sills 2001, Sen 2003). Of the identified crises all of the households had experienced at least one, with some reporting the occurrence of several. Households can experience multiple crises over a reasonably short time-period suggesting the need for either a select few effective means of coping or a diversity of strategies to ensure resilience. It is hypothesised that with potentially limited recovery time between crises, a diversity of strategies ensures robustness. An appreciation of households' means of coping is necessary to effectively target assistance.

Rural households use various NTFPs for both consumption and sale (Cavendish 2000, Shackleton *et al.* 2001). The proportion of households can be high particularly for key resources such as fuel wood and wild foods (Dovie 2003, Shackleton *et al.* 2002). This study supports these findings: all households sampled reported the use of NTFPs with wild herbs and fruit, sand and fuel wood being used by more than 80%. Summarising findings of resource use across South Africa, Shackleton *et al.* (2001) noted 70-100% of households use fuel wood, 72-100% use wild fruits, 93-100% use wild herbs, 50-100% use medicinal plants and 90-100% use wooden utensils. This study shows spatial variability in NTFP use with local conditions playing a role. This spatial variability may have implications for land-use planning, development programmes and policy aimed at poverty alleviation and sustainable NTFP use.

Twenty-two percent of households were selling NTFPs supporting findings by Shackleton *et al.* (2000) who identified regions of South Africa where up to 25% of households were selling. Households in Dixie were selling a significantly greater average number of resources per household than their Dyala counterparts. Local conditions affect the trade in NTFPs. In Dyala the sale was largely to meet local demand. Households in deeper rural areas market products through informal networks selling opportunistically or in response to orders from community members (Campbell *et al.* 1997). In Dixie resources were sold to meet local demand as well as the growing market offered by tourists. This commoditisation of traditional crafts for sale to tourists is an important aspect of NTFP trade throughout South Africa (Shackleton 2005).

The safety-net role of NTFPs was prevalent with 70% of households reporting this function. If the substitution of purchased products with NTFPs in response to increasing living costs is included, then the safety-net function was reported by 82% of households. This safety-net function is an important component of NTFP use (Pattanayak and Sills 2001). The high proportion of households relying on NTFPs as a safety-net combined with the proportion that use and sell NTFPs regularly, suggests households derive considerable benefits from NTFPs. Additionally it suggests that the direct-use value may be an insufficient indication of the contribution made by NTFPs to livelihoods. Shackleton and Shackleton (2004) suggest that the safety-net option may be of higher value than the direct-use value.

The safety-net function of NTFPs was found to manifest through direct household provisioning and sale allowing for consumption- and income-smoothing. The results show the use of NTFPs to be a more prevalent manifestation of the safety-net function. The use of NTFPs included: (i) the use of wild foods as a dietary supplement and substitute when crises impacted on household food security and ability to purchase foods; (ii) the use of medicinal plants as a cheaper alternative to "western medicines", and (iii) the use of fuel wood as a substitute for more costly forms of energy. Pattanayak and Sills (2001) noted the reliance on NTFPs for food, medicine and to generate cash through sales. Wild foods constitute both a nutritional supplement and a gap-filler particularly during times of low agricultural productivity (McSweeney 2003, De Merode *et al.* 2004). De Merode *et al.* (2004) highlight that the unsustainable use of particular wild foods is not only of concern for conservation but also that the depletion of these foods may exacerbate food insecurity, vulnerability and poverty. De Jong *et al.* (2000) noted an increased reliance on medicinal plants in Zimbabwe in response to declining health services while Skoufias (2003) highlights that if households rely on NTFPs for minor crises they can save their other options, ensuring future welfare.

With respect to the sale of NTFPs as a manifestation, fewer households sold NTFPs with the most commonly sold product being fuel wood (10%). Other products sold included reed mats, carvings, thatch grass and bushmeat (8.6%). McSweeney (2003) noted approximately 9% of households relying on the sale of NTFPs with different products sold to meet different needs. This study however identified the sale of fuel wood in response to a range of crises with fewer households selling other products. Fuel wood was identified as a key product to sell as it is both available and used throughout the years. Additionally the wood can be collected and stored to be sold when the need arises. Others have noted the importance of wood products for this reason (Pattanayak and Sills 2001). The findings suggest that as a livelihood and coping strategy the sale of NTFPs is becoming increasingly important in response to continued vulnerability in South Africa's rural areas supporting findings by Shackleton (2005): more than 70% of those households selling NTFPs had started to sell within the preceding five years.

Conclusion

This study has shown that rural households are vulnerable to various crises corroborating others who have noted this vulnerability (Pattanayak and Sills 2001, Sen 2003). The results highlight the extent of vulnerability with all of the households reporting experiencing at least one misfortune over the two year period. NTFPs contribute towards risk reduction and decreasing vulnerability on a daily basis and during exceptional circumstances (Pattanayak and Sills 2001). Findings on the high proportion of households using NTFPs, the resources used most prevalently as well as the trade in NTFPs support findings from elsewhere in South Africa (Shackleton *et al.* 2001). For most households the trade is a recent development in response to increasing vulnerability with the majority of households stating they would continue to sell due to a lack of alternative income sources.

Over a two year period more than two-thirds of households had relied on NTFPs as a safety-net. This safety-net role was found to compare favourably to other coping strategies. Households used NTFPs in response to a variety of crises highlighting the importance and multi-functionality of this role. Most of the households increased their use of NTFPs in response to crises with a smaller proportion selling products. The findings suggest that particular resources are used more commonly for coping, with a focus on fuel wood, medicinal plants and wild foods. Fuel wood and curios are selected for their marketability whilst wild foods and fuel wood contribute to household consumption-smoothing. The use of select products implies that if increasing poverty drives more households to an increased reliance on NTFPs, particular products face the risk of unsustainable use and over-utilization.

To deliver “real” benefits to those living with persistent vulnerability, cognizance needs to be given to the variability of opportunities, risks and choices households face. In light of evidence that NTFPs contribute to a significant proportion of households in both villages on both a regular basis as well as through the safety-net function, access to and maintenance of this resource base should not be undermined unless alternatives are provided (Cavendish 2000). The safety-net role needs to be communicated to policy developers and land-use planners for the benefit of poverty alleviation strategies and to ensure the sustainable use of NTFPs. Well managed systems of access to subsistence resources should be essential both with respect to safety-nets and environmental sustainability (Scherr 2000). Ackermann (2003) advocates the need for long-term forest management, increased agricultural production, land-use planning, sustainable use, the provision of alternative insurance mechanisms and the domestication of wild foods. Findings of the high proportion of households relying on NTFPs recommends further research and suggests that the realization and valuation of the safety-net function may contribute to arguments to sustain natural systems in order to contribute towards poverty reduction. Maintenance of and continued access to communal lands and the resources provided may contribute significantly towards sustaining and improving the welfare of rural households.

Understanding households’ own strategies for combating vulnerability is important for the effective targeting of public safety-nets (Skoufias 2003). NTFPs are considered an important safety-net for the poor who lack access to alternatives (Pattanayak and Sills 2001) however the realisation of the contribution made must not detract attention from other development strategies required to ensure livelihood sustainability and poverty alleviation. Further research would be required on abundance, re-growth rates and so forth to establish the strength of the resource base and the impact of these factors on the safety-net function of NTFPs.

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GENERATING INCOMES FROM DRY FOREST PRODUCTS CASE STUDIES FROM MWINILUNGA, KAPIRI AND CHONGWE DISTRICTS, ZAMBIA

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Abstract

With the increasing demand for forest products due to population growth, urbanization and the opening of global markets, the harvesting and sale of these products has become part of the livelihood strategies of many rural African poor. The low barriers for entry, such as the low cost of production, create the opportunity for very poor households to engage in the trade of many NTFPs. However, the potential of forest based enterprises to contribute to poverty alleviation in African dry forests is not well understood, creating a barrier for effective supporting policies and institutions. This paper presents the findings from a survey conducted in four areas in Zambia. Particular attention is given to the range of products sold by rural households and the opportunities and constraints to participate in this trade. Recommendations to increase returns from forest based enterprises are given.

Introduction

People living in or around Africa's dry forests have always depended on this resource as a supply of products and services, to fulfil subsistence needs in their everyday lives or as a safety net in times of need. With the increasing demand for forest products the harvesting and sale of these products has also become an important income generating strategy for many rural African poor (Shackleton *et al.* 2008). Incomes from forest products make up, on average, 20% of total household income in southern Africa's dry forest regions (Campbell *et al.* 2002, Fisher 2004). Increasingly, forest based enterprises are considered to have a potential for poverty alleviation and triggered the interest of donors, governments and development agencies (Auren and Krassowska 2004). However, the success of commercial use of forest products to indeed live up to these expectations is debated in the literature (e.g. Belcher 2005, Neumann and Hirsch 2000). Wunder (2001) argues that, although many forest based enterprises have the advantage that they are accessible for the poor and require limited capital investment, in most settings these activities have little comparative advantages for large scale poverty alleviation, compared to other livelihood strategies such as agriculture.

Zambia's forest resources cover approximately 42% of the total land area (FAO 2005). Although the available statistics are poor, the few case studies show that the contribution of forest product use and trade may be as high as 50% of total rural household income (Mutamba in press). Single forest products, such as caterpillars, charcoal and honey may even provide more cash income than agricultural activities, but commercial exploitation of these resources depends on various conditions, including access to markets and local biodiversity (Jumbe *et al.* 2008). Nevertheless, the belief that agricultural activities can contribute more to poverty alleviation than forest products, has influenced both the Zambian government's and donors' investment in the forestry sector. In 2008, the Forestry Department, under the Ministry of Tourism, Environment and Natural Resources, received 0.11% of the national budget, whereas the Ministry of Agriculture and Cooperatives received 7.40% (GRZ 2008). External support from NGOs and the private sector to forest enterprises has also been infrequent, often short term and uncoordinated, compared to agricultural support. The only non-timber forest product that has (historically) been given a lot of support is beekeeping.

This study is part of a larger ongoing research initiative, which aims to improve the incomes of the poor through reinforcement of economic, institutional and policy incentives for sustainable management of Africa's dry forests. The objective of this paper is to explore the use of forest products in general, identify which households participate in the trade of different products, the existing markets for these products and opportunities and constraints for rural households to benefit from the trade.

Materials and Methods

Study sites

This study includes four case studies from three provinces in Zambia. Study areas were chosen, due to variability in environmental and socio-economic conditions and related livelihood strategies. The villages in Salujinga area, Mwinilunga district, are surrounded by dense *Cryptosepalum* forests. The area is connected to the provincial headquarters, Solwezi, by a 411 km road in very poor condition and is one of Zambia's historical hot-spots for beekeeping. Kasisi and Chinyunyu, in Chongwe district, are 40 km and 80 km, respectively, from Lusaka, the country's capital. The forests in this area are heavily degraded. Chidumayo (2001) estimates that 9,000 households in Chongwe district are involved in charcoal production. Lunchu in Kapiri district, lies between Zambia's two major urban centers, Lusaka (240 km) and Ndola (115 km). Its forest cover is higher than in Chongwe district, but less dense than in Salujinga. In these latter three areas, beekeeping has been promoted by the Government and various NGOs during the last decade in an attempt to encourage sustainable forest use and introduce new income generating opportunities.

Data collection

A cluster of neighbouring villages comprising of a total of approximately 150 households was selected in each study area. The main source of data was a survey, conducted in 2007, using a structured questionnaire. A randomly selected sample of 30% of the households was interviewed in each study area (N=221). Forest product trade is often seasonal and has a highly erratic nature in levels of production, farm gate prices and buyers (Wynberg 2006). This impedes accurate data collection on volumes collected and incomes derived from this trade in a single snapshot survey. This study therefore did not attempt to record income data, but focused on more descriptive information on the trade. The findings were supplemented with information from in-depth interviews and group discussions in the communities. Quantitative data was analyzed in SPSS. Households were categorized into five wealth classes using Principal Components Analysis to determine the influence of wealth on participation in forest product trade. Variables included size of cultivated land, type of shelter, food self-sufficiency and ownership of assets (e.g. plough, tractor, television, cell phone etc.).

Results

Forest products in rural livelihoods strategies

Almost all the interviewed households collect forest products for domestic use (Table 1). On average households collect six products for their own use: the most popular include firewood, thatching grass, mushrooms and medicinal plants. The number of households trading forest products varied significantly between areas.

In Salujinga shifting cultivation is practiced and farmers do not have longer term (official or traditional) tenure rights for their plots. The average area cultivated by households is the lowest in this area (1 ha, see Table 1). Cultivated crops are mainly consumed by the household and more than 60% of the households were categorized as relatively poor or very poor (Figure 1). Only one household was classified as very wealthy: one of its members had a paid job in town. Dependency on forest product trade appears to be highest in this area: 95% of the households sell forest products. Also, households in this area trade significantly more types of forest products: on average three forest products (Table 1). The main commercial forest products are caterpillars, mushrooms, honey, thatching grass and reed products (Table 2). A recently completed project promoted commercialization of a wide range of forest products in Salujinga area. This included training in improved production technologies and participating groups were given equipment. However, little attention was given to market linkages and as a result the farmers have not been able to reach new markets for these products and trade has not increased compared to prior to the project.

Table 1: Details of the four Zambian study sites

	Chinyunyu (Chongwe district)	Lunchu (Kapiri District)	Kasisi (Chongwe district)	Salujinga (Mwinilunga district)	*Significance level for* χ^2
Population density (people km^{-2}) [B]	13.2-17.9	11.2	13.2-17.9	6.2	
Female headed households (%)	7	5	24	17	$\chi^2=10.639$, $df=3$, $p=0.014$
Average area cultivated (ha)	4.04	8.93	2.91	1.01	$\chi^2=92.219^A$, $df=3$, $p=0.00$
Major crops	Maize, cotton, groundnuts	Maize, cotton, tobacco	Maize, groundnuts, vegetables	Cassava, maize, beans	
Households collecting forest products (domestic use) (%)	98	100	100	98	$\chi^2=2.00$, $df=3$, $p=0.572$
Average number of forest products collected (%)	5.95	7.17	7.55	7.64	$\chi^2=60.630$, $df=33$, $p=0.00$
Households collecting forest products (sale) (%)	40	53	31	95	$\chi^2=52.246$, $df=3$, $p=0.00$
Average number of forest products sold (%)	0.62	0.92	0.51	3.14	$\chi^2=129.832$, $df=3$, $p=0.00$
Households selling forest products that they did not collect (%)	*31*	*8*	*8*	*2*	$\chi^2=24.923$, $df=3$, $p=0.00$

Lunchu is the other extreme: average cultivated areas are the largest here (9 ha), a wide range of commercial crops are grown, and it is not unknown for farmers to own ploughs, tractors and other productive assets. Farmers rotate their fields on plots which are acknowledged as theirs by traditional institutions. Less than 10% of the households were classified as very poor and more than half of the households sell a forest product. Both beekeeping and mushroom cultivation have been promoted by the Forestry Department in the last decade. Two NGOs have also trained beekeepers in this area and provided them with equipment on credit. Almost a third of the households keep bees and most started less than a decade ago.

Households in Chinyunyu also practice subsistence and commercial agriculture on customary land, for which they have traditional usufruct rights. They ranked as slightly poorer than in Kapiri and Kasisi. Households collect on average fewer products for domestic use than in the other three sites, though 40% of the households trade at least one forest product. Significantly more households (31%) in this area, trade forest products, which they did not harvest themselves (i.e. reed mats). Beekeeping was introduced in this area by an NGO in 2004. Groups of farmers were given bark hives and seeds, if they stopped charcoal production. However, due to limited training and experience only one farmer was able to harvest sufficient honey for sale in 2006.

Kasisi is an interesting case study, because many of its farmers are retirees who cultivate land with title deeds. This area has a remarkably high percentage of female headed households (24%). Commercial agriculture dominates in this area and many farmers produce (organic) vegetables, maize and groundnuts for both urban and export markets. A third of the households trade forest products. Many of the farmers in Kasisi have participated in training, including beekeeping, at a nearby training centre, although they were not given any equipment.

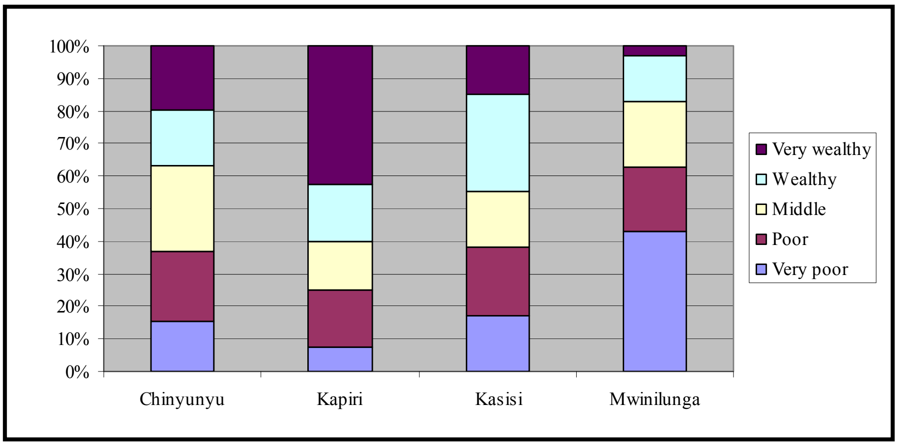

Figure 1: Distribution of relative wealth classes within the four study areas

Table 2: Percentage of households collecting forest products for domestic use and sale

	Chinyunyu		Lunchu		Kasisi		Salujinga	
	Domestic	Trade	Domestic	Trade	Domestic	Trade	Domestic	Trade
Caterpillars	65	7	15	0	80	2	95	84
Charcoal	15	5	19	8	27	16	5	2
Firewood	98	4	100	2	98	2	98	0
Medicinal plants	85	0	78	0	82	0	84	0
Mushrooms	75	25	97	14	90	4	89	52
Reed products	13	4	3	3	2	0	54	43
Thatching grass	98	5	98	12	88	12	88	43
Timber	4	0	10	0	4	2	25	18
Tubers	18	0	42	10	6	0	18	14
Wild vegetables	11	0	68	2	96	0	43	0
Wild fruits	56	5	86	2	94	2	93	0
Woodcarvings	4	0	14	3	0	0	18	7
Beekeeping	35	2	39	29	18	8	50	48
Honey hunting	18	4	47	7	69	4	5	4

Who sells forest products?

Wealth did not significantly affect if households sold or did not sell forest products ($\chi 2=2.253$, df=4, p=0.690) or the number of types of forest products a household sold ($\chi 2=31.753$, df=24, p=0.133). The only traded product that showed significant variation between wealth classes was mushrooms: more very poor households sold mushrooms than wealthy and very wealthy households ($\chi 2=10.105$, df=4, p=0.039).

Gender of the household head also did not influence whether or not the household sold any of the forest products. However, within households men and women collect and sell different products. For example, charcoal is mostly produced and sold by adult men, and so are timber and woodcarvings. Typical female forest based enterprises include mushrooms, wild fruits, tubers and reed products. Some products are collected by women for domestic use, but when traded the men become more prominently involved (e.g. thatching grass and caterpillars). Variations in gender involvement did not vary between areas, except for beekeeping. In Salujinga, where this is a traditional activity, adult men are in charge of keeping bees in 85% of the households. If women are involved, it is together with the men. A major restriction to female participation in beekeeping is the suspending of bark hives high in trees. In Lunchu and Kasisi modern production technologies have been introduced and, as a result, almost half of the beekeepers are women.

Markets for forest products

Many forest products are sold in villages, but other markets also exist. Charcoal is sold in villages, along roads or in urban markets. Roadside trade also includes mushrooms, caterpillars, wild fruits and reed products. Value chains for honey are more organized than those of the other products. In Salujinga and Kapiri medium and large companies purchase honey in bulk for processing, packaging and sale in urban and export markets. On the other hand, beekeepers in Kasisi have discovered high value retail markets in Lusaka and although volumes traded are lower than in Salujinga and Kapiri, prices received are four and eight times higher than in Lunchu and Salujinga, respectively.

Discussion

The above presented results show that livelihood strategies of the rural poor in Zambia are characterized by a diversity of activities. Although households grow crops they also depend on dry forests for a wide range of products consumed or used at household level. At least a third of the households in each area collects and sells forest products. It appears that the number of households involved in trade of forest products decreases with proximity to urban areas. This could be related the lack of forest resources in these areas (e.g. due to higher population densities, clearance of forest land for agriculture and charcoal production), but also to the availability of alternative income sources. The forests surrounding the remote Salujinga area provide the largest number of families with an income. This area lies further from urban markets, agricultural production is marginal and poverty levels are high. Our wealthiest study area, Lunchu, ranked second highest: more than half of the households sell forest products. Farmers living close to Lusaka have the advantage of selling their products at high retail prices.

This raises interesting questions on the relationship between the involvement in forest product trade and poverty. The low barriers for entry, such as the low cost of production, create the opportunity for very poor households to engage in the trade of many forest products, but some authors argue that, although this trade is important for poverty mitigation, it will not significantly alleviate poverty (e.g. Wunder 2001). Others suggest that when an enterprise yields a substantial amount of income, the poor will lose out to the elites (Dove 1993). In our case studies both the wealthy and the poor traded all the forest products, except mushrooms, which are sold predominantly by the poor. Gender involvement, however, varied amongst the different products, and may even differ if a product is collected for domestic use or sale. External support can empower women by facilitating participation in forest product trade, but it may be necessary to plan separate strategies for protecting households who depend on forests for basic survival, and supporting enterprises that can significantly increase household incomes (Arnold and Ruiz Perez 2001).

The key constraints for marketing forest products varied between the study areas: lack of markets, inputs and low producer prices ranked high in Salujinga; whereas low production levels, lack of skills and forest degradation were mentioned frequently in the other three areas. Te Velde *et al.* (2006) argue that the complexity of products in the eyes of local collectors is not necessarily in the product itself, but in the information required to successfully market it. Hence, when activities require some skills and access to capital and markets, it is the wealthier and more entrepreneurial people who are able to be successfully involved in the trade of forest products (Arnold 2002). The importance of good extension services, that include linking producers to markets and stimulate entrepreneurship, is evident when we compare the experiences of projects in the four areas. Only in Lunchu and Kasisi, have farmers successfully managed to generate income from the introduced forest based enterprises (i.e. beekeeping).

The example of beekeeping is unique, because no other forest product has a similarly organized sector. It illustrates the necessity of structured partnerships between producers, service providers and the private sector, with strong government oversight, to ensure that the interests of the poor are protected (Wynberg 2006). The high demand for Zambian honey in both domestic and international markets has encouraged an increasing number of companies to purchase honey from beekeepers, even in the remoter parts of the country. Although large urban markets exist for charcoal, mushrooms and caterpillars, amongst many others, these are all traded informally. Neither does the trade in any of the forest products receive the support that beekeeping does. This activity is included in many development programs and as a result of training many new beekeepers, including women, have been able to generate additional income. Institutional support, such as the recent launch of a quality assurance mark for honey and the organic certification of bee-products in large parts of Northwestern Province, has also boosted the industry. Current efforts to formulate a national Beekeeping Policy highlight the recognition that the sector receives from the Zambian Government.

Conclusions

Small scale farmers in Zambia do not specialize in a single agricultural product and it is also unlikely that these farmers will specialize in the trade of a single forest product. This, however, does not exclude the need to support these various sectors and poverty alleviation initiatives need to take into account the diversity of rural livelihood strategies and the important contribution of forest product trade. Specific attention should thereby be given to the prevailing local conditions of a target area and the specific actors involved, including women and the poor. Training, the development of market information systems and legislation that encourages private sector involvement can facilitate the adoption of and enhance income from forest product trade. Sustainable forest management should hereby be encouraged to ensure the potential for future generations to earn an income from these valuable resources.

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Forest Management through institutional arrangements

TRADING LEGALITY WITH PRECAUTION: PRELIMINARY IMPACTS OF MANAGEMENT PLANS AND FOREST CERTIFICATION IN THE CAMEROONIAN FORESTS

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Abstract

As of mid-2008, 63 of the 101 available forest management units (FMUs) in Cameroon were managed according to approved management plans, and seven FMUs had received a FSC certification. This paper provides a preliminary assessment of the volumetric and financial variations incurred by logging companies and by the government when adopting both the management plans and the FSC regulations. The full adoption of sustainable, or at least precautionary, values into approved management plans could reduce available volumes of the most harvested species by 17%, while foregone revenues for the State could amount to about 18%. The financial losses incurred by both the State and logging companies by fully adopting improved forest management in Cameroon should deserve more attention, if viable alternative options are to be found and resistance to reform diminished.

Introduction

In 1994, Cameroon adopted a new law to regulate forests, wildlife and fisheries (Republic of Cameroon 1994). The law was shaped around the concept of sustainable forest management (SFM) (Karsenty 2006), and in order to reach that goal, the preparation of management plans was mandated for all protected areas and forest management units (FMUs). Management plans are considered by many in the Congo Basin as evidence of SFM (e.g. COMIFAC 2004, CBFP 2006, GTZ and MINFOF 2006), but the latter remains very difficult to quantify, especially because scientific knowledge of fundamental ecological processes on tropical timber species remains weak (Repetto 1988, Karsenty and Gourlet-Fleury 2006).

When scientific knowledge is lacking, and the risk of negative impacts on valuable timber species is high, sustainable rules must be translated into precautionary ones. These rules should be applied by logging companies when preparing their management plans, until knowledge becomes greater and forest management can be bounded by better management practices (Kiker and Putz 1997).

The Cameroonian law embeds the concepts of both improved knowledge, by mandating management plans to be revised every five years, and precaution. Precautionary values for fundamental silvicultural parameters, such as the minimum cutting diameter (MCD), were proposed by two major research projects carried out in the 1990s (Durrieu de Madron *et al.* 1998a, 1998b, Forni and Mbarga 1998, Jonkers and Foahom 2004), later acknowledged by both the government and logging companies (MINEF 1998a, 1998b), and eventually embedded into the 2001 Ministerial Decree regulating the preparation, adoption and follow up of management plans for logging concessions (MINEF 2001).

The current legal framework, i.e. the 2001 decree, regulates the preparation, adoption and implementation of management plans, and explains the need to focus the analysis on different MCDs, but has some weaknesses. The 2001 decree only partially translated precaution into legal prescriptions (Vandenhaute and Doucet 2006, Cerutti *et al.* 2008). The decree allows logging companies to harvest several valuable timber species with no precaution taken, i.e. to apply values to basic silvicultural parameters, such as the MCDs, with the risk to be 'not compatible with a sustained production' (Bureau Veritas Certification 2006, p.24). The Ministry of Forests (hereafter the Ministry) has recently acknowledged the weaknesses of the 2001 decree and started a consultation process to amend it. Meanwhile, FMUs keep being harvested according to management plans approved through a flawed legal framework, and many valuable species are logged at non precautionary MCDs (Cerutti *et al.* 2008).

The Cameroonian law mandates precaution and prescribes that harvesting of any given timber species must be carried out in such a way that, at the end of the current harvesting cycle, at least 50% of the number of trees harvested, at a given MCD, must be available for logging during the next harvesting cycle, at the same MCD (MINEF 1998a, 1998b, 2001). For reasons of clarity, the 50% limit will hereafter be referred to as the reconstitution rate (RR). Although a precautionary RR of at least 50% is mandated by the law, it is not applied to all timber species (Cerutti *et al.* 2008). The decree allows logging companies to select the timber species to which a higher RR than 50% will be applied from the list of all the species inventoried in their FMUs. The selection process must comply with two rules: the number of selected species must be larger than 20, and the total volume of the selected species must be larger than 75% of the total volume inventoried in the FMU (art.6, MINEF 2001).

This legal prescription does not guarantee that companies select the timber species they harvest the most (Vandenhaute and Heuse 2006, Cerutti *et al.* 2008). It only guarantees selected species to be the most abundant in volumetric terms in the FMU. And since precautionary RR of at least 50% must be applied only to selected species, excluded species can be legally harvested at the MCD established by the administration (hereafter MCD_{adm}), which often imply RR smaller than the precautionary ones (Cerutti *et al.* 2008).

Recently, several weaknesses of the legal framework have been corrected in a few FMUs that adopted voluntary forest certification schemes such as the Forest Stewardship Council (FSC). Certification, however, remains a voluntary non-state market-driven process (Cashore *et al.* 2004), to which not all logging companies may be interested to adhere. Thus, forest management risks not improving on a national or regional scale if public policy change does not occur (Elliott 2000).

For public policy change to occur, however, the financial constraints of improved or precautionary forest management, for both the Ministry and logging companies, must be understood and quantified. The financial challenges of implementing SFM are well documented (e.g. Kiker and Putz 1997, Karsenty and Gourlet-Fleury 2006), but so far a quantitative assessment of those challenges in the Cameroonian forestry sector, notably since the adoption of the new regulatory framework, has never been attempted.

This paper tries to shed some preliminary light on those financial constraints by focusing on the volumetric variations and consequent financial challenges faced by both the government of Cameroon and logging companies in adopting different levels of improved forest management, from the legally required management plans, to more demanding precautionary levels, to the stricter parameters adopted as a consequence of FSC certification. As of mid-2008, seven FMUs had received an FSC certificate, and thus a detailed analysis is carried out on them.

Materials and Methods

Calculation of minimum cutting diameters

Four MCDs must be compared to estimate the changes in the volumes available for harvesting by applying different levels of improved management:

(i) Standard administrative MCDs (MCD_{adm}) for any given timber species are established by law. Where the rules of SFM and management plans are not adopted, logging companies could harvest all species at MCD_{adm}, and thus the latter can be considered as the reference MCD to estimate the volume of timber available for logging in any given FMU.

(ii) The MCD applied and calculated by logging companies in their management plans (MCD_{mp}) can legally diverge from the requirements of the precautionary principle. About 40 management plans were reviewed for this study although only those pertaining to the seven certified FMUs were eventually used. Some of the reviewed plans were accessed through the German Cooperation's (GTZ) library in Yaoundè and some were kindly provided by the logging companies.

(iii) The MCD that respects the precautionary principle (MCD_{ame}) is the MCD that the company will have to adopt if all species were mandated to be harvested at RRs higher than 50%. The MCD_{ame} was calculated for the FMU considered to estimate the volumetric and financial differences between the MCD_{mp} and the MCD_{ame}.

(iv) The MCD when applying the principles and criteria required by the FSC (MCD_{fsc}) is recommended by the certifying bodies to certified logging companies. The MCD_{fsc} was used to estimate the volumetric and financial changes occurring when adopting FSC rules. Management plans with MCD_{fsc} have been downloaded from the certified companies' websites for such a comparison.

In order to calculate the RRs for different MCDs, the population structures of the species considered were calculated by allocating the stems of each species to 10-cm wide diameter classes in a spreadsheet. The RRs were calculated for the MCD_{adm}, the MCD_{mp}, the MCD_{ame} and the MCD_{fsc} by applying the formula prescribed by the law [1].

$$[1] \qquad \text{Reconstitution rate (RR\%)} = [N_0(1\text{-}\Delta)(1\text{-}\alpha)T]/N_p$$

Given any particular MCD, and considering the population structure of any given species, 'N_0' is the number of trees that will have reached that MCD at the end of the first logging cycle, and thus 'N_0' accounts for the annual growing rate of the species considered, 'Δ' is a factor accounting for the harvesting damages, 'α' is the mortality rate of the species considered, 'T' is the duration of the harvesting cycle, and 'N_p' is the number of trees, with a diameter larger than the MCD considered, harvested during the current cycle. In Cameroon, although logging companies usually harvest all trees above the MCD, 'N_p' does not consider all diameter classes above the MCD considered, but only the trees comprised between the MCD and the MCD+40 cm. For example, if the MCD considered is 50 cm, 'N_p' will be the number of trees harvested between 50 cm and 90 cm.

In theory, given the population structure of each species, the values assigned in [1] to the growing rate, harvesting damages, and mortality rate should vary with the characteristics of the forest being considered. The forest manager will then go through an iterative process to establish the best combination of the length of the harvesting cycle and the MCD that results in a RR higher than 50%.

In practice all parameters are assigned standard values by the administration; logging companies never apply their local knowledge to adapt them in their management plans: harvesting damages are fixed at 7%, mortality rates at 1% and harvesting cycle at 30 years. The MCD is therefore the only variable which can be modified in order to obtain a RR higher than 50%.

Once the MCD at which RR higher than 50% occur (MCD_{ame}) is calculated, it can be compared with the MCD_{mp}, which can be smaller, and the MCD_{fsc}, which can be larger, to assess the differences among them and the baseline MCD/adm. The latter can still be used by logging companies, for example when their management plans are not approved or when they harvest outside the permanent forest domain.

Selection of most harvested species

In the analysis for this study only the population structures of the five most harvested species in each FMU were used. The most harvested species were selected by using annual production data provided by the Ministry. The decision to focus on the five most harvested species was taken because, historically (Hédin 1930, Chambre d'Agriculture de l'Elevage et des Forêts du Cameroun 1959, MINFOF 2006) as well as presently, they represent the bulk of timber production. Over the period 2000-2007, for example, they accounted for about 83% of total production in all active FMUs. Ayous (*Triplochyton scleroxylon*), sapelli (*Entandrophragma cylindricum*) and tali (*Erythrophleum ivorense*) have constantly been the three most harvested species, accounting together for over 72% of total production, while four other species, i.e. fraké (*Terminalia superba*), azobé (*Lophira alata*), iroko (*Milicia excelsa*), and more recently okan (*Cylicodiscus gabonensis*), ranked fourth or fifth in varying percentages over the period considered (Figure 1).

The five most harvested species in the seven FMUs considered in this paper represented between 68% and 97% of the FMUs' average annual production, with the two most harvested species accounting between 52% and 92% of average annual production.

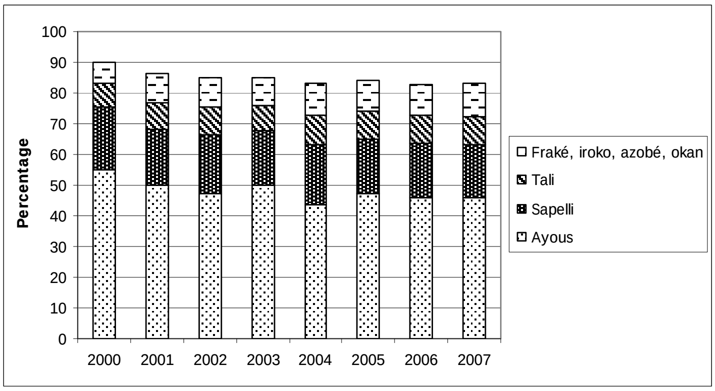

Figure 1: Five most harvested species per year as percentage of the total annual production of active FMUs.

Volumetric variations

Total available timber volume vary in the selected FMUs when the three MCDs are applied (Figure 2). Three bars are shown for each FMU considered. The first bar shows the variations incurred by logging companies when moving from the MCD_{adm} to the MCD_{mp}. The second bar shows variations taking place when moving from the MCD_{adm} to the MCD_{ame}, i.e. when all the five most harvested species were harvested with precautionary RR, and the third bar shows variations occurring by adopting the MCD_{fsc}.

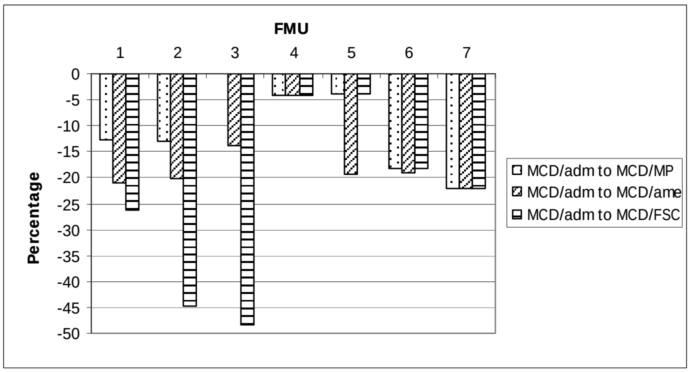

Figure 2: Volume reduction (%) in selected FMUs by type of minimum cutting diameter (MCD) increase over the standard administrative MCD (MCD_{adm}) for the five most harvested species

In the cases of FMU 1, 2, 3, 5, and 6 (Figure 2), the differences between the first and the second bars represent the quantitative effects caused by the flawed legal framework, which allows companies to harvest valuable species at MCDs (MCD_{mp}) smaller than precautionary ones (MCD_{ame}). In the case of FMU 3, the MCD_{mp} of all the 5 most harvested species were equal to the baseline MCD_{adm}, thus the first bar equals zero.

The certifying bodies requested FMUs 1, 2 and 3 to increase their MCDs (MCD_{fsc}, third bar), and thus decreased the volume available for logging (Figure 2), well above the levels requested by the application of available knowledge and precautionary RR of at least 50% (MCD_{ame}, second bar). By contrast, FMUs 5 and 6 show that the requirements of the certifying bodies were as good as those of the legal framework ($MCD_{mp} = MCD_{fsc}$), but still insufficient to guarantee adoption of the precautionary RR.

On average, the annual reduction in the volumes of the 5 most harvested species available for harvesting, as compared to the baseline MCD_{adm}, can be estimated at about 11% with the implementation of the current legal framework (MCD_{mp}), at about 17% when adopting he precautionary RR (MCD_{ame}), and of about 24% when adopting the MCD_{fsc}.

Apart from average values, adoption of the precautionary RR (MCD_{ame}, second bar) does not impact all FMUs evenly (Figure 2). For example, in FMU 4 the implementation of the management plan, where the five most harvested species were already logged at precautionary RR ($MCD_{mp} = MCD_{ame}$), implied a decrease in available volumes of about 4%, while in FMU 7 it implied a decrease of about 22%. Similarly, the adoption of the FSC requirements (MCD_{fsc}) caused a decrease of about 4% in FMU 4 ($MCD_{ame} = MCD_{fsc}$) and of about 48% in FMU 3, as compared to the volumes available for logging at MCD_{adm}.

Financial variations

Three points are noteworthy to consider in terms of profit losses of logging companies and foregone revenues for the State:

(i) Profit and revenue losses have been estimated on actual harvested volumes. That is important because a comparison between the available volumes as estimated in the management plan inventories (sampling intensities of 0.5% to 1.0%) and the actual annual harvest of the sampled FMUs as derived from production data, shows that only about 50% of the volumes found in the management plan inventories are eventually harvested by logging companies. Companies pay volumetric taxes on actual harvested volumes. Moreover, a commercialisation factor was used to estimate profit losses of companies. The commercialisation factor accounts for the amount of timber which is eventually processed and sold, and thus it better represents the volumes on which profits are made. Average commercialisation factors as found in the literature have been applied (e.g. Durrieu de Madron *et al.* 1998a, ONF-International *et al.* 2002).

(ii) FOB values for each species considered, averaged over the period 2000-2008, have been used to estimate both profit losses and foregone revenues. FOB values are a reliable indicator of the State's foregone revenues because volumetric taxes are indexed on the FOB values per species that are published each year by the Ministry of Finance. However, they may underestimate profit losses for logging companies. The FOB prices published by the Ministry of Finance are often lower than those published by the ITTO. For example, the FOB prices adopted in Cameroon for logs of ayous in 2007 were 32% lower than the FOB prices reported by the ITTO for the same species (Figure 3). Similar trends can be observed for azobé and sapelli.

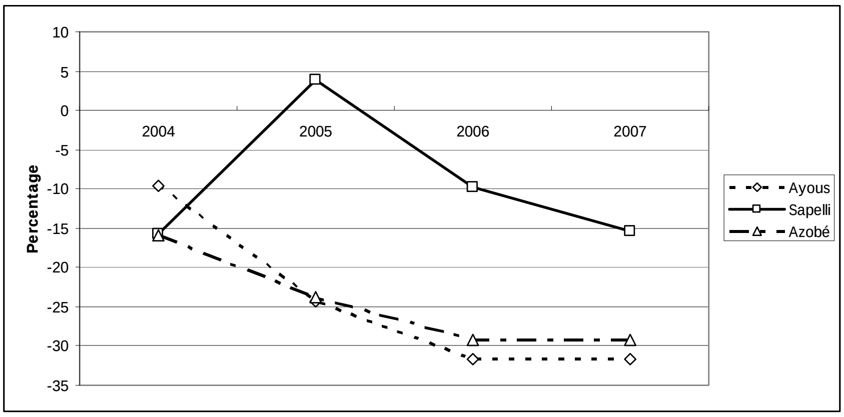

Figure 3: Official Cameroonian vs ITTO FOB prices (Grade B logs)

(iii) Annual losses are only tentative estimates, assuming that the average FOB values over the period 2000-2008 are representative of the FOB values for the entire harvesting cycle, i.e. 30 years. Moreover, inflation has not been accounted for.

Profit losses for logging companies

The decrease in the timber volumes available for logging implies profit losses for logging companies. Results show that, on average, profits for the five most harvested species in selected FMUs could be about 13% lower when adopting the MCD_{mp}, when compared with a situation of not implementing the management plans (MCD_{adm}). Estimated profit losses are higher when adopting MCD_{ame} (-21%) and MCD_{fsc} (-23%).

In absolute terms, average annual profit losses per FMU are estimated at about €460,000 with the adoption of the MCD_{mp} and at about €520,000 with the adoption of the MCD_{ame}. Estimated losses were higher for logging companies adopting the MCD_{fsc}, but it is worth noting that, while profit losses due to certification should in theory be counterbalanced by premium market prices, it is the government that should decide whether to provide incentives to logging companies who adopt improved forest management.

Foregone revenues for the State

The decrease in the timber volumes available for logging implies foregone revenues for the State, because several taxes, such as the felling and the sawmill taxes, are paid by logging companies on harvested volumes. After accounting for the different FOB values for each of the five most harvested species in each of the seven FMU, results show that State revenues could decrease by about 11%, 18%, and 23% when adopting, respectively, the MCD_{mp}, the MCD_{ame} and the MCD_{fsc}.

In absolute terms, the estimated average annual foregone revenue for the State per FMU for the five most harvested species could be about €14,000 by adopting MCD_{mp}, €24,000 with MCD_{fsc} and about €21,000 with MCD_{ame}.

On average, over the period 2004-2007, sixty-five FMUs have been paying volumetric taxes for their five most harvested species totalling about €7.9 million. If all FMUs would adopt the precautionary RR (MCD_{ame}) for their five most harvested species, the State could incur annual losses of about €1.3 million only in terms of the felling and sawmill taxes.

Discussion

Political will and ownership, and especially the lack thereof, are often singled out as the main obstacles to the implementation of reform by the government (World Bank 2004). That seems to be the case for the implementation of SFM in Cameroon: the 1994 law, a 1995 decree and two manuals of procedures adopted in 1998, all acknowledged the value of sustainable forest management. Yet, when it came to the adoption of the practical rules to prepare management plans, the 2001 decree included weak rules when the government knew the negative consequences for SFM at least since 2000 (Durrieu de Madron and Ngaha 2000).

Political will, however, can only be shaped by changing the priorities of the government's agenda. Adoption of precautionary MCDs showed that the profits to companies and revenues to the State would be less than with implementing the actual legal framework. That could partly explain why the reform of the current legal framework is not a top priority for neither the government nor the logging companies. Viable forms of incentives will have to be looked for.

Certified companies did improve forest management, and voluntarily adopted several more stringent harvesting parameters, reducing the average available volumes of their five most harvested species by about 24%. Market incentives certainly played a role in making the changes acceptable, but that shows that other forms of incentives could possibly be used by the government to improve forest management nationwide. Certification remains a voluntary process that several particularly smaller companies may not be willing to adopt (Elliott 2000). Hence, if forest management is to be improved on a national scale, it must be coupled with public policy changes (Gale and Burda 1998, Elliott 2000).

However, before sound policies could be developed, the financial implications of the implementation of improved forest management for the government of Cameroon call for the clarification and harmonisation of roles and responsibilities within the government itself, notably between the Ministry of Forests, charged with the implementation and control of sustainable forest management, and the Ministry of Finance, in charge of revenue collection. Results show that the adoption of precautionary reconstitution rates could imply volumetric revenue losses for the five most harvested species of about 18%, as compared to a reduction of about 11% caused by the adoption of management plans with the current flawed legal framework. If the two Ministries shared a common vision, those losses could be accounted for and counterbalanced by the development of a mid- to long-term strategy, for example in the form of fiscal incentives authorised by the Ministry of Finance on lesser used species (MINEFI 2006), while the Ministry of Forests could plan concurrent modifications of the annual authorised volumes in FMUs.

Instead, notwithstanding frequent calls for that common strategy (MINEFI 2000, 2006), the Ministry of Finance, in line with its mandate, remains more concerned with the maximisation of revenues than with the adoption of improved forest management. The Ministry of Forests, because of its weak analytical capacity, has not yet been able to provide Finance with viable alternatives, based on assessments of annual harvesting potential, species abundance, and production trends that could foster forest management while maintaining or increasing revenues. In this respect, the role of international donors must not be underestimated. It often happens that pressures from the latter on the Ministry of Forests to adopt, implement, and control the sustainable management of its forests, are dissonant with the parallel pressures made on the Ministry of Finance to increase non-oil revenues as much as possible.

If public policies do not develop along with certification, even the best intentioned logging companies, as well as their certifying bodies, could resort to what Cashore *et al.* (2004) call the adaptation of FSC principles to lower standards, i.e. standards that are still in line with the legal requirements but that are only a degraded version of the original targets of the FSC model. That is what seems to be happening in Cameroon, with certifying bodies allowing logging companies to trade the use of non-precautionary MCDs on the top species with very generous decreases on the available volume of lesser harvested species (Figure 5). The top harvested species in selected FMUs are still harvested without precaution ($MCD_{fsc} < MCD_{ame}$), but a MCD_{fsc} much larger than the precautionary ones is allowed for lesser harvested species, with no scientific evidence justifying such increases.

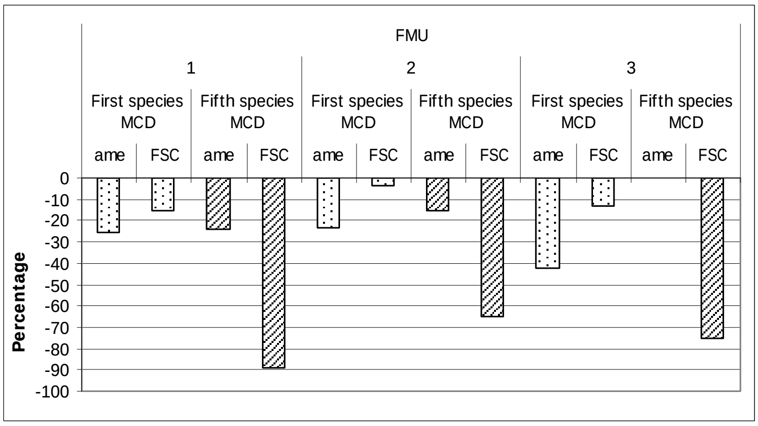

Figure 5: Volume variations (%) in selected FMUs by type of minimum cutting diameters (MCD) increase for the first and fifth most harvested species.

Paradoxically, if this trend continues, it could be more difficult for certified companies to increase the harvested volumes of lesser used species in the future, notwithstanding any incentive, such as tax reductions, the government might adopt in order to promote their use. The FSC approach of allowing logging companies to harvest their top species at non precautionary MCDs is economically viable in the short-term, and it is indeed justified by the companies and certifying bodies on the basis that their activities in Cameroon could be halted if precautionary values had to be adopted (Bureau Veritas Certification 2006, RP Pallisco 2008).

However, in the long-term, this approach could run against at least two results expected from the implementation of improved forest management in Cameroon: the sustainable, or at least precautionary, harvesting of all species and the promotion of lesser harvested ones.

Conclusion

The adoption of management plans since 2004 and of the stricter management rules requested by the FSC since 2005 in the Cameroonian forestry sector, pushed logging companies to improve the way their FMUs are managed, at least as far as minimum harvesting parameters, such as the minimum cutting diameter, are concerned.

There is certainly scope for further improvements, both on the part of the government of Cameroon and the certifying bodies and logging companies. The government must correct one important weakness of the current legal framework that allows logging companies to harvest their top harvested species at non precautionary levels. Certifying bodies should resist the tendency to allow logging companies to adopt degraded FSC standards. The latter are certainly legal, but in several cases they risk being non sustainable and often they are not backed by scientific evidence.

We do not argue FSC standards be made legally binding for all companies, but we do argue legal standards be improved at least to minimum precautionary levels, which could be modified when new scientific knowledge become available. However, this paper shows that the full adoption of improved forest management could be hampered by the lack of viable alternative options for logging companies as well as for the State to cope with the monetary losses incurred by applying stricter management rules, be they precautionary values or the FSC standards.

Financial losses are a major issue. In the seven FMUs analysed, it is estimated that the adoption of precautionary values could decrease the production of their five most harvested species by 17% and with the FSC rules by 24%. Foregone State revenues could amount to about 18% and 23% respectively, as compared to the baseline situation where management plans were not implemented.

Those losses must at least be partly counterbalanced if forest management is to be fully adopted on a national scale. It is in the very nature of certification schemes to adapt and improve through periodic audits (Putz and Romero 2001), but not all logging companies can be expected to enrol in a certification scheme, and the role of the government in providing parallel alternative viable options is paramount.

The agenda of the Ministry, and the private sector, can be changed only when those disadvantages, or at least part of them, are fully understood, quantified, and counterbalanced through viable alternative options. To that end, one of the most urgent steps needed in order to foster the adoption of improved sustainable management is the adoption of a common strategy by the Ministry of Forests and the Ministry of Finance, with clear and quantifiable incentives that stimulate the use of more secondary species while the volumes of the most harvested species decrease.

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BENEFITS AND SHORTCOMINGS OF DECENTRALISED FOREST MANAGEMENT IN BURKINA FASO

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Abstract

Decentralization initiatives are on-going in many developing countries. In Burkina Faso, the government has embarked on a long-term decentralization effort that groups rural villages into self-governing communes with the capacity to plan their own development programs. Nearly two decades before this process, a system of joint forest management was introduced. The new form of administrative decentralization has impacted on joint forest management. This study sought to examine the effects of decentralization on joint forest management and the livelihoods of the rural poor. Information was obtained through semi-structured interviews, interviews with local forestry officials, direct observation, and by reviewing existing literature. The results indicated that administrative decentralization brings legality to joint forest management, which was already legitimated by local people. In return, joint forest management generates benefits to local people through socio-economic infrastructure, wood and non-wood forest products, to the local government through tax collection systems, and to the forest through some extent improved ecological sustainability. There were shortcomings however, such as land tenure insecurity, low local organizational capacity; lack of transparency in the wood fuel market, low level of diversification of the sources of revenue and weakness of local institution to implement their functions. Thus, a concerted effort should be made to manage the remaining natural forests through the development of appropriate strategies to empower local communities to manage and benefit from forest resources through the new arrangements for administrative decentralization. Caution is needed regarding transparency, financial and technical incentives and long-term commitment from the central government.

Introduction

Dry forests are central to rural livelihoods (CIFOR 2002). They provide people with a wide array of wood and non-wood forest products, such as firewood, construction materials, edible fruits, pastures and medicines. Various studies have indicated that African dry forests are experiencing an unprecedented level of degradation (Lambin 1999, Wardell *et al.* 2003, UNEP 2006) due to climate change and, particularly, over-harvesting by people (Darkoh 2003). The damaging consequences of deforestation and degradation of dry forests include disruption of ecosystem goods and services and, in turn, the livelihoods of forest-dwellers (Darkoh 2003).

In Burkina Faso, the rural sector is primordial for the nation's economy; it employs 86% of the total population. Approximately 40% of the Gross Domestic Product (GDP) comes from agricultural activities (MECV 2004). The woody vegetation is disappearing with a deforestation rate estimated at 0.2% per year (FAO 2001). The remaining dry forests and woodlands are being preserved through the establishment of “State forest” reserves, ranches, buffer zones outside the ranches that constitute the villagers’ hunting zones, unprotected forests and forests managed by cooperatives for wood as well as biodiversity conservation. These areas are not strictly protected against human impact and are being utilized both legally and illegally by local people. Because they are ecologically and socio-economically valuable, sustainable management of these forested areas is of growing concern.

A brief review of the literature on institutional development of forest management from across the country, shows that the environmental policy in Burkina Faso has shifted from indifferent exploitation via conservation to management conservation aiming at sustainable use of forests, empowerment of local populations in land management and fostering multi-use forest production (Anonymous 1997). Involvement of local communities and securing the rights of marginalised groups in management of natural forest is a central theme for the development agenda. The poverty-governance-environment link has been further highlighted in recent years through interventions aimed at building local capacity in forest management. To this respect, joint or participatory management of natural forests was introduced in the 1980s after plantation efforts had failed to solve the perceived energy crisis (Delnooz 1999). The aims of joint forest management were to supply cities with wood fuel, ensure sustainability and fight against desertification (Kaboré 2002).

The national forest management plan was originally designed for State forests (forêts classées), then widened to include other forests. In this paper we use the term forests in its broad sense that includes all types of woodlands and other woody vegetation that usually is not dense enough to be classified as forests according to the strict FAO (2006) definition: ‘a “forest” is a minimum area of land of 0.05-1.0 ha with tree crown cover (or equivalent stocking level) of more than 10-30% with the potential of *in situ* trees to reach a minimum height of 2-5 m at maturity. A forest may consist either of closed forest formations where trees of various storey and undergrowth cover a high proportion of the ground or open forest’. Experimental sites were established to satisfy needs of the national forest management plan for more scientific input to ensure sustainability. On the sociological level, participatory methods were introduced that allowed local people with backstopping from the government to manage forests according to a management plan and a contract with the State.

Like many other African countries, Burkina Faso embarked on a decentralization process in the 1990s and this was supported by a wide range of donors. In theory, decentralization is believed to increase democratization of natural resource management by allowing local stakeholders to make decisions on the control and use of local resources (CIFOR 2003). It is seen as an important means to foster and nurture the important elements of good governance in developing countries. Policy-makers and researchers recommend decentralized natural resource management for many reasons (Ribot 2002, Rondinelli *et al.* 1983). Some of them are that (i) local people are likely to identify and prioritise their environmental problems more accurately than centralised organisations, (ii) resource allocation is more efficient and transaction costs lower when decisions are taken locally, so that State expenditure on management can be reduced, while resource conservation is improved, (iii) local groups are more likely to respect decisions that they have participated in taking, (iv) monitoring of resource use is improved, and (v) marginalised groups gain greater influence on local policy.

This article examines the case of a Joint Forest Management (JFM) program in the Center-West region of Burkina Faso, where significant development of institutional reforms in the management of *de facto* common property resources such as forests has been undertaken in the past few decades (Delnooz 2003). It provides an account of the participatory natural forest management and the enhancement of personal and collective social, economic and environmental benefits, institutional benefits and potential shortcomings of decentralized forest management.

Background to forest cover and joint forest management

Management of forests and woodlands has been influenced by the political and climatic histories in all West African countries. In the 1930s a large part of the North Sudanian zone of West Africa was delimited and protected by the colonial administration as wildlife sanctuaries to prevent land use change due to the expansion of shifting cultivation (Shepard 1992). After independence, forests and woodlands were preserved through the establishment of State forests for wood production and biodiversity conservation. The need to ensure that local people have access and use rights to the nearby forest and to develop a sustainable relationship with these forests has grown since the mid 1970s. During this period development strategies and practice, were moving towards a rural led focus (World Bank 1978) and the need to help rural populations mobilise by devoting greater efforts towards meeting their “basic needs”. Meanwhile, the wood fuel crisis (Eckholm 1975) following the 1973 jump in fossil energy prices and accelerated reduction of tree cover in Sahelian countries during and after the prolonged period of drought in the 1970s, drew more attention to the dependence of people on forests and the need to engage the knowledge of people living in the nearby forests (through dialogue and collaboration) to maintain the vegetation cover required for environmental stability.

In Burkina Faso, the forest cover was 7,154,163 ha in 1990, 6,914,276 ha in 2000 and 6,794,332 ha in 2005 (about 25% of the country area) (FAO 2005). These forests include tree savanna and open forests (28.6%), shrubby savanna (37.14%), striped thickets (1.41%), gallery forests (0.99%) and original anthropogenic vegetation (32%; fallow, agro-forestry parklands, plantations and woodlots). These forested lands have continuously been used as sources of urban wood fuel legally and sometimes illegally. After the severe drought years in the Sahelian region, large-scale plantation projects using introduced species such as *Eucalyptus camaldulensis* Denh., *Gmelina arborea* Roxb., and *Tectona grandis* L.f. were initiated to meet the urban wood fuel needs and to control desertification; unfortunately these turned out to be costly and unsuccessful due to lack of involvement of local people (Jensen 1997, Bellefontaine *et al.* 2000, Nygård 2000, Zida 2007). From the 1980s, natural forest management emerged as a subject of interest in Burkina Faso, and joint or participatory forest management (with wide responsibility and ownership assigned to the local population) has been implemented with the help of a joint UNDP/FAO project (Delnooz 1999, FAO 1990). These activities were part of a National Program of Forest Management covering the technical, political or legal aspects of natural forest management, including regulation of disturbance factors such as fire, tree cutting and livestock grazing (Sawadogo 2006, Bellefontaine *et al.* 2000, Kaboré 2004). The activities that involved men and women were mainly intended to ensure sustainable supply of wood fuel for urban centres like Ouagadougou (Delnooz 1999). The project formed Forest Planning Areas (*chantiers d'aménagement forestier*) and the control was attributed to Forest Management Cooperatives (*groupements de gestion forestière*) and represent a form of decentralized forest management. As urbanization increases, wood fuel extraction has largely influenced land use around urban areas and along main roads. In 1999, a national report on sustainable forest management (MECV 2004) showed 775,000 ha of managed forests, of which 29% are managed by different projects. The managed forests represent less than 12% of the national forest cover. The wood fuel drawn from these forests is the main source of energy for neighbouring big cities. Table 1 shows the firewood production for the seven forests closest to Ouagadougou.

Context of joint forest management

The participatory approach of natural resource management and the concept of decentralization reforms in West Africa took place over the last two decades (Ouédraogo HMG 2004). These reforms aimed to improve local management and development by transferring management responsibility and powers to local institutions (Ribot 1999, Hermosilla 2000). However, suitable conditions for more equitable and efficient management have not yet been established in Africa (Ribot 2003, Anderson *et al.* 2006) and the real incorporation of the local communities' priorities remains questionable (Ribot 2001, Mwangi and Dohrn 2008). In Burkina Faso, joint or participatory forest management has developed significantly in the context of institutional arrangements regarding forest management. The inevitable continued forest depletion, much to the detriment of the country's ecological, economic, and environmental stability, led to the exploration of managerial alternatives, which could halt this phenomenon. Effective involvement of village communities in evolving sustainable forest management systems was looked upon as an important approach to address the long-standing problems of deforestation and land degradation. With the development of village forestry, rural people started to engage in environmental protection activities through tree planting, soil conservation, agroforestry improvement, construction of wind breaks and the use of improved stoves. During this time, the participatory approach to forest management emerged based on the involvement of local communities, which was more promising than the former top-down approach (Ouédraogo B 2002, Ouédraogo HMG 2003, Kaboré 2004). Various usufruct agreements providing increased access to wood fuel or non-wood forest products, revenue sharing or other instruments have been tried as incentives. In this process, joint forest management was based on the following major principles (Renes and Coulibaly 1998, MECV 2004):

- participation of local people organized in forest management associations referred to as GGF in our case study;
- self-funded forest management;
- some silvicultural practices namely selective tree cutting, livestock grazing and prescribed fire that take into account the dynamics of the forest and the socio-economic requirements of adjacent villages.

Material and Methods

Study sites

This research was carried out in the forest planning areas of the Centre-West region (1°02’-l2°00’N and 1°30’-2°80’W), one of Burkina Faso's 13 administrative regions (Figure 1). The main reasons for selecting this region were the climatic location of the region (North-Sudanian) and the importance of the area for wood fuel supply to the main cities, with more than 75% of the total wood fuel consumption of Ouagadougou (Ouédraogo M 2002). Agribusiness is of growing importance in the region characterized by a large demand for land from intellectuals investing in commercial agriculture (Ouédraogo M 2003).

The forest management sites are located in three provinces (Sanguié, Sissili and Ziro). The region is very flat with an average altitude of 300 meters. Phyto-geographically, it is situated in the Sudanian regional centre of endemism in the the south Sudanian Zone (Fontes and Guinko 1995). The climate is tropical with a unimodal rainy season lasting from May to October. The vegetation cover consists of tree savanna in the south and shrubby savanna in the north. The most common woody species are *Vittelaria paradoxa*, *Parkia biglobosa*, *Lannea microcarpa*, *Acacia albida*, *Tamarindus indica*, *Adansonia digitata* and *Detarium microcarpum*. The herbaceous vegetation is dominated by *Andropogon gayanus* and *A. pseudapricus*. The region has quite important wildlife populations. The most abundant animals are elephants (*Loxodonta africana*), buffaloes (*Syncerus caffer* and *Alcelaphus bucelaphus*), hipotragues (*Hyppotragus equinus*), cobs (*Kobus defassa*), warthogs (*Phacochoerus aethiopicus*), red monkeys (*Erythrocebus patas*), hares (*Lepus capensis*), and significant bird and reptile fauna.

In 2006, the population density was 55 persons/km², against a national average of 34 persons/km². The region has a high in-migration rate (farmers mostly) since the 1980s (Henry *et al.* 2003). Ethnically it is constituted of Lyele, Nuni, Sissala, Wala and migrant groups dominated essentially by Mossi (farmers) and Fulani people (pastoralists) respectively from the central (Central Plateau) and northern (Sahel) parts of the country who come to the area in search of new land suitable for cultivation and grazing (Kristensen and Balslev 2003). The dominant production methods in the study area are traditional subsistence farming systems with cereals (such as sorghum, millet, and maize) and tubers (yam and sweet potatoes), and animal husbandry. Since about a decade ago, there is high competition with lucrative production systems: wood fuel and non-wood forest product NWFP) harvesting activities, cash crop production (cotton and fruit-tree plantation) and ranching (Paré *et al.* 2008). The region has seven jointly managed forests (CAF), covering 240,000 ha. Trees are mainly cut for commercial wood fuel (with a capacity of 120,000 m^3 of wood fuel per year), charcoal and poles by local populations that are organised in co-operatives. The wood is transported to towns (Ouédraogo M 2002). NWFPs such as fruit, leaves, tubers, perennial grass straw and hay, and meat are also harvested.

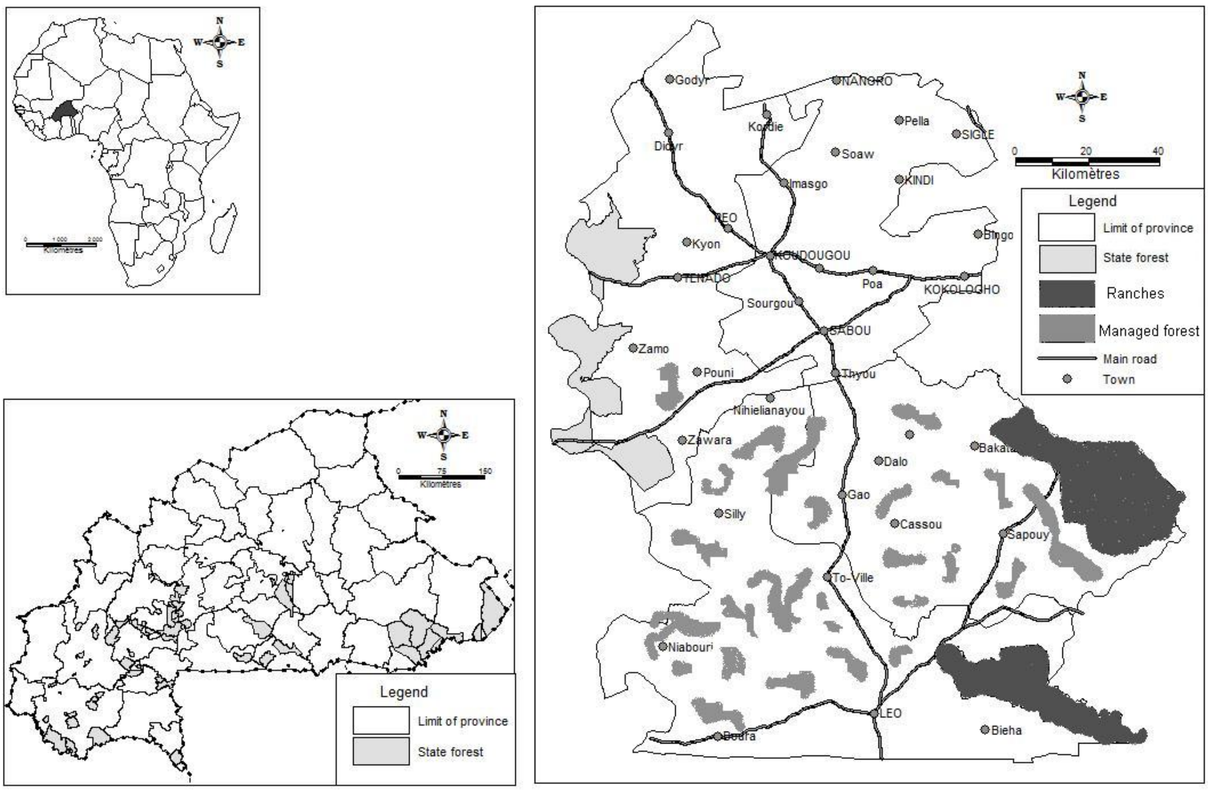

Figure 1: Location of the classified areas and forest management units in the region of Centre West region, Burkina Faso

Research methodology

Information was obtained using a combination of participatory rural appraisal and personal conversation with various stakeholders in forest management, direct observation and by reviewing existing literature (available recent publications, development plans, policy documents and research studies / reports). When required to fill information gaps, we collected information through a structured questionnaire survey at local level. The main question asked was: what are the benefits and shortcomings of the decentralized forest management in your area? Rural leaders and forest administration officials were interviewed to discuss their views on the benefit and shortcomings of decentralized forest management. A participatory diagnostic called *Méthode Active de Recherches Participatives* (MARP) was used with the support of a team of experts (lawyer, geographer, sociologist, forester, economist) to obtain information from stakeholders involved in joint forest management of what works in terms of institutions, organization, socio–economic aspects and services.

Results and Discussion

Forest income contribution to household economy

Wood constitutes the main source of energy for households in the country (Kaboré 2004). In the capital city Ouagadougou the dominating source of household cooking energy in is wood-energy which is used by 76.3% of the households; 70.1% mainly use firewood and 6.2% charcoal (Ouédraogo B 2006). They satisfy their needs through harvesting from natural forest (Renes and Coulibaly 1988; Sawadogo and Ouédraogo 2005), but the production capacity is weak; only 30% of the exploitable wood is sold according to the management plans (Pakodé 2004). The wood fuel harvesting is of tremendous importance for people living in and around community managed woodlands. Supplies of wood to the cities come solely by road from the wooded savanna formations existing in the region. The wood is cut either during clearing for crop-growing or expressly for processing of wood fuel for sale. In both cases, the work is done by local smallholders and it provides them with a by-no-means negligible addition to their income. In 2000, the city of Ouagadougou consumed nearly 350,000 tons of wood which came mainly from the center-west region (>75%). This amount was estimated at more than $US 10 millions, calculated at FCFA500 per (fluctuating) US$1 (Ouédraogo B 2002). The forest management unit of Cassou contributed the highest proportion of wood and cash income (Table 1). The distance to be covered to find wood is now 70-100 km along the main roads. Off these highways, little wood is still to be found within reasonable distance and the difficulties related to transportation increase. Light trucks (3.5-ton or more) are increasingly replacing vans and donkey-drawn carts, which had in turn replaced donkeys, bicycles and humans. The consumption greatly exceeds the production of the remaining surrounding stands and the production decreases as the trees disappear.

Table 1: Wood fuel production and estimated values in 2002 and 2003 for the Centre west region of Burkina Faso, West Africa

Forest management unit	2002			2003	
	Production (m^3)	Value ($US)	Income to Local people* US$	Production (m^3)	Value ($US)
Bougnounou/Nébiel	21 992	113 841	98 317	26 611	137 751
Cassou	31 545	163 292	141 025	38 386	198 704
Nazinon	19 336	100 092	86 443	14 272	73 879
Sapouy-Biéha	23 380	121 026	104 522	14 541	75 271
Sud-Ouest Sissili	7 404	38 327	33 100	5 157	26 695
Silly Pouni/Zawara	9 024	46 712	40 343	10 476	54 229
Tiogo	7 408	38 347	33 118	9 027	46 728
Total	120089	621 637	536 868	118 470	613 256

After Pakodé (2004)

* Income to local people = 86.4%

The final price of wood fuel in the main cities (Koudougou or Ouagadougou) was three times higher than the prices at the collection sites. The wood is in fact bought by middlemen, often the transporters. The price paid is about $US4.4/m^3. Once transported, this wood is resold at $US14/m^3 and more, according to whether an entire load is delivered, if it has been split or, finally, whether it is sold in small quantities. A study of the forest management associations in Burkina Faso (Ful 2000) showed that only 20% of the income from wood fuel ends up in the pockets of the 46,000 woodcutters. The remainder is shared between 134 wholesalers buying and trading from the forest sites and the 7,200 retailers, earning 50% and 30% respectively (Table 2). The erratic rainfall adds to the price variations because the rainy season is also the crop-growing season and the harvesters no longer have the time to cut wood. There is then a wood shortage on the market.

Table 2: Repartition of the income drawn from managed forests from 1986 to 1999 in the Centre West region of Burkina Faso, West Africa

Destiny of receipts	**Amount (US$)**	**%**	**Average/year**
Forest taxes (Public treasury)	5,882	13.74	420
Woodcutters (GGF members)	21,647	50.55	1,546
Village management funds (GGF)	3,529	8-24	252
Management funds (Forest Service)	11,765	27.47	840
Total	42,824	100	3,059

After Sawadogo and Ouédraogo (2005)

Forest income contributed to household cash income in addition to agriculture that provided sorghum and millet (main staple foods in the zones) for the woodcutters. With an average of $US680/year/head of household (according to a survey made of 144 households), this contribution is much higher than the national poverty threshold established at $US164.9/year/adult (MECV 2004).

Impacts of decentralization on joint forest management

The assessment of sustainable natural forest management confirms the existence of enormous possibilities but also of insufficiencies and raises concerns regarding the change related to administrative decentralization (Pakodé 2004). The impacts of decentralization on joint forest management are discussed under three headings: benefits, shortcomings and the relationships between local associations, decentralization and joint forest management.

Benefits of administrative decentralization for joint management of forests

The current joint forest management system which has been in place for 20 years could serve as a source of inspiration for the relatively new process of administrative decentralization. Administrative decentralization is now reaching rural areas and could be a great opportunity to improve the scheme for joint management of forests.

(i) Impact on the legal status of forests
The joint forest management areas now have legal status as State Forests (forêts classées) and remain the property of the State who only transfers the right to the villagers for management. Villagers are organised in management groups and decentralization has led to the establishment of local authorities. These authorities are now trained to represent the central administration locally, especially when it comes to natural resource management. A large part of the managed forests becomes the property of rural communities and this has led to the need to revise the contract between the State and the local management groups that takes the new partner into account. The specific mandates given to local governments and communities include: management of local forest reserves for biodiversity conservation; to regulate policy implementation; to conserve and manage village forest reserves and trees on farms; and to participate in joint management of conservation areas. The question of traditional rights is however an important one since decentralization affects the legitimacy of traditional rights to forest land. The opposition between modern law and traditional law therefore gains in strength although decentralization is supposed to help find a resolution. Without customary rights and benefit sharing mechanisms of natural resources, local populations will continue to become indifferent to the environment because they have no incentive to contain degradation and conserve the environment and natural resources.

(ii) Ecological impact
Fear that local authorities will adopt bad management practices of natural resources has slowed down with the transfer of forest resources to local stakeholders. Lack of technical capacity in the rural communities can quickly be resolved since the transfer of management is accompanied by transfer of financial and human resources. There is however fear that different kinds of social infrastructure such as health clinics, schools and roads could lead to

over-exploitation of forest resources since they are their principal source of revenue and the needs are tremendous. This exploitation could in turn lead to serious environmental impact such as a shift in the species composition due to overharvesting of certain wood fuel species and a subsequent disequilibrium of ecosystems.

(iii) Impact on the value of forests
The management plans that are currently in place focus on management for one objective only: supply of wood fuel to big urban centres. This approach excludes actors who are interested in building enterprises based on NWFPs. Since the 1990s there has been a strong decrease of forest land in favour of agricultural activities. In 1999, 22 villages in the Ziro province gave up 2,081 ha of their joint forest management land to 61 agro-businessmen (DRED/CO 2003) which means an average chunk of land of 34 ha/person which in turn is more than 10 times the size of the average personal property.

The Tiogo State Forest, another forest in the Sudanian Zone, generates more than US$100,000/year (Yelkouni 2004). This amount includes wood and other benefits people draw from the forest. The same study showed that if the Tiogo forest, is cleared and turned into agricultural land, its value decreases to US$74,000/year. These figures clearly show that there is incentive for local people to preserve forests rather than clearing it for cotton or other cash crop production.

Local communities living adjacent to the forest, extract a variety of non-timber products from forests to consume or to generate income. These products include food, fodder, medicines, spices, resins, dyes and utensils. NTFPs are important for food security, health and social and economic welfare of rural communities. They provide a significant nutritional contribution, especially crucial during times of drought and famine and create more varied, palatable, and balanced diets. Rural people also depend on forests for income and employment. Since forests constitute a very important source of revenue for rural communities they will very largely rely on valuation of the forests. Also policies targeting better valuation need to be explored at local, national, regional and international level. This will have to include rigorous control of land trading and diversification of forest products.

(iv) Impact on redistribution of revenue
One of the biggest challenges when it comes to decentralization will be benefit sharing of the revenue from joint forest management schemes. The principal actor here will be the local administration. They will claim their share of the pie and the current sharing arrangement need to be revised. The woodcutters, like the management associations, already complain over their share which they find too small and static (has remained the same for years). In 2000, households in Ouagadougou spent more than US$12,000,000 on wood fuel but less than US$ 710,000 ended up in the pockets of woodcutters (Ouédraogo B 2002). An analysis by Thiam (1998) showed that the current level of funds reinvested into the management of the forests is not enough. These management funds rarely go back to maintaining forest sustainability. The context of decentralization is an opportunity for all stakeholders to revise this sharing arrangement in order to avoid future conflicts.

(v) Impact on formalization of relations between different stakeholders through local by-laws
The relationships between the management groups, their union and other partners are often of a very informal character. Many decisions are oral which makes it difficult to put them into practise and to follow up on them afterwards. The context of decentralization may allow for formalization of these relationships between the different forest stakeholders and the local government through local by-laws.

(vi) Impact on respect of the management plans
Closer management of forests through decentralization may be an opportunity to correct imperfections regarding the management plans. The management plans are not followed all the way and this is the joint responsibility of the union of forest management groups, their leaders who are sometimes negligent, the technical backstopping team who is supposed to help the management groups but who in many cases are very tightly connected to the forest service (Pakodé 2004). The forest management plan must be approved by the local authorities who also should monitor its implementation.

Shortcomings of administrative decentralization for joint management of forests

If decentralization presents itself as an opportunity to reinforce local management of forest resources, it will not happen without friction for the current system. Putting rural decentralization into place will reshape existing rules. What are the shortcomings of decentralization for joint forest management?

(i) Politicizing the joint forest management scheme
Until now the forest management groups have economic activities that are more or less disconnected from politics. The entry point for local administration may bring about a political side of the approach and control of this source of revenue might allow for control of a good part of the voters. There are therefore potential risks of elite capture.

(ii) Conflicts of interest
The arrival of a new player (local government) may increase conflicts of interest between stakeholders. The technical services may become less cooperative if they see a part of their source of revenue disappearing. The new local authority would like to maximise its profit to be able to address the different needs of the rural communities. The revenue of the forest management group and the woodcutters may decrease. In this competition for benefit, good judgement and sustainable management may have to run against corruption and strong competitors such as technical services, wholesalers and local authorities.

(iii) Unclear land rights and the place for customary law
If decentralization sets the stage for formal management it does not guarantee security in its current state. Land management and especially forest land management under decentralization clearly excludes customary rights which have played an important role at the local level for centuries. Managed forests are located on land that is characterized by overlapping multiple

rights (customary and modern). The establishment of these managed forests is the result of negotiations with the traditional owners who always encourage joint management. Today these traditional owners are overlooked because the law does not provide use and withdrawal rights on their own land. If discussions and negotiations do not take place on time the system can not guarantee land tenure security (MAHRH 2007). Traditional leaders support the joint forest management schemes because they still have certain influence over the land. What will happen when they are sure they have lost this influence? And what can we say about the vast chunks of land that have already been bought by agro-businessmen on land that should have been transferred to rural communities? Some communities will end up with very little land because so much of it has already been bought. There are no guarantees for success since all stakeholders have their own views on land rights. The gap between legal (modern law) and customary law remains.

Local associations, decentralization and joint forest management

Rural organizations play a central role in the management of forest resources. Their most important role is to protect the forests against all forms of degradation. This goal remains difficult to reach, however, because the management groups have neither the competence, nor the means to accomplish this mission. That explains many infringements happening now: no respect for the management plan, uncontrolled clearing, late fires, illegal cutting, infringement by some migrants, some agro-businessmen and even some surrounding native populations.

In addition to the union of management groups, the area has several rural organizations which constitute an inescapable link with the local community that needs to be taken into account within the context of decentralization. The roles they have played on the ground before implementation of administrative decentralization will now be devolved to the local government. The municipal councils and the mayors should therefore engage a dialog with these organizations and other actors to define a platform of action with them. The assets already accumulated by the local organizations within the context of local development should benefit the process of administrative decentralization. Thus these organizations will be able to legitimate the process of administrative decentralization, to be sources of security and solidarity, and provide income for investment in social infrastructure. In return, the process of decentralization should offer to the rural organizations a relevant framework to undertake development activities in their districts. This support can be:

- better identification of priorities with the participation of rural populations;
- building and management of social infrastructure (schools, community clinics, rural road network);
- bring administrative services closer to the rural population (civil action, training, technical support);
- arbitration and management of conflicts;
- better organization for rural participation in the management of local development activities;
- land use security.

Conclusion

The thorough analyses of the jointly managed forests reveal positive elements at technical and organizational levels, as well as some challenges to be taken into account.

At the local level, joint management allowed better planning of the space and resources, possibility to defuse conflicts between farmers and pastoralists, opportunity to help local people to meet their needs (schools, food, medicine, etc.), possibility to reinforce the endogenous capacity of self-promotion of the populations in the sustainable management of forests and creation of frameworks for dialogue between actors of the wood fuel commodity chain.

At the environmental level, joint forest management helped to improve the ecological balance through concrete action. For example, the environmental heritage is safeguarded by the decisive and permanent role of rural populations. They develop new socio-ecological balances through perpetuation of the forest by afforestation, enrichment by direct seeding and protection against late fires.

Achievement of such results remains dependent on a certain number of parameters however, such as availability of appropriate laws regulating forestry development, adapted tools for implementation and skilled staff.

In addition, the scheme of joint management of forests should, if applied properly, be more profitable for local people. Nowadays, the forest management groups are weak when it comes to negotiating prices with wholesalers and the administration. Moreover, more than 50% of the taxes paid at the forest sites by wholesalers turn over directly or indirectly in the treasury of the State through the management fund, the working capital and the cutting license. Within the context of administrative decentralization with the creation of the rural communities, the stakes will consist in passing from an exogenous approach imposed from the top to an endogenous approach including the seeking of local compromise between actors for a dynamic and respectful production of forest resources. In addition to the cost, the length and the complexity of the process of establishing jointly managed forests constitute a real brake to up-scaling it to all the forests of the country. It is necessary to work towards a simplification (technical and cost) of this process to accelerate the rhythm of setting up the joint management approach in other forests and to work more in the direction of a real appropriation of forest management by the local communities.

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TWENTY YEARS OF EXPERRIENCE OF JOINT DRY FOREST MANAGEMENT IN BURKINA FASO

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Abstract

A series of projects In Burkina Faso, West Africa, started in the 1980s led to the establishment of a system of joint forest management that should be sustainable, produce wood fuel to the nation's capital and allow local people to engage and benefit from management of their forests. The model tested in the Nazinon state forest is the pioneer that has inspired management models throughout the country and outside its borders. Harvesting started in 1988 and the first 20-year rotation period has now come to an end. This study evaluates this management system. It assesses the current state of the resource (biodiversity and production) and tries to project future impacts of the current model. The study also provides background material for the national evaluation of the plan. The Nazinon forest management area was assessed with a sampling ratio of 0.30%. It has a functional administration and organisation of producer groups but several practises go against the management plan, such as large numbers of livestock graze in the forest and most of the land burns annually. Legal wood harvesting concentrates on six species but illegal wood harvesting is also common. The reason for and consequences of such practises are discussed. More emphasis on non-timber forest products is recommended for the revised management plan. There is also a need for better archiving systems for various types of documents, empowerment of producer groups, review of the management policies, better follow-up of regeneration and better criteria for selecting what tree individuals can be legally cut.

Introduction

In Burkina Faso, forests and other woodlands cover 25.9% of the country, of which 75% are community controlled areas and 25% are state owned (FAO 2001). Most woodlands are found in the southern, eastern and western parts of the country. These woodlands are under great pressure due to migration of people from the north and central parts where land degradation is severe. These people search for agricultural and pastoral land and this often leads to conflicts between farmers and cattle owners, migrants and natives as well as farmers and state officers. The overall consequence is accelerated forest degradation. In Burkina Faso, annual deforestation is estimated to 40,000 to 60,000 ha and annual reforestation is 1100 ha (Ouédraogo B 2001). The woodlands are also experiencing degradation of biodiversity due to

recurrent droughts and other anthropogenic factors like bush fires, overgrazing, land clearing for agriculture and tree cutting for wood fuel. Rapid growth of urban centers leads to increasing demand for wood fuel. For example, the population of the capital Ouagadougou increased from 465,969 people in 1985 to 1,066,082 people in 2006. Similar trends can be seen across the continent. The wood fuel demand of Ouagadougou was estimated at 1,376,056 stères (m^3) in 2000 (Ouédraogo B 2006) with an annual increase of 9.88% (ESMAP 1991).
Plantations of introduced species (mainly *Eucalyptus*) was attempted to resolve the wood fuel crisis in big cities but this failed and in the 1980s Burkina Faso turned towards sustainable natural forest management instead.

Funded by UNDP and implemented by FAO, the project PNUD/FAO/BKF/89/011 was launched in 1986. It aimed at participatory management of Nazinon forest to supply Ouagadougou with wood fuel. This project was the pioneer that inspired all the forest management programs in the country and some in neighboring countries too. For instance, Niger and Mali started rural wood fuel markets in 1992 and 1995 respectively by taking the experiment of Nazinon forest management into account.

People in adjacent villages are organized in forest management cooperatives to cut wood fuel in the forest according to a management plan and conditions that are stipulated in a contract with the State. Wood fuel is cut in a selective manner and the rotation period is 20 years. The wood fuel is sold by producers to transporters who convey it by old trunks to the capital where they sell it to the consumers.

In Nazinon the first plot was cut in 1988 so the first 20-year rotation period ended in 2007. It is therefore crucial to assess the system in order to highlight successes and shortcomings for better orientation of the next phase. This would be a useful exercise of lessons to be learnt, not only for this and other joint forest management schemes in Burkina Faso but also for other countries on the continent.

The objective of this paper is to present the results of an assessment of the current state (biodiversity and production) of the vegetation in the Nazinon forest, to attempt to project future changes due to the current management model, and to provide the background for the national evaluation of the management plan that started in April 2008.

Materials and Methods

Study site description

The Nazinon forest (11°30'-11°51'N and 1°27'-1°50'W) is located ca 70 km south of Ouagadougou, the capital of Burkina Faso, in the province of Ziro. Physiographically the area is classified as a slightly undulated plateau with altitude ranging between 260 and 360 m (Ky-Dembele *et al.* 2007). The soils are characterized as Haplic Luvisols and Haplic Alisols (Rietkerk *et al.* 1998). The forest is located in the south-Sudanian zone with a mean annual rainfall of 907 mm (1990-2007) falling in summer between May and October. The mean daily temperature ranges between 15 and 40^{o}C.

The Nazion forest area under management (CAF) is 23,699 ha. The CAF of Nazion is divided into seven forest management units (FMUs or UAF in French) of 2,000 to 4,000 ha each. They are indicated with different colors in Figure 1 (Red, Blue, Green, Yellow, Gray, Brown and Orange). Each FMU is subdivided into 20 blocks of 100 to 200 ha each, for harvesting one block each year over the 20-year harvesting cycle. Every year one block is selected at random for harvesting. In total, 25 cooperatives (GGF) totaling 850 members participate in the Nazinon joint forest management scheme.

Summary of management and harvesting prescriptions

- Vulnerable areas such as slopes, river banks, vegetation on termite mounds should not be cut;
- Areas with less than 200 stems/ha should not be cut;
- Harvesting cycle (rotation period) is 20 years;
- Selective tree cutting was adopted instead of clear cutting;
- Only trees with a diameter (at breast height) ranging between 10 and 25 cm can be cut; wood fuel from this diameter class is considered as merchantable;
- 50% of the merchantable volume of the plot can be cut;
- Priority must be given to felling of malformed trees and individuals most affected by disease;
- Trees should be cut at 15 cm stump height;
- Tree composition of cut areas should be supplemented by direct seeding and tree planting;
- Cut areas should be protected from bush fires and grazing for at least 3 years;
- The remaining areas should be burnt annually in prescribed early burning.

Vegetation inventory method

The complete inventory of all the woody plants on sample plots was done during 1 to 22 May 2006. Four (4) circular plots of 20 m radius were sampled in each of the 20 blocks of the seven FMUs, giving a total of 560 sampled plots. The sampling ratio was 0.23 to 0.46% based on the area of each FMU. The geographic coordinates of the plots were recorded to allow follow up.

The following information was recorded for each woody individual:

- Scientific name
- Stump (or individual) number
- Number of stems per stump

- Height of every stem per stump
- Circumference at stump level (15 cm) of stems with a circumference greater than 10 cm
- Circumference at breast height (CHP) (130 cm above ground level) of stems with a stump level circumference greater than 10 cm
- Health status (healthy, burnt, dead, pollarded, infestation by Loranthaceae, etc).

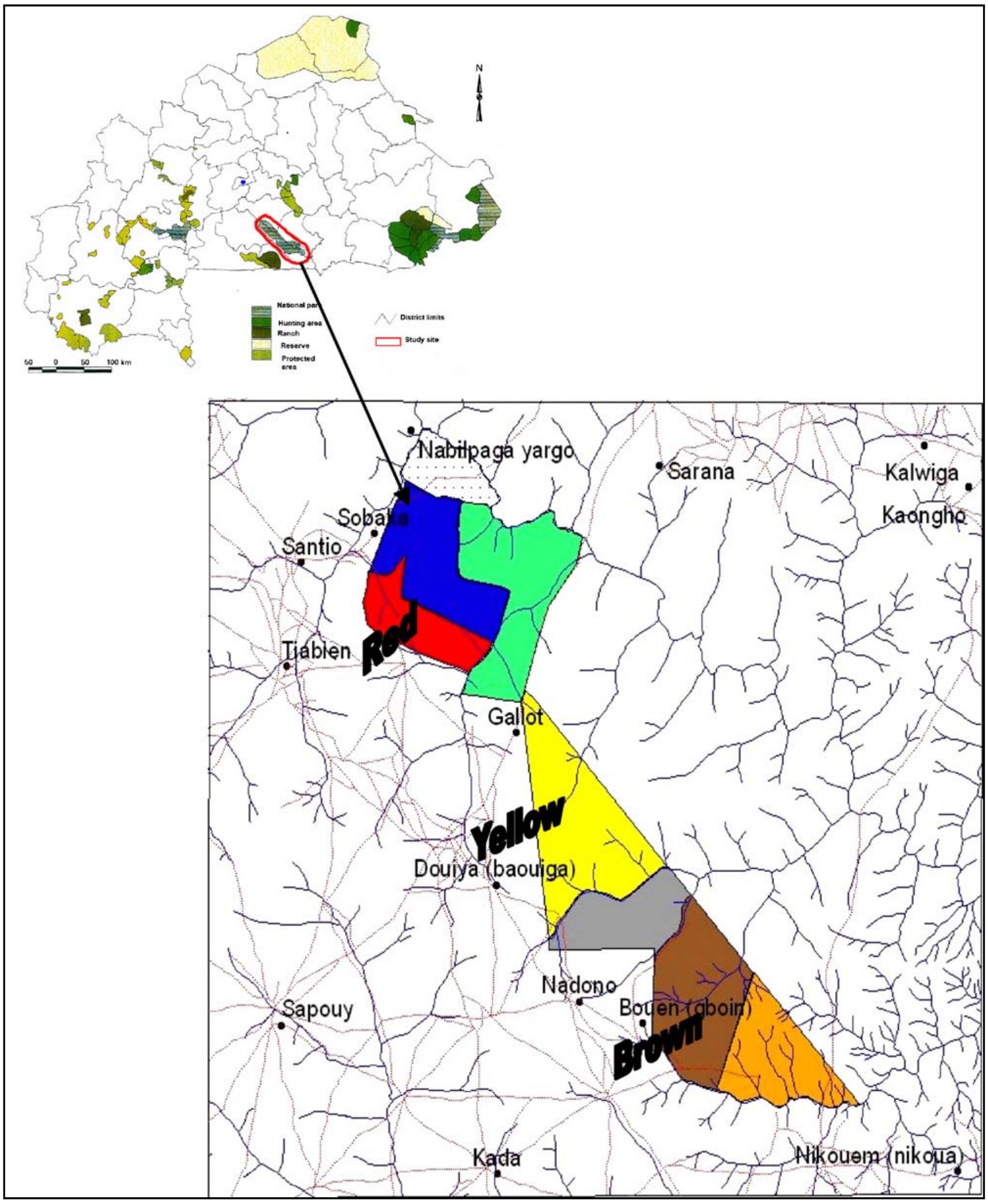

Figure 1: Location of Nazinon forest and the different Forest Management Units (FMUs or UAF) denoted by colors as follows (in order from top left to right, then top to bottom): Red, Blue, Green, Yellow, Gray, Brown and Orange.

Other observations included occurrence of fire, livestock presence and recent wood cutting, to assess the degree to which the management prescriptions were followed.

The collected data were analyzed for species richness, density, basal area and health status to characterize the vegetation status (biodiversity and production) after 20 years of implementing joint forest management. Tree individuals were divided into three diameter classes for practical reasons as follows:

- DBH <10 cm (regeneration class)
- DBH 10-25 cm (merchantable wood class)
- DBH >25 cm (seed-tree class).

Results and Discussions

Species richness

In total, 90 woody species were recorded during the inventory in the Nazinon forest. Similar figures were found in Tiogo forest in the same vegetation zone (Sawadogo L 1996, Savadogo P 2002).

Only six species were found in all seven FMUs (UAFs) (Table 1). Two (2) species, *Detarium microcarpum* and *Vitellaria paradoxa* (shea tree), were the most abundant in all FMUs ranging from 29% (Green FMU at top right) to 43% (Brown FMU at second from bottom). These are the two most valuable ones in terms of wood fuel and fruit. They are both cut for wood fuel. The nuts of *Vitellaria paradoxa* are collected by women to produce shea butter. The fruit of *Detarium microcarpum* are edible and rich in vitamin A. Wine can be made from the fruit. *Piliostigma thonningii* is an indicator of fallows in recovery. *Dicrostachys cinerea* is an invading shrub that should be kept under control in order to avoid encroachment.

Table 1: Relative abundance (%) of woody species in the seven forest management units (FMUs or UAF) of Nazinon CAF, Berkina Faso

Species	FMU or UAF							N*
	Red	Yellow	Gray	Blue	Green	Brown	Orange	
Detarium microcarpum	18.61	26.04	22.05	23.32	17.42	34.05	26.81	7
Vitellaria paradoxa	13.60	10.82	10.21	16.14	11.62	9.32	8.95	7
Piliostigma thonningii	6.22	3.96	3.17	3.73	2.20	2.80	3.42	7
Pteleopsis suberosa	3.56	9.84	5.80	8.95	5.26	6.54	8.56	7
Strychnos spinosa	3.21	2.78	4.72	4.00	2.56	6.17	3.89	7
Terminalia avicennioides	3.83	5.17	4.61	4.94	5.37	6.51	4.43	7
Acacia dudgeoni	-	1.83	3.15	1.89	4.97	2.37	4.01	6
Anogeissus leiocarpus	6.62	4.67	7.05	2.03	3.90	-	3.85	6
Burkea africana	-	3.94	2.83	2.63	2.42	4.98	4.03	6
Combretum glutinosum	3.96	3.19	3.16	3.75	4.05	-	3.00	6
Crossopteryx febrifuga	2.10	4.05	4.30	2.61	-	4.95	4.28	6
Combretum molle	-	2.13	6.39	-	1.94	2.36	3.30	5
Dicrostachys cinerea	2.69	-	3.02	4.57	5.87	-	2.20	5
Total number of species	73	77	73	74	78	70	77	

* N = Number of FMUs or UAF where the species was encountered during the inventory

Stand structure

This is presented by stem density over tree size categories. The highest density was found in the Yellow FMU with 2925 stems/ha while the lowest density was recorded in the Red FMU with 1345 stems/ha (Figure 2).

The dominance of young and small individuals could be due to recurrent bush fires that almost every year destroy the stems of most species and keep their bushy stature. Most of the species regenerate by coppice and root suckers and this make them very resilient. The most abundant species, *Detarium microcarpum,* produce large numbers of stems (coppice and root suckers) post disturbance such as cutting and fire. These stems go through a thinning period of a few years of die-off until 2 or 3 stems take over, become remnant and grow into the next classes.

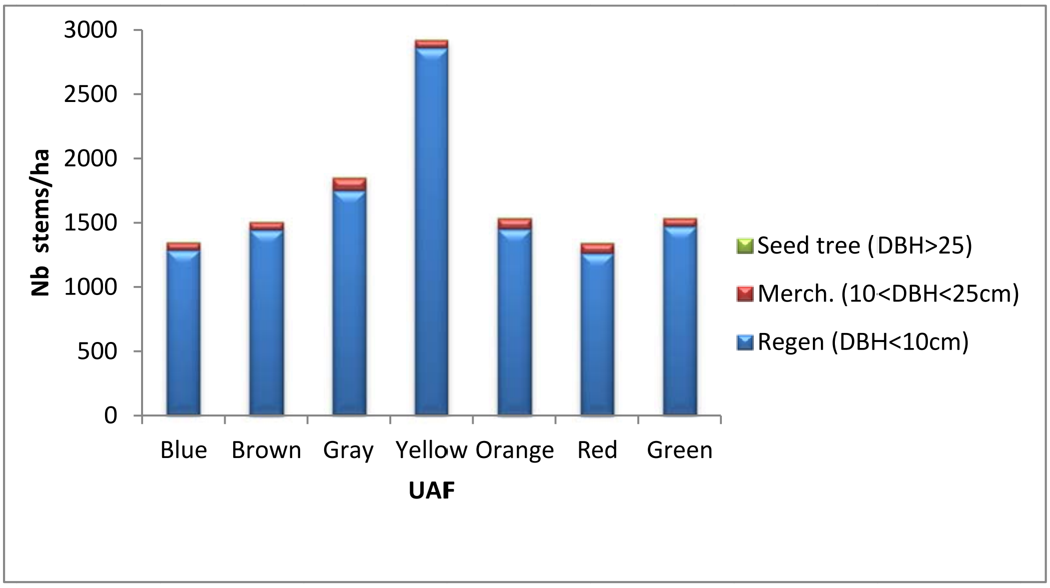

Figure 2: Stem density (horizontal structure) of woody species in the seven FMUs (UAFs) of Nazinon forest

Basal area

Total basal area is a good estimate of the potential wood production of a forest. Merchantable wood basal area is the production that could be legally cut. Only six species are commonly cut and sold for wood fuel: *Detarium microcarpum, Vitellaria paradoxa, Terminalia avicennioides, Crossopteryx febrifuga, Anogeissus leiocarpus* and *Burkea africana*. The total basal area varied from 6.92 m^2/ha (Gray FMU) to 4.67 m^2/ha (Blue FMU) (Figure 3).

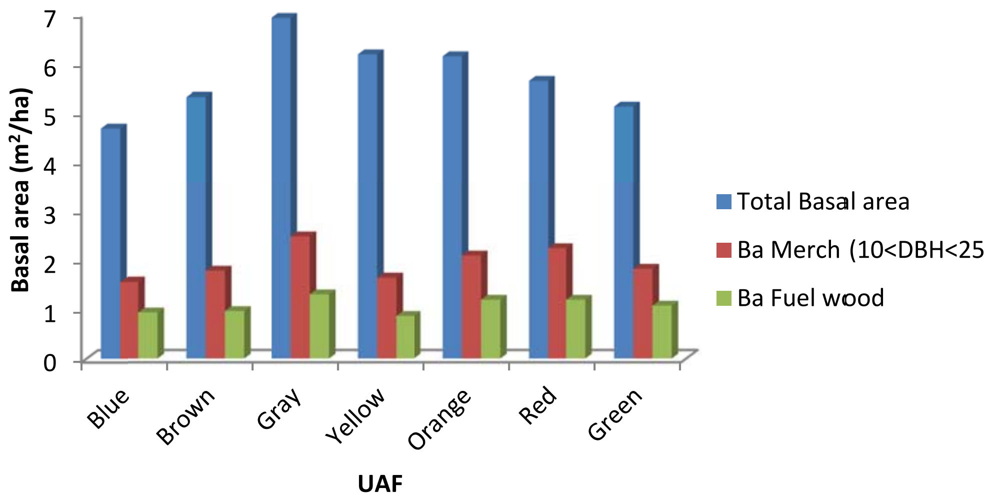

Figure 3: Basal area at breast height of woody species in the seven FMUs in Nazinon forest.

The merchantable wood basal area represents from 27% to 40% of the total basal area of the FMU. Most of the remaining basal area is made up of a few large seed trees. The basal area of the six most cut wood fuel species ranges from 14% to 21% of the total basal area depending on the FMU. The proportion that can be legally cut for wood fuel is therefore relatively small compared to the potential wood production of the forest.

Health status of woody vegetation

More than 92% of the individuals >4 m height of woody species in the FMUs of Nazinon forest are in good health (Table 2).

Table 2 : Health status expressed as % of tree individuals >4 m height in the seven FMUs (or UAFs) Nazinon forest

Health status	FMU or UAF						
	Red	**Green**	**Gray**	**Yellow**	**Orange**	**Blue**	**Brown**
Good health	94.9	95.4	94.6	95.0	93.1	92.8	94.4
Burnt	1.8	2.0	2.4	2.2	1.8	3.2	3.0
Infested by Loranthaceae	2.2	1.6	1.6	1.3	2.2	3.2	1.5
Dead	0.7	0.9	1.1	0.8	2.2	0.6	0.8
Pollarded	0.4	0.1	0.3	0.7	0.7	0.2	0.3

The most common damage is caused by bush fires that burn trunks and branches and even top-kills saplings. The species *Crossopteryx febrifuga* is most sensitive to fire. All mature individuals of this species have holes in the trunk due to fire. It is likely to become a threatened species over time as there are very few young individuals of it (personal observation). *Vitellaria paradoxa* is often infested by Loranthaceae (*Tapinanthus* spp.). *Pterocarpus erinaceus* is frequently pollarded for forage. The relative low proportion of dead wood is certainly due to permanent collection by people and destruction by bush fires.

Discussion of state of Nazinon joint forest management

Strengths of joint forest management to date

Well structured administration

The existence of a management plan (Figure 4), conditions of contract with the State and a well structured administration is a good step for efficient participative management of the forest and transparency in benefit sharing.

Forest potential in natural resources

With its 90 woody species, the Nazinon forest has great potential to produce more natural resources than just wood fuel. The resilience of these species is remarkable. For example, despite the great pressure on *Detarium microcarpum and Vitellaria paradoxa*, they are the most abundant species (as in the uncut areas) after 20 years of wood harvesting.

Shortcomings of joint forest management to date

Lack of or insufficient knowledge of forest productivity parameters

There are no reliable methods for assessing dry forest resources (i.e. wood production) in the Sahelian and Sudanian zones. This makes it difficult to predict the quantities of wood that can be cut and therefore assess the income generated by this activity. The growth rate of the species cut is not known which makes it difficult to assess the rate of recovery of the harvested part and therefore the harvesting cycle. Indeed, the 20-year cycle for this forest was not based on sound data but more or less taken out of the blue. Another complicating factor is insufficient knowledge of the influence of disturbances such as droughts, fire and livestock on the vegetation. Research is crucial to understand the biology and ecology of local species. Management prescriptions depend on knowledge of these factors.

Figure 4: Organisational chart of the Nazinon Joint Forest Management

Lack of respect for the management prescriptions

The woodcutting focused only on two species, *Detarium microcarpum* and *Vitellaria paradoxa*. In the long run, the impact of this species-based selective cutting could have negative impacts on the stand. The high pressure on these few species could be a threat to their survival. The size-based criteria for cutting for all species are another shortcoming. Some species will remain uncut because they are small even at the mature stage. They could become invading and then force people to harvest species with a lower fuel value.

Vitellaria paradoxa is cut for wood fuel but should rather be protected for shea butter production. The species does not regenerate well (seedlings grow very slow). Disappearance of the species would cause a loss of the profit from shea nuts and its value-added products on the international market. *Detarium microcarpum* on the other hand sprouts vigorously which makes it more resilient than many other species. Nevertheless, the high cutting pressure maintains its bushy stature which decreases its productivity.

Cutting is not done uniformly in all blocks. Indeed, some blocks are almost clear-cut (over-exploited) while some are hardly cut at all (under-exploited). Similar observations were made by Nouvellet *et al.* (1995) in the neighboring CAF of Bougounou-Nebielyanayou where well-stocked areas were overharvested and areas with sparser tree cover were under-exploited. In addition, illegal logging occurred in blocks not planned to be cut that particular year.

The 15 cm height at which cutting should be done according to the plan is not respected. In this study cutting height ranged from 23 to 57 cm in the Nazinon forest according to the species cut. This is probably because it is a comfortable height to work at but it reduces the regeneration capacity of the stump.

Fire and livestock exclusion from plots newly cut is not respected. In this study, the whole forest was every year subjected to grazing and fire.

Management based on one product

The current management is based only on wood fuel although non timber forest products (NTFPs) and pastoral management are mentioned in the management plan. For example, the abundance of *Vitellaria paradoxa* in the Nazinon forest is an opportunity to develop a shea-butter based business. The growing international market for this product is a real opportunity for increasing the economic value of the forest. The exports of shea butter and unprocessed shea kernels brought in US$7 million in 2000, making it the country's third most important export product, after cotton and livestock (Harch 2001).

Proper management of grazing (timing and intensity) could be used for fire management in the forest. Grazing could remove grass biomass and help to lower fire intensity and therefore increase wood productivity. In Tiogo and Laba forest in the same climatic zone, moderate grazing reduced herbaceous biomass and decreased stump mortality following selective wood cutting (Sawadogo L *et al.* 2002). Similar levels of grazing did not negatively affect soil infiltration in the same forests (Savadogo P *et al.* 2007).

Land insecurity

During the last 10 years, the province of Ziro where Nazinon forest is located was subjected to intense land grabbing for cash-crop agriculture mainly by private investors (civilian servants, politicians and traders). In 2004, more than 117 so-called agro-businessmen having between 5 ha to more than 600 ha each, have been inventoried in the province (Ouédraogo M 2004). The scarcity of land forces migrants and local people to encroach the managed forest to grow crops and cotton. During this study, fields have been found in some plots of the CAF. In summary, this new set of pressures raises the risk not only of increasing poverty, social exclusion and civil conflict among local people, but also of increased CO_2 emissions from increased deforestation and forest degradation.

Deficiency of archiving systems and activity monitoring

It was impossible to find data concerning the first inventory of the vegetation of Nazinon CAF. We could not assess the real impact of the management model during the twenty year period.
No follow up is done on the regeneration by coppice, direct seeding or planting in the cut plots. This would have given valuable information that could have been used to re-assess the new plan especially regarding the suitable harvesting cycle.

Lack of empowerment of producer groups

The relative weakness of local organizations and a lack of empowerment and accountability are major constraints for sustainable forest management. For example, the price of wood fuel at the producer level is established by the state administration although it's stipulated in the management plan that the producers could negotiate the price according to market conditions. Wood fuel is the only product where the price at producer level remained unchanged since 1998. One stere (m^3) of wood fuel cost FCFA2200 (ca US$4) from which 50% make up the share of the woodcutter. The value in town is more than 10 000 FCFA (ca US$20). Transporters, who buy the wood fuel from producers in the forest to sell in town, are the winners of the system; they set the price and the species to be cut by the producers.

Conclusions and future perspective

The viability of the Nazinon forest will depend on a number of things. Firstly, the next generation management plan will have to be diversified to include other products than wood fuel, for example NTFPs such as shea nuts, honey, and medicinal plants, etc. This could be an opportunity to target the international market. People could therefore benefit from certification and fair trade schemes to increase their income. The growing carbon market is another opportunity to conserve the forest instead of clearing it for agriculture. Secondly, a political will to empower the local population is crucial for sustainable management of the forest. Thirdly, there is less and less respect for basic management principles which lead to undesirable extreme exploitation of the Nazinon forest management area. It is important for sustainable management to sensitise and continuously train actors in resource use.

One thing is clear, the need for energy for the capital will not decrease with the current levels of urbanization. Increasing prices of fossil fuels are likely to further add to the need for wood fuel in many parts of Africa. Therefore the focus should be put on managing the remaining forest instead of planting deforested areas. More attention should be paid to biological and ecological studies to increase the knowledge in assessing forest resources, local species regeneration and the impact of climatic and anthropogenic factors on the productivity of these resources in order to get tools for better planning of management actions.

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Rehabilitation of degraded and cleared forests

GERMINATION OF *Widdringtonia whytei* SEED TO PROVIDE ALTERNATIVE RESOURCES OF THIS NARROW ENDEMIC TIMBER TREE IN MALAWI

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Abstract

Widdringtonia whytei (Mulanje cedar) is the national tree of Malawi and endemic to Mount Mulanje. The tree is highly valued because of its durable timber and fragrant oil. Currently, Mulanje cedar is at the verge of extinction due to over-exploitation. Ex-situ conservation of this valuable tree is problematic due to inadequate knowledge of the behaviour of the seed. This study investigated seed handling techniques to improve germination of *W. whytei* seed. Seed germination occurred only at 20ºC. Mean percentage germination is shown between brackets for the following equilibrium relative humidity 68.4% (81±2), 64.5% (92±3), 37.5% (90±1), 19.7% (91), 11.0% (89±1) and 5% (92±1). *W. whytei* seeds can tolerate desiccation. Highly significant differences between the moisture contents ($P \leq 0.001$) probably indicate that seed should not be exposed to fluctuating relative humidity. Pre-treatment (KNO_3) achieved germination percentages of 92±7, 90±12, 88±9, 89±11%, and 87±3%, respectively with no significant statistical differences ($P \geq 0.05$). KNO_3 failed to trigger seed germination. Results revealed large proportions of empty seeds. Further research should therefore investigate the reproductive biology of *W. whytei* seed to establish the cause of these empty seeds.

Introduction

Widdringtonia whytei, commonly known as Mulanje cedar, is endemic to Mount Mulanje and also the national tree of Malawi (Chapman 1995). It is confined to steep gorges at 1,800 – 2,100 m altitude, where it grows to 30 – 40 m high with a breast height diameter of 1-1.5 m (White *et al.* 2001). The wood of Mulanje cedar is excellent for construction, furniture and panel boards. One *W. whytei* tree is valued at £1,000 (Chapman 1995). It can significantly contribute to the economy of Malawi if sustainably managed. However, the species is currently fragmented into small clusters covering a total area of only 847.3 ha (Makungwa 2004) showing a decline in area from 1,462 ha in 1989 (Sakai 1989). Over-exploitation is the major cause of this population decline coupled with invasive species, bush fires and Cinara cupressi infestation (Hilton-Taylor 2000, Chilima 1989). Hence, *W. whytei* is endangered (IUCN 2006). Unless immediate and decisive steps are taken to counter the effects of Mulanje cedar destruction, much of it will be irreversibly lost in a few years to come.

Ex-situ conservation seems to be a viable option for sustaining Mulanje cedar. However, its success is currently limited due to scanty information on the behaviour of the seed. Optimum seed moisture content and germination have been poorly documented, resulting in haphazard implementation of ex-situ conservation strategies. This study investigated seed germination responses in order to improve conservation and sustainable use of Mulanje Cedar. The study specifically aimed at (i) establishing the optimum moisture content (MC) that would enhance desiccation survival and conservation potential of *W. whytei* seed, (ii) examining pre-sowing treatments that could improve seed germination, and (iii) determining the optimum temperature regime for germinating *W. whytei* seed.

Materials and Methods

Study site, cone collection, seed extraction, cleaning and initial MC determination

Mature cones were collected from 25 trees spaced at 100 m intervals at Sombani on the northern section of Mount Mulanje (15°50'S, 35°42'E), at 2,068 m altitude. Mean annual rainfall is 2,859 mm and mean annual temperature range is –3 to 24°C (Eastwood 1988). Cones were spread on a wire mesh tray at room temperature to dry and release the seed. Seed were then cleaned through a ziz-zag seed blower to remove empty seed and debris. Initial MC was determined by equilibrating sample seeds in the hygro-palm chamber for 30 minutes after which the relationship between RH and temperature was used to determine seed MC from the psychometric chart (Prober 2003).

Desiccation of seed in lithium chloride (LiCl) and silica gel

One thousand five hundred (1,500) seeds were suspended in an atmosphere above each of the four (4) different Lithium Chloride (LiCl) concentrations and silica gel until the relative humidity of the seed equilibrated to the target eRH of LiCl solutions (Table 1). Seven hundred seeds were kept under ambient conditions to serve as a control.

Table 1: Levels of relative humidity attained for Lithium Chloride solutions of varying concentrations

Desiccating solution g (g LiCl/100 ml water)	Corresponding equilibrium Relative Humidity% (eRH)
30	64.5
50	37.5
60	19.7
90	11.0
Open air (Control)	68.4
Silica gel	5.0

Seed pre-treatment

Appropriate amounts of KNO_3 powder were weighed and dissolved in distilled water to the required concentrations of 0.2, 0.4, 0.6 and 0.8% (Matasyo-Banda 1999). Then 100 seeds from each of the six moisture contents (Table 1) were soaked in the four KNO_3 concentrations and covered to prevent contamination for 12 hours. Distilled water served as a control.

Experimental design, treatments and germination of equilibrated seeds

The experiment was a 6 x 5 x 3 factorial design with six moisture content levels (Table 1); five pre-treatments; and three constant temperature regimes of 10, 20 and 30°C. Each treatment unit consisted of 100 seeds and was replicated four times. Seeds were then sown on 1% agar and incubated at 10, 20 and 30°C in a completely randomised design (CRD). Germination counts were recorded daily using a visible protrusion of the radicle till 30 days elapsed. Seeds that failed to germinate were tested for viability using the Tetrazolium Chloride (TZ) test. The general statistical model for the experiment was:

$$Y_{ykl} = \mu + S_i + M_{ij} + T_k + (SM)_y + (ST)_{ik} + (MT)_{ik} + (SMT)_{yk} + \varepsilon_{ijkl}$$

Where; Y_{ykl} = Expected response variable (germination); μ = grand (population) mean; S_i = seed pre-treatment effect; M_{ij} = moisture content treatment effect; T_k = effect of temperature; $(SM)_y$ + $(ST)_{ik}$ + $(MT)_{jk}$ + $(SMT)_{yk}$ = all interaction and ε_{ijkl} = residual (error).

Data analysis

Seed germination percentage and germination energy

Germination percentages were calculated as the total number of seeds that germinated in each treatment. Seed germination energy, which predicts seedling establishment in the field, was regarded as the number of days required to attain 50% of the final germination percentage (Schmidt 2000).

Analysis of variance

Germination percentages were first transformed into arc sine values in order to normalize the data. Analysis of variance (ANOVA) was then performed on the transformed data using GenStat computer package to determine significance and interaction between the treatments. The best treatment mean(s) were separated using Fisher's Least Significant Difference (LSD).

Results

Effect of cleaning on W. whytei seed quality

Thirty percent of 27,365 seeds collected were filled whereas the other proportion consisted of empty but fully formed seeds.

Seed germination responses to constant temperature regimes

Figure 1 shows that only 1% and 3% of seeds germinated at 10 and 30ºC, respectively. Seeds that failed to germinate at 10ºC were however, viable (Figure 1). At 30^{o}C, 30% of the seeds died (Table 2). However, seed germination was extremely high at 20ºC (Figure 1 and Plate 1). Only dormant seeds failed to germinate at this temperature (20ºC).

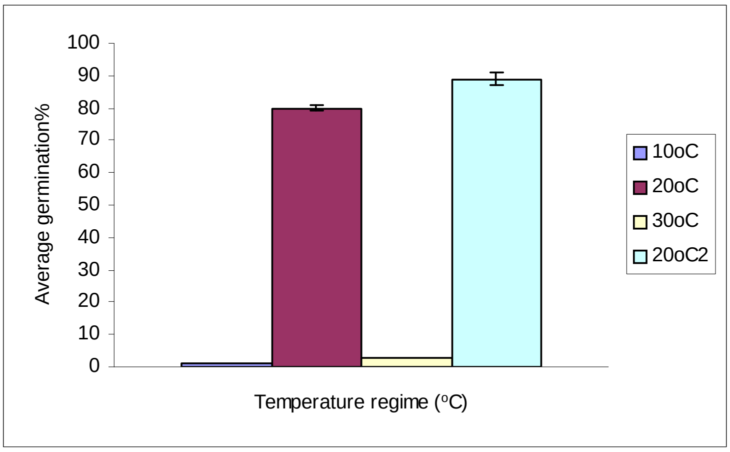

Figure 1: Effect of temperature on germination of *W. whytei* seed after 30 days incubation at 10ºC, 20ºC and 30ºC. 20°C2 = viability percentages at termination of experiment

Effect of desiccation and KNO_3 treatment on seed germination

ANOVA showed highly significant differences ($P \leq 0.001$) in seed germination between moisture contents (Table 3). Highest germination occurred at 64.5 and 5.0% RH whereas 68.4% RH attained lowest germination (Table 4). Pre-treatments were not statistically different ($P \geq 0.05$) in terms of seed germination although lower concentrations recorded slightly higher germination than seeds soaked in 0.8% KNO_3 concentration (Table 5). There were no significant interactions between the moisture content levels and KNO_3 concentrations (Table 5).

Table 2. Average seed viability at 30ºC temperature regime

Relative Humidity (%)	Viable seeds (%)	Dead seeds (%)
68.4	46	37
64.5	43	32
37.5	44	32
19.7	44	32
11.0	43	32
5.0	42	30

Table 3: Two way analysis of variance for Relative Humidity (RH) and pre-treatment -KNO_3 concentrations

Source of variation	df	Sum of Squares	Mean Square	F	Sig.
Pretreatment	4	118.19	29.55	1.98	0.105
Relative Humidity	5	560.14	112.03	7.49	<.001
RH * Pretreatment	20	300.58	15.03	1.00	0.465
Residual	90	1345.93	14.95		
Total	**119**	**2324.84**			

Table 4: Germination at 20 ºC of desiccated *W. whytei* seeds to different desiccation periods (days)

Target RH (%)	Corresponding MC (%)	Mean germination (%)	Viable seeds after germination test
68.4	13.6	81b	18
64.5	13.4	92a	10
37.5	7.9	90a	11
19.7	5.2	91a	5
11.0	3.8	92a	9
5.0	2.0	92a	11

Key: MC= Moisture content, RH= Relative humidity
Figures with same letters are not significantly different (P=≤0.05)

Table 5: Interaction between Relative humidity (RH) and KNO_3 concentration treatments at 20^0C temperature regimes on germination (Values are arcsine transformation)

Pre-sowing treatment KNO_3 solution (%)	Relative Humidity (%) 68.4	64.5	37.5	19.7	11.0	5.0	Mean germination %
Distilled water	93	95	91	93	90	91	92
0.2	82	91	93	91	89	94	90
0.4	94	90	93	93	89	89	88
0.6	80	92	89	91	87	94	89
0.8	78	91	83	88	88	94	87
Mean germination percentage RH	81b	92a	90a	91a	89a	92a	**89**
LSD 2.49							

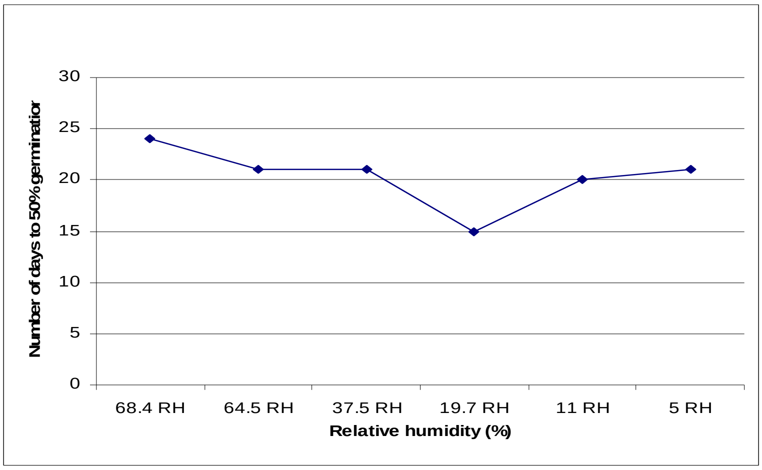

Figure 2: Average seed germination speed for each moisture content

Discussion

Effect of blowing on W. whytei *mature seed quality*

Large proportions of empty, but fully formed seed in *W. whytei* could be due to unpollinated female cones (ovulate cones) and/or embryo abortion whose cause is open for speculation. *W. whytei* is wind-pollinated (anemophily). Efficient wind-pollination occurs with large homogeneous populations with trees located close together. However, *W. whytei* stands on Mount Mulanje consist of different age gradations some of which may be too young to produce pollen (Bayliss *et al.* 2007, Makungwa 2004). This may limit the amount of pollen present in the air for fertilization. Conversely, anemophily requires large amounts of dry pollen that can be efficiently carried down by breeze. However, Mulanje Mountain is usually associated with misty weather conditions (Hardcastle 1978). Thus, if pollen production coincides with these conditions, it may fail to 'wind down' because of the high moisture content of the air. Thorough investigations should be carried out to establish these hypotheses. These results are consistent with those of Bonner (2000) who found only 20% of filled seed in cones of Atlantic white cedar. As a result, poor seed germination of *W. whytei* in previous studies could be attributed predominantly, to the naturally low percentages of filled seeds, about which, seed managers have no knowledge.

Effect of temperature on germination of W. whytei seed

Comparing the viability percentages at termination of experiment (in Figure 1 shown as 20ºC2), and failure of the same seed to germinate at 10ºC (Figure 1), it would be reasonable to believe that the rate of metabolic processes was reduced at 10ºC due to the cold environment. Consequently, the seed remained quiescent. Gondwe and Kambadya (2004 unpublished) found similar results in a thermal gradient plate. Probably, high rotting of seed at 30ºC (Table 4) was due to accelerated ageing as a result of high temperature. Pritchard and Dickie (2003) stipulate that temperature range of 30^{o}C - 40^{o}C facilitates rapid seed ageing. Also, high temperature (30^{o}C) might have caused induced dormancy on the viable seeds (Table 5). The results support earlier findings by Gondwe and Kambadya (2004 unpublished) where *W. whytei* seeds did not germinate at high temperature (≥30^{o}C). These results may have relevance on the sites where *W. whytei* seedlings are currently being raised in Malawi. It is doubtful as to whether or not nurseries are established in sites with temperatures around 20^{o}C. Otherwise, optimum seed germination may be inhibited. In addition, the global climate change may have implications on these results. Current predictions on the global climate change indicate that the global mean temperature over the next 100 years will be at the high end of or even exceed the IPCC 2001 estimates of 1.4 to 5.8^{o}C above the temperatures of the 1990s (Reilly *et al.* 2001). Although some seeds exhibited tolerance to high temperature (Table 2), the global rise in temperature may have far reaching consequences on the survival of *W. whytei* on Mount Mulanje, as seed germination would be severely impeded. Persistent heat during drought stricken years may also have negative consequences on the germination and survival of *W. whytei* on the mountain. However, metabolic processes seem to have been activated at 20^{o}C as evidenced in preceding sections.

Effect of desiccation and KNO_3 treatment on the germination of seeds at 20^{o}C

Significant differences ($P \leq 0.001$) between the moisture contents (Tables 4 and 5) may indicate that moisture content strongly influenced seed germination. Further, 92% germination recorded at 5.0% RH (Table 4) might imply that seed of *W. whytei* were tolerant to desiccation. Thus *W. whytei* seed may be classified as orthodox and, as such, can be stored for a long time under sub-freezing temperatures. This could be an opportunity to intensify ex-situ seed conservation strategies for the Mulanje cedar tree. Although Nyman (1963) recommended KNO_3 as a stimulant of germination of some coniferous seeds, germination of *W. whytei* seed treated with KNO_3 did not show any statistical differences ($P \leq 0.05$) (Tables 3 and 5). Consequently, KNO_3 treatments were ineffective in enhancing seed germination of *W. whytei* in this study. KNO_3 increases sensitivity to positively photoblastic seeds and interacts with temperature to increase germination (Ferreira and Small 1974). However, Tooley (1938) found that KNO_3 stimulated germination of Polypogon only at alternating temperatures. Hence, ineffectiveness of KNO_3 in stirring up seed germination in this study (Table 5) may possibly be ascribed to constant temperature regimes.

The low mean germination percentage for 0.8% KNO_3 (Table 5) may indicate that KNO_3 activated seed germination only at low KNO_3 concentration. Similar results have been reported in seed germination of *Atriplex nummularia* and *Epilobium montanum* seed (Abu-Zanat and Samarah 2005, Mayer and Poljakoff-Mayber 1975). At higher concentrations, it is argued, KNO_3 solutes decrease the osmotic potential of the germination solutions, which impairs imbibition, thereby retarding germination (Bonner 1968, Salisbury and Ross 1978).

Effect of moisture content and KNO_3 treatments on the germination vigour of W. whytei seeds at 20^0C

It had been suggested that slow seed germination is a sign of the seed being dormant (Baskin and Baskin 1998, Bewley and Black 1994). Sporadic seed germination at the different RH levels (Figure 2), may indicate that *W. whytei* seed may have some form of dormancy. Germination vigour determines the response of seed to stress conditions (Schmidt 2000). Hence, extrapolating the experimental results to field conditions (Figure 2) only seeds incubated at 19.7% RH predicted high seedling survival (Figure 3). Furthermore, high seed vigour in all the treatments at 19.7% RH might designate that generally, KNO_3 was more effective at 19.7% RH than in the other treatments (Figure 3). This may demonstrate that based on speed of germination, 19.7% RH could be the optimum equilibrium relative humidity for drying *W. whytei* seed (Figure 3). Vertucci and Roos (1990) claimed that seed moisture content in equilibrium with 19-27% relative humidity are safe for long-term seed longevity as opposed to ultra-dry moisture content. Probably, *W. whytei* seed should be dehydrated to this equilibrium moisture content range for it to survive long-term storage. However, seed storage studies are needed to substantiate these observations.

Conclusion

These results showed that *W. whytei* seed can be safely dried to ≤5% MC level. It is therefore concluded that *W. whytei* seed is orthodox and can withstand subfreezing storage temperatures. The seed germinates readily without pre-treatment. However, for optimum germination, empty seeds should be removed before sowing. It was also established that 20^oC is the best temperature regime for germinating *W. whytei* seed. These findings offer an opportunity to the Government of Malawi to intensify ex-situ conservation in the form of seed and/or plantation for sustainable management and utilization of Mulanje cedar. Further research should determine the maximum longevity of Mulanje cedar seed under subfreezing temperature regimes. Another study should investigate the phenology of Mulanje cedar.

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INFORMING FOREST RESTORATION: AN APPRAISAL OF LOCAL ECOLOGICAL KNOWLEDGE FROM A COMMUNITY ON THE WILD COAST OF SOUTH AFRICA

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Abstract

The dependency of rural people on the forest resources of the Wild Coast of the Eastern Cape Province of South Africa and their need for arable land has not been without impact. Forests are becoming increasingly fragmented and degraded which in turn has had negative feedbacks on rural livelihood security. The opportunities associated with the carbon market have opened doors for financing the restoration of degraded forests. Such a project has been proposed for a section of the Matiwane Forest along the Wild Coast. Standard ethnobotanical techniques and participatory learning approaches were used to elucidate priority species for restoration whilst appraising the institutional context into which such an endeavour would be embedded. While a suite of locally-important species emerged, it seems the traditional forest management practices and customs of the region have become threadbare and for effective restoration to occur, revitalisation of these forest management institutions is required.

Introduction

The importance of forests and their products in contributing to the well-being and, often, the survival of millions of rural poor across the globe has been widely recognised (Sunderlin *et al.* 2005, Shackleton *et al.* 2007). In South Africa, population growth, increasing poverty, the HIV/Aids pandemic, political and administrative reform, and growing commercial markets for forest resources all play a role in communities having to cope with a deteriorating resource base and increasingly stressed livelihoods (Lawes *et al.* 2004). This is particularly the case in the O.R. Thambo District Municipality (formally Transkei) of the Eastern Cape; home to one of the few remaining areas of biodiversity-rich, closed canopy Transkei Coastal Forest in South Africa.

Because of low rates of formal employment in the Municipality, most residents rely on welfare grants, cultivation of crops and a range of forest products for their livelihood needs (Chalmers and Fabricius 2007). Pressure for both arable land and essential forest products has resulted in progressive erosion of the forest resource with some 42 forest patches in the region being reported as partially or totally cleared (De Villiers 2002). Forest restoration linked to the carbon market has, consequently, been mooted as one potential avenue for thwarting further biodiversity loss and ensuring a continued supply of key livelihood resources.

The impetus setting this research in motion was, therefore, recognition of the need for baseline studies that will provide a platform for restoration to commence. One of the foremost objectives was to identify suitable tree species for rehabilitation based on local livelihood needs and forest dependency. The expectation is that once baseline studies have been carried out, restoration of the degraded forest will proceed and this will provide job opportunities for local residents who will also be involved in managing the project. Moreover, it is hoped that trade in sequestered carbon will provide sustainable income for the community into the future, as well as an incentive for forest conservation.

In order to elucidate the degree to which local livelihoods and forest products are intertwined, a suite of participatory methods were selected that worked in concert with the recognised importance of local ecological knowledge (LEK). Aside from pinpointing priority species for restoration, insight was sought concerning the institutions the community has in place to govern its forest resources and their competency. Each of these objectives should assist in better understanding how restoration of the degraded forest can be accomplished.

Study area

The study site, an area of the Matiwane Forest known as Gongwane and its adjacent community (31°49'25.3''S; 29°15' 73.0''E), is located in the Local Municipality of Nyandeni in the north-eastern part of the Eastern Cape Province, South Africa (Figure 1). It falls under the jurisdiction of O.R. Tambo District Municipality, the poorest district in the Eastern Cape having some 1.5 million people living below the poverty line (Eastern Cape Department of Social Development 2008). Nyandeni Local Municipality, in turn, has the highest population density within the district (91/km^2) and an unemployment rate of 76.1% (Nyandeni Local Municipality, n.d.). Gongwane State Forest lies adjacent to Hluleka Nature Reserve, a protected area managed by the Eastern Cape Parks Board. According to the reserve manager, local access to forest resources is restricted save for thatch grass (*Cymbopogon validus* [(Stapf.) Stapf ex Burtt Davy]), which is harvested between August and October (Ntokoza pers. comm. Eastern Cape Parks Board 2008).

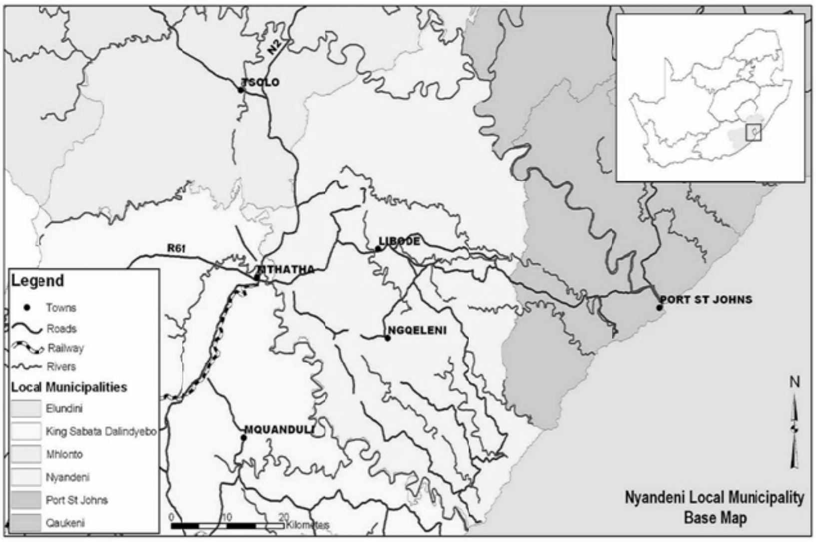

Figure 1: Location of the study site along the Wild Coast of the Eastern Cape Province, South Africa

Materials and Methods

Three complementary methods were used: a 'tree quiz' to identify important species, interviews and participatory rural appraisal exercises to ascertain other information related to the use and management of the forest. This provided the opportunity for triangulated analysis of largely qualitative data derived from local peoples' perceptions and knowledge.

A list of priority tree species was ultimately formed, founded upon a number of criteria: (i) the frequency with which the species was referred to during the course of the three methods used; (ii) respondents specifically stating that it was a priority species for restoration; (iii) a species that could be used as an alternative to other more scarce tree species; (iv) it is particularly susceptible to exploitation both by locals and non-locals due to its importance (Table 2).

'Tree quiz'

The 'tree quiz' was based on a modification of a standard ethnobotanical technique known as the 'informant consensus' method (Krog *et al.* 2005). Prior to data collection, ad hoc interviews with forest guards and locals resulted in a list of 15 locally-important woody species to be used in the quiz. Specimens of these species were taken to households with the assistance of a local interpreter. Every effort was made to involve as diverse a user, gender and age group as possible (Krog *et al.* 2005, Theilade *et al.* 2007). A sample of 31 informants performed the 'quiz', varying in age from 13 to 76 and representative of user-group diversity in the village.

The evaluation of the importance of each species in the 'quiz' with regards to its specific uses was recorded on a scale from 0 – 1.5 (Table 1). The four point scale works on the following basic assumption: an unknown product scores a 0; a useful product will score a 1.0 and this is adjusted by half a point up or down if the informant can provide definite information denoting superior or inferior characteristics of the species (Theilade *et al.* 2007). For example, a species scores 1.5 if it is given preference over other species, while a species that is seldom used will score a 0.5 (Theilade *et al.* 2007).

Table 1: Abridged use-value score table for *Duvernoia adhatodoides**

Use-categories	USE-VALUE (*Duvernoia adhatodoides*)					
	1.5	1	0.5	0		
	No. of informants				Total value	Average
Construction	4	18		9	24.0	0.8
Total use-value						0.8

Following this, 10 use-categories were formed based on participants' responses, including construction, human and veterinary medicine, fuel wood, domestic utensils, implements, food and water, farming, traditional and other (Table 1). A use-value was then calculated for each species in each use-category across all informants. These scores were summed within each use-category and total use-values were calculated for each species as the sum of average use-values for all use-categories.

Interviews and participatory rural appraisal exercises

Following the 'tree quiz', 30 participants were further questioned concerning their knowledge on local institutional structures for forest management and their perceptions of the current state of the forest. Focus group sessions were held with the specific aim of illuminating local perceptions regarding the restoration initiative proposed for the area. A Venn diagramming exercise was undertaken with a local women's group to identify key institutions and needs within the community, and a ranking exercise to identify priority tree species in the eyes of children took place at a local primary school. Key informant interviews were also conducted with the forest manager [Department of Water Affairs and Forestry (DWAF)] and the reserve manager (Hluleka Nature Reserve).

Results and Discussion

Priority species

Based on the multi-criteria approach described in the methods, *Millettia grandis* [(E.Mey.) Skeels], *Ptaeroxylon obliquum* [(Thunb.) Radlk] and *Duvernoia adhatodoides* (E.Mey. ex Nees) (Table 2) were revealed as the top priority species for restoration. These species also appeared in a list compiled by Cawe and Geldenhuys (2007) of locally-important species harvested from the Port St John's Forest Estate north of the study site. Their list was based on the number of stems harvested, frequency of presence in plots and total basal area found.

Table 2: Priority species for restoration based on local perceptions

Variable	*Milletia grandis*	*Ptaeroxylon obliquum*	*Duvernoia adhatodoides*
Locally-important	Yes	Yes	Yes
Alternative to use of scarce species	Yes	Yes	Yes
Growth rate	Slow	Slow	Fast
No. of use-categories	6	6	3
Susceptible to exploitation	Yes	Yes	Yes

Local ecological knowledge, gender and age

The 'tree quiz' revealed that three species were widely recognised, with 97% of participants being familiar with *Acacia karroo* (Hayne), while 90% and 84% were familiar with *Millettia grandis* and *Grewia lasiocarpa* (E.Mey. ex Harv) respectively (Table 3). With respect to the other 12 species, recognition varied between 74% and 13% of informants. Interestingly, a species like *Ptaeroxylon obliquum*, which was mentioned in every engagement with the community, was only recognised by 42% of participants. Participants were reported to know a species only if they could provide its correct name and one or more of its uses. It is possible that the 15 woody species identified for this exercise were not fully representative of the broader community's most important species, perhaps because the selection was made by men. The low levels of recognition may, however, also have been due to difficulties identifying the species from a sample rather than viewing the whole specimen in the forest, where the bark and the shape of the tree may be more indicative than the leaves.

Concerning the number of use-categories that species fell into, *Vepris lanceolata* [(Lam.) G.Don] and *Acacia karroo* were recorded as having the most number of uses (nine and seven respectively). The trees with the highest use-value score included *Millettia grandis* (1.9), *Grewia lasiocarpa* (1.6) and *Acacia karroo* (1.5) (Table 3).

Men displayed a greater knowledge of the tree species employed in the 'quiz' than women (Table 4). This may be because of the skewed tree selection in favour of male-user preferences or because males are invariably the primary collectors and users of wood-based products, with the exception of fuel wood for home consumption (Neumann and Hirsch 2000, Shackleton and Shackleton 2004). If the study had looked at the entire array of forest products, including non-wood products, used by local inhabitants, then perhaps the findings would have been different as women tend to make use of a more diverse range of resources than men (Shackleton and Shackleton 2004).

The middle-aged to older generation (>29 yrs) was revealed as being more knowledgeable of the tree species than the younger generation (<29 yrs). Although this was not statistically significant (p = 0.0526), it may have been so had the sample size been larger. This finding is comparable to that of Dovie *et al.* (2008), who found that males and older people were generally more knowledgeable regarding the usefulness of woody plant species. Discussion with the interpreter unearthed the effect of westernisation in the area and the consequent lack of appeal LEK has among the younger generation (<29 yrs).

Table 3: 'Tree quiz' responses

Botanical name	Vernacular name	% of respondents identifying correctly	No. of use-categories	Use-value score
Millettia grandis (E.Mey.) Skeels	*Umsimbithi*	90	6	1.9
Grewia lasiocarpa E.Mey. ex Harv	*Umhlolo*	84	5	1.6
Acacia karroo Hayne	*Umnga*	97	7	1.5
Duvernoia adhatodoides E.Mey. ex Nees	*Ihlehlwe*	71	3	1.2
Vepris lanceolata (Lam.) G.Don	*Umzani*	61	9	1.1
Rauvolfia caffra Sond	*Umjelo*	74	3	1.1
Tricalysia lanceolata (Meisn. ex Hochst.) Sim	*Isixesa*	61	4	0.9
Coddia rudis (E.Mey. ex Harv.) Verdc	*Intsinde*	71	3	0.9
Ptaeroxylon obliquum (Thunb.) Radlk	*Umthathi*	42	6	0.8
Dais cotinifolia L	*Intozane*	68	6	0.8
Zanthoxylum davyi (I.Verd.) P.G.Waterman	*Umlungumabele*	55	5	0.7
Buxus macowanii Oliv	*Umgalagala*	26	3	0.5
Strychnos henningsii Gilg	*Umnonono*	13	4	0.3
Chaetachme aristata Planch	*Umkovoti*	13	4	0.3
Schotia afra (L.) Thunb	*Umgxam*	13	3	0.2

Table 4: The association between gender and age and positive species identification

Category	Average % of respondents positively identifying a species	Sample size (n)	Statistical test
Female	42.8 ± 21.3	17	Mann-Whitney ($z = 3.57$; $df = 29$; $p = < 0.05$)
Male	71.42 ± 13.3	14	
<29 yrs	44.2 ± 22.2	10	T-Test for independent groups ($t = 2.02$; $df = 29$; $p > 0.05$)
>29 yrs	61.2 ± 21.7	21	

Local perceptions of 'the state of the forest'

The findings regarding respondents' opinions on the 'state of the forest' were mixed and difficult to interpret. The better part of respondents (60.0%) believed the forest to be in a degraded state. On the contrary, some 30.8% of males believed that the forest was regenerating, while only 5.9 % of females believed this to be the case. Furthermore, 29.4% of females did not perceive the forest to be in a degraded state and of these, several mentioned exotic tree species to be of significant importance to them.

Interestingly, the impact of the increased availability of household grants for the community has resulted in a decline in the practice of forest clearing for cultivation. McAllister (2000 in Shackleton *et al.* 2001) remarks that in the broader region all agricultural efforts are being invested in home plots as opposed to the cultivation of fields; something which was apparent in the study village.

Local forest resource management practices and institutions

Perspectives regarding current institution/s responsible for management

Most respondents (43.3%) indicated that government employed forest guards are primarily responsible for the management of the forest, while only 3.3% mentioned the existence of cultural norms and taboos to control the harvesting of important tree species. A significant proportion of respondents (30.0%) believed that both current government management systems (forest guards) and traditional systems have failed to result in effective management of the forest (Figure 2).

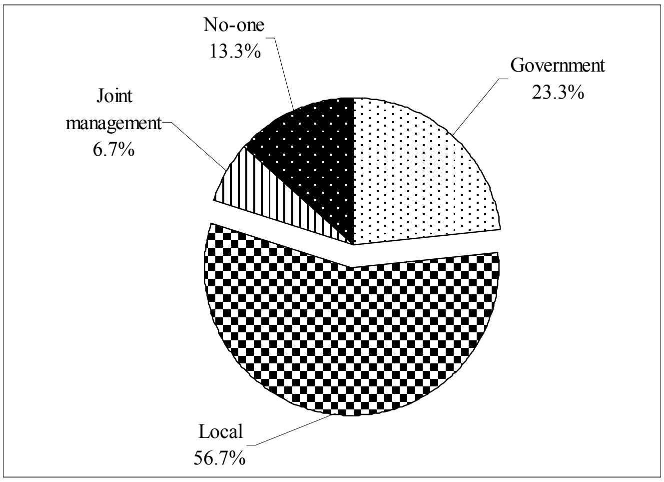

Figure 2: Perspectives regarding current institution/s responsible for management of Gongwane Forest

Conversations with village members and the forest manager yielded many different responses regarding access to harvesting from Gongwane Forest. The latter averred that the State Forest is closed to the community but they, as the authority, have to 'turn a blind eye' to local harvesting because more challenging tasks have to be attended to, like curbing indiscriminate clearing for agriculture (Nkibi pers. comm. DWAF 2008). According to the National Forest Act (No. 84 of 1998), 'everyone has reasonable access to state forests for purposes of recreation, education, culture or spiritual fulfilment' (Section 19) within designated areas [Section 20 (2)]. Furthermore, there is a list of activities which may be licensed in state forests including 'the felling of trees and removal of timber; the cutting, disturbance, damage or destruction of any other forest produce; the removal or receipt of any other forest produce' [Section 23 (1b, c, d)]. With regards to both the designation of areas of access within the State Forest and the issuing of licenses to locals for harvesting, the forest manager maintained that they (DWAF) are ill-equipped to do so (Nkibi pers. comm. DWAF 2008). This lack of capacity needs attention if the authorities are to provide meaningful support to the restoration initiative.

Locally-proposed management

The local population, possibly as a result of the failings of current government-led management of the forest, are in favour of locally-led management of the forest with 56.7% of respondents in support of this option (Figure 3). Only two respondents were aware of the concept of joint management between local institutions and government.

This strong support for local management of the forest is suggestive of some degree of social cohesion which is encouraging in terms of the ultimate goals of entrusting restoration in the hands of the community. Yet the need for government support is crucial (Crook and Clapp 1998, Shackleton *et al.* 2001) and the community's lack of understanding regarding joint management is something that will require attention. Their unanimous opinion that the restoration site should be located within the nature reserve where it would be properly protected is almost contradictory to their desire for self-governance because it denotes that they do not have faith in their own actions. This institutional haphazardness is a potential stumbling block for the proposed restoration endeavour in the region.

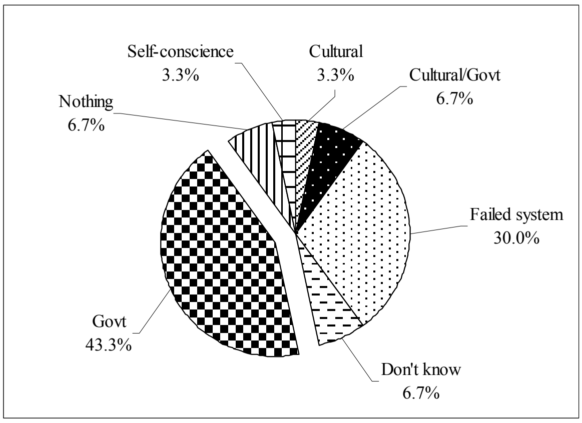

Figure 3: Locally-proposed management for Gongwane Forest

Conclusion

A total of 66 different tree species were referred to during the course of fieldwork; a reflection of the importance of tree diversity in local people's livelihoods. Participants in the 'tree quiz' listed multiple uses for each of the 15 species included, with certain species like Vepris lanceolata falling into nine different use-categories. The priority species for restoration included *Millettia grandis, Ptaeroxylon obliquum* and *Duvernoia adhatodoides*, each of which are indigenous trees and provide a good base from which to make future decisions regarding restoration.

Local participation in the restoration process and subsequent management of the restored sites is critical as highlighted by the wide perception that the community should have at least some forest management responsibilities. The reality is that rural poverty is a significant driver of resource depletion and no restoration endeavour, or any other programme orchestrated to address the sustainable management of forests, should take place without simultaneously addressing local needs (von Maltitz and Shackleton 2004).

With this in mind, the following recommendations are made:

- The proposed restoration of Gongwane and Matiwane Forests needs to bolster the use of LEK in implementation.
- The restoration endeavour should take cognisance of the gender dimensions of forest use, as what is important for men may not be for women.
- An understanding of co-management needs to be developed within the community; a successful restoration programme will require buy-in from a number of stakeholders – fundamentally the community themselves.

- Strong local institutions are required, together with capacity at government level, to develop sustainable harvesting guidelines and to allocate and enforce use rights, and in so doing ensure sustainability of restored sites.
- DWAF needs to redefine the boundaries between State and communal forest so that it is clear to all parties which regulations are applicable to which areas.
- The proposed restoration focus on degraded communal land while the community is in favour of the Nature Reserve as a site needs to be reconciled.
- Participatory research similar to what has been undertaken in this study should continue with other communities adjacent to the larger Matiwane Forest.

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IMPACT OF CHANGING GROUNDWATER TABLE ON TREE GROWTH IN ZAZAMALALA FOREST

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Abstract

Expansion of wet rice cultivation in the immediate vicinity of the Zazamalala reafforestation project in Madagascar caused the groundwater table to increase from a depth of 4 m to new levels between 1 and 2 m depth since the year 2000. This will have serious consequences on the future of the reafforestation project as it is meant to provide for the restoration of the endemic dry deciduous forest in southwest Madagascar. A GIS-based model of the groundwater table, based on systematic gauging conducted in 2007, allowed to formulate suggestions on the spatial distribution of further reafforestation with endemic and introduced species in response to groundwater table depths. Tree ring analysis of six key tree species in Zazamalala was conducted: *Commiphora guillaumini, Tamarindus indica, Dalbergia purpurascens, Ziziphus mauritania, Poupartia caffra* and *Broussonetia greveana*. It was concluded that diameter increment in response to increasing depth of the groundwater table was different for the sampled tree species. These conclusions may serve to formulate proper management prescriptions for forest areas subject to drastic site alterations due to changing land use.

Introduction

The dry deciduous forests of Madagascar feature a high degree of ecosystem biodiversity (Gauthier and Goodman 2003). Due to population pressure and deforestation, this forest type is seriously threatened. It covered about 400,000 ha in the 1970's, but the total surface area decreased to less than 30,000 ha today (Sandy 2006).

The Zazamalala reafforestation project was established to try to counteract this negative evolution. The project area is almost completely surrounded by rice fields. Hence, the recently established forest serves as the last refuge for local plant and animal species. The project would also provide important information about the conflict between socio-economic development and conservation, as around the nearby Kirindy nature reserve new rice fields are being planned.

In the Zazamalala forest almost no forestry research has taken place. The primary issue is the relationship between tree growth and the presence of rice fields in the immediate vicinity of the forest. The groundwater level under the forest in the dry season is several meters deep. Expansion of wet rice cultivation caused the ground water level to increase considerably, with a visible impact on the forest vegetation. For example, the endemic baobab *Adansonia gradidieri* is dying off, and there is a serious risk of the species becoming extinct in this area.

Materials and Methods

Study area

The dry coastal area in the southwest of Madagascar is known as the Menabe region (Figure 1). The climate features a dry season lasting from 6 to 8 months. Most of the rainfall falls in December and February, with the annual mean around 800 mm.

Figure 1: Menabe region and location of Morondava Tsinjorano (MapSource 2004).

The structure and phenology of the dry deciduous forest is largely determined by the availability of water. With a few exceptions (Sorg and Rohner 1996) very little data about the phenology of this forest in Madagascar have been published. About 80% of the vegetation consists of big flat leaved grass species, that are very sensitive to fires, and which are regularly burnt by herdsmen. Loss of nutrients and damage to the organic top layer cause loss of fertility. The remaining trees are small, and survive mainly by vegetative reproduction from the underground root system: *Ziziphus mauritania*, *Poupartia caffra*, *Tamarindus indica*, etc. Baobabs (*Adansonia* spp.) are emergent species in this deciduous forest type, that once covered 400,000 ha on the west coast of Madagascar. With the exception of a few fragmented patches (mostly related to graveyards, and sites of religious significance), all original forest has gone. The construction of the canal of Dabera in the colonial era made wet rice cultivation possible. Next to occupying large tracts of forest land, new farm projects (irrigated citrus cultivation, tobacco and cotton cultivation, sugar cane) resulted in a large scale immigration of farmers, further increasing the pressure on the forest, predominantly by swidden agriculture and clearing of the forest by fire. This canal was renovated in 1982 after a long period of neglect, and is in fact a diversion from Morondava River. The level of the canal can be regulated by wooden barriers.

The original forest used to cater for all timber requirements in Morondova, but over-harvesting and degradation caused a marked shift in available species (Table 1).

Table 1: Distribution of timber species as recorded on the market of Morondava (Raonintsoa 1996)

Species	1985 (%)	1987 (%)	1988 (%)	1989 (%)
Hazomalania voyroni	65.0	62.0	0.3	0
Dalbergia spp.	11.5	11.5	7.9	14.8
Broussonetia greveana	7.2	19.3	5.3	0
Commiphora spp.	7.2	6.3	30.1	68.9
Zonthoxylum spp.	8.3	0	0	0
Other species	0.8	4.7	64.3	15.5

The Zazamalala reafforestation project is located in the village of Tsinjorano at the national road No. 35, about 30 km from Morondava. It is next to the Dabera canal mentioned above. It is a private project established in 2000 by Dr. Simon Rietveld and Jocelyne Farazamalala, by the purchase of 40 ha, that was a part of a deserted orange farm. The forest is characterized by a marked dominance of *Ziziphus mauritania*, *Tamarindus indica* and *Poupartia caffra*. These species are typical for degraded forest and abandoned fields.

The main aim of the project was to restore the endemic deciduous forest type by enriching the thorny vegetation with endemic tree species. As it is a project funded by private means, the expansion of the forest area proceeds slowly, but nevertheless a total of 60 ha has been established, with annual purchases of 5 to 10 ha being planned (Rietveld 2008). The project has suffered considerably from theft, illegal logging, poaching and forest fires. As a countermeasure, the local population was offered assistance with education, health services and consulting with farming practice. In addition, seeds and tree seedlings were distributed.

Research rationale

The present expansion of wet rice cultivation and the associated increase in the groundwater table is the primary concern for the long term survival of the reafforestation project. Most endemic species do not withstand water logging. Some introduced species such as *Ceiba pentandra* grow well, but in general there is a lack of knowledge regarding the suitability of tree species to the changing site conditions, and to the increased groundwater table in particular.

Tree ring analysis was an obvious approach to assess growth patterns over time. While effects of water logging on diameter increment have been documented extensively with temperate species (Schweingruber 2007), similar studies with trees in semi-arid climates are scarce. Trees in the seasonal tropics often feature false or barely discernable tree rings, coincident tree rings and growth anomalies (Schweingruber 1996).

The suitability of tree species for growth analysis was determined from the following criteria: presence of tree rings, visual assessment of the difference between early wood and late wood, presence of ring-porous wood vessels, and presence of borer parenchyma cells. Based on published data (Inside Wood 2004), the following species were retained (vernacular names between brackets): *Commiphora guillaumini* H. Perrier (*Arofy*), *Tamarindus indica* L. (*Kily*), *Ziziphus mauritania* Lamk. (*Mokonazy*), *Dalbergia purpurascens* Baill. (*Manarifotsy*), *Poupartia caffra* (Sonder) H. Perrier (*Sakoa*), and *Broussonetia greveana* (Baillon) C.C.Berg, (*Vory*).

A number of potentially important species were excluded from the experiments. Timber core samples of *Adansonia za* Baill. could not be preserved properly, although tree-rings were clearly visible. Tree-rings of *Albizzia greveana* Baill. were barely detectable. Too few specimens of three other *Dalbergia* species were present in the research area. The wood of *Stereospermum euphorioides* (Bojer) A.DC. and *Cedrelopsis* spp. was too hard to obtain wood-core samples.

Groundwater table measurements

The level of the groundwater table was assessed using an Edelman 7 cm diameter hand augur, a PVC piezometer and a bell attached to a measuring tape. No groundwater table measurements have been carried out in the research area before. The influence of the adjacent rice fields on the ground water table was assessed by sampling along a linear transect into the forest. A similar exercise was conducted to assess the influence of the presence of the Dabera canal. Given the time limits of the field campaign, a systematic sampling procedure was carried out inside the forest (Figure 2).

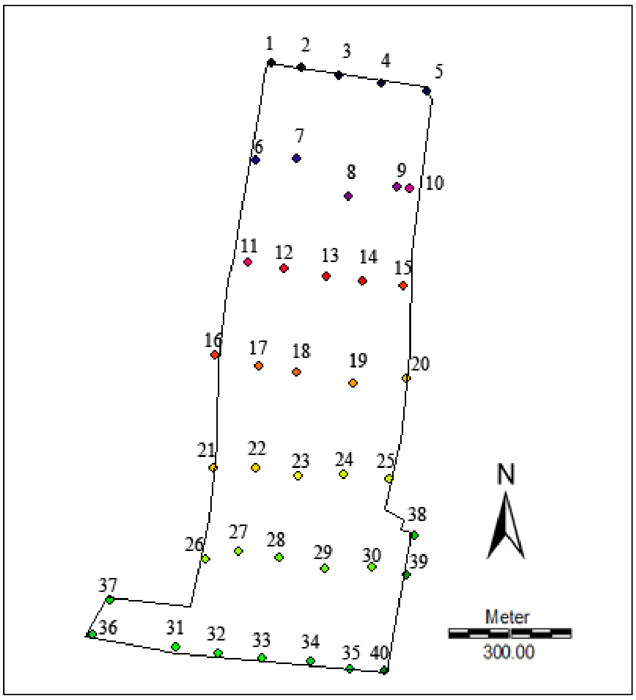


Figure 2: Shape of the Zazamalala reafforestation project and location of the sample points to measure the groundwater table level.

A total of 40 measuring points was determined. In addition, 42 extra measurements were conducted, amongst which there were 10 unused water reservoirs. The groundwater table level of six corner points was monitored daily, and all others were measured at least three times in a 2-month period. This setup allowed the assessment of temporal variability between measurements. The coordinates of the raster points were recorded with a GPS. Using a raster GIS a groundwater level model of the research area was obtained. A model including all 82 measuring points proved to be the most reliable representation of the groundwater level in the study area. Using interpolation techniques a model with three groundwater table zones was obtained (Table 2). An overlay operation between the map area and the ground table model resulted in a map describing the average groundwater table per area.

Table 2: Groundwater table zones resulting from GIS interpolation of a systematic sampling network

Groundwater table zone	Depth (cm)	Average level of groundwater table (cm)	Surface area (ha)
1	0-100	84	8.68
2	100-200	144	43.18
3	>200	218	13.90

Tree-ring analysis

Timber core samples were obtained using a Pressler type Suunto drill, featuring a drill diameter of 5 mm, and a length of 40 cm. The samples were taken at breast height. In each water table zone a minimum of six core samples were obtained from the selected tree species. A total of 100 trees were sampled. The fact that a particular species was absent in a zone was taken as an indication of the unsuitability of the site. Reference timber core samples were obtained from Kirindy and Mahabo, to allow for a comparison with average tree-ring width in primary forest.

At least two core samples were taken of every sample tree. The second sample was taken at 180° from the first one. From smaller trees only one sample was taken straight through the bole. Large trees were sampled close to the centre of the bole. In a number of cases additional samples were taken at 90° and 270° from the first one. The field work yielded 211 core samples in Zazamalala.

Core samples were put in specially manufactured receptacles to prevent damage during transport to Belgium. Prior to analysis with a stereo microscope the samples were mounted and polished with abrasive paper. The mean annual increment of the diameter was determined for the period 1995-2000, and for the last four years, in order to assess growth change patterns due to the changing groundwater table. The hardware was a Lyntab, and the software was TSAP-Win, an often used tool in dendrochronological research.

Results and Discussion

Influence of rice fields and the Dabera canal on the ground water table

The presence of rice fields strongly influences the groundwater table in the forest (Figure 3). However, care should be taken in the interpretation of this single measurement as the groundwater table profile is dependent upon soil type and hydraulic conductivity. The influence of the Dabera canal is less conclusive (Figure 4). The relationship between the distance to the rice field and the groundwater table was described by the following exponentially decreasing model:

$$GWT = -a*e^{-b.X} + c*X + d$$

With: a, b, c and d = constants
X = distance to the rice fields (in m)
GWT = ground water table (depth, in cm)

The result confirms that the influence of rice fields is apparent to a distance between 100 m and 200 m (Figure 5). The sizeable spread around the model can be attributed to pedomorphological characteristics of the soil that are likely to vary across the forest.

Nevertheless, the influence of adjacent rice fields causes the groundwater table to increase considerably. The southern parcels are drier, and here endemic tree species are to be preferred for reafforestation. The northern parcels are much wetter and here preference could be given to introduced species (for fuel wood and construction timber) that are suited to this particular type of environment.

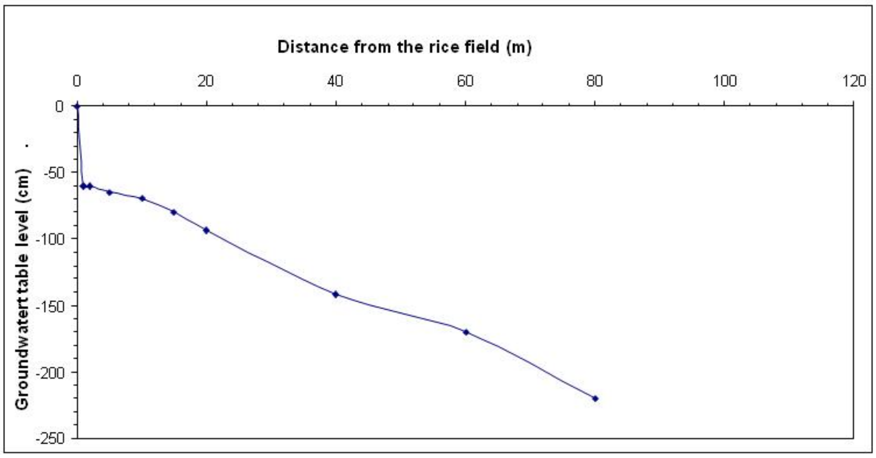


Figure 3: Profile of the groundwater table as a function of distance from the rice field.

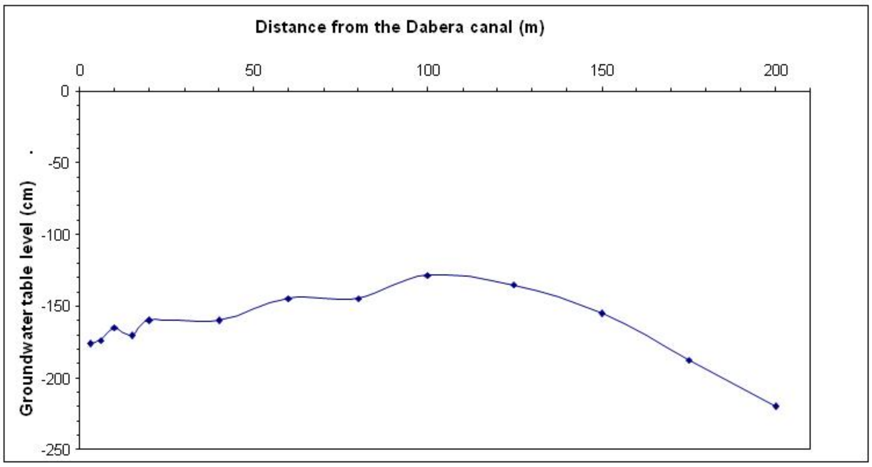


Figure 4: Profile of the groundwater table as a function of distance from the Dabera canal.

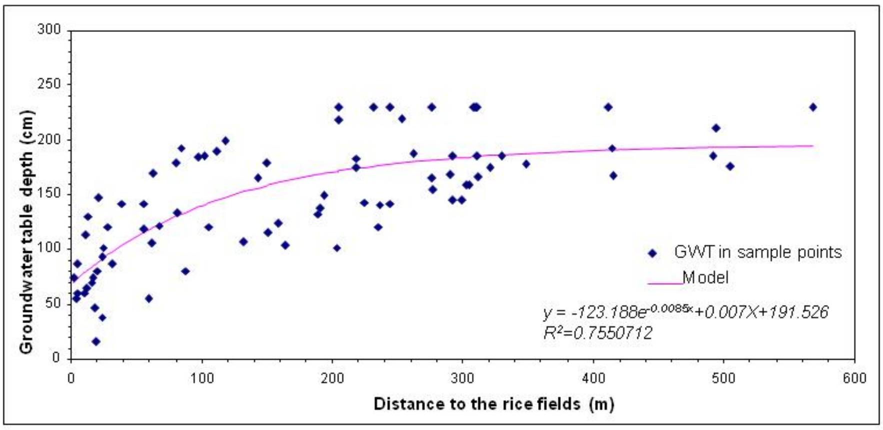


Figure 5: Groundwater table as a function of distance to the rice fields.

Relationship between tree-ring width and groundwater table level

The average tree-ring width of the period 1995-2000 was compared with the period 2004-2007. As it took several years to establish the rice fields from 2000 on, it was assumed that 2004 was a safe starting date for the analysis. All data were subjected to the same rigourous set of tests including (1) cross date parameters to establish whether there is a correspondence between different core samples; (2) calculation of Kolmogorov-Smirnov and Levene tests to check normality and homoscedasticity, and (3) parametric and non-parametric tests to ascertain significance of difference of tree-ring width across groundwater table zones and periods. The results are presented for each of the six selected tree species.

Commiphora guillaumini

Arofy is one of the most important construction timber species in the Zazamalala area, and it usually occurs in the drier sites of the dry deciduous forest. It was therefore assumed that this species is particularly susceptible to an increase of the groundwater table. Average tree ring width in Mahabo and Kirindy is not significantly different for the two periods (Figure 6a). It is therefore assumed that any significant difference in Zazamalala is due to changing groundwater tables. That was only the case for groundwater table zone 2. It should be noted that only very few specimens occurred in groundwater table zone 1, so the results are not conclusive.

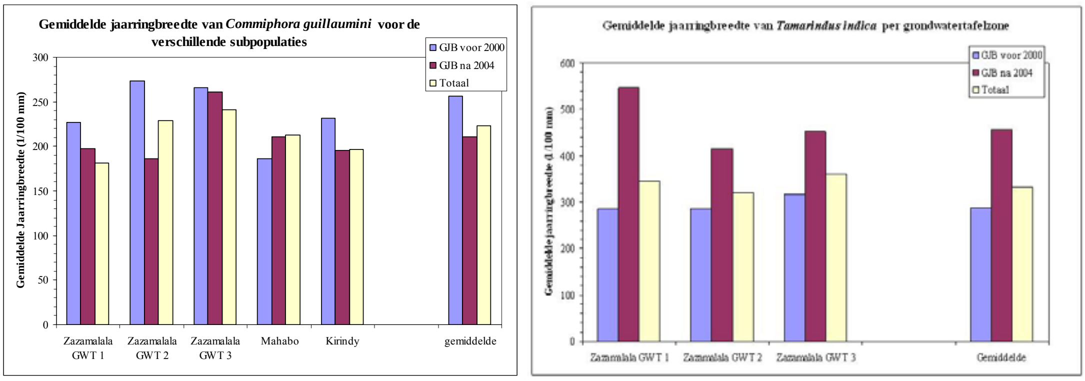


Figure 6: Average tree-ring width (ATW, in 1/100 mm) of *Commiphora guillaumini* (a, left) and *Tamarindus indica* (b, right) in the different groundwater table zones (GWT) and in reference populations.

Tamarindus indica

Kily is one of the most dominant species in Zazamalala, and as it is a species with modest site requirements, it is expected that diameter increment will not change significantly with changes of the groundwater table. *T. indica* showed a significant increased average tree ring width in the second period (Figure 6b) and therefore appears to benefit from an increasing groundwater table.

Dalbergia purpurascens

Manarifotsy is an endemic species yielding very valuable wood. It grows well in the better sites. In Zazamalala It did not occur in groundwater table zone 1. Hence only data for the other two zones were available. There are significant increases in ring width for both groundwater table zones between the twee observed periods (Figure 7a). The control measurements in Mahabo and Kirindy do not display significant differences and much narrower rings.

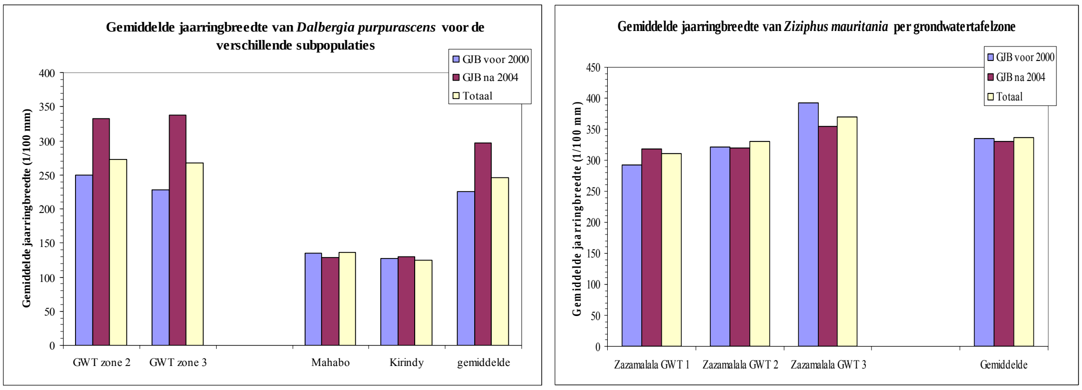


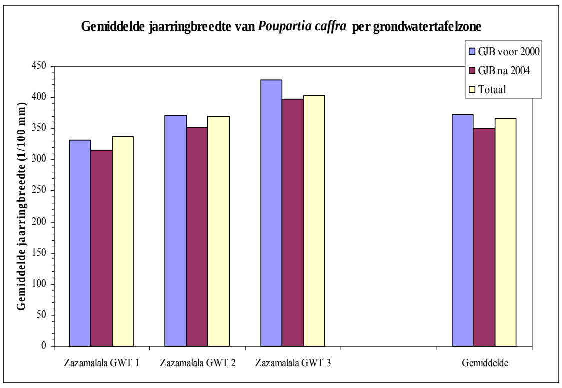
Figure 7: Average tree-ring width (ATW, in 1/100 mm) of *Dalbergia purpurascens* (a, left) and *Ziziphus Mauritania* (b, right) in the different groundwater table zones (GWT) and in reference populations.

Ziziphus mauritania

Mokonazy is the most dominant tree species in Zazamalala, and is characteristic for secondary forest and tree savannas. It is an important source of fuel wood in the region, and the fruits are consumed by the local population. The species has moderate site requirements and is typical for dry and warm climates. Tree ring width varies very little with groundwater level (Figure 7b). The largest values are found in groundwater table zone 3, confirming the fact that the species thrives best in well-drained sites.

Poupartia caffra

Sakoa, similar to Mokonazy, is typical for secondary vegetation and tree savannas. The site requirements are moderate. The small differences in tree ring growth between the considered periods is not significant (Figure 8a), but the species has higher growth rates in drier areas, which could be expected.



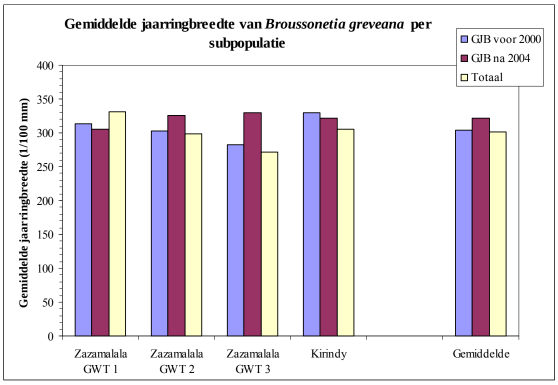


Figure 8: Average tree-ring width (ATW, in 1/100 mm) of *Poupartia caffra* (a, left) and *Broussonetia greveana* (b, right) in the different groundwater table zones (GWT) and in reference populations.

Broussonetia greveana

Vory is endemic and produces excellent construction timber. It prefers moist sites, but does not tolerate flooding. It is therefore expected that diameter increment will increase in zones with higher groundwater tables. The results confirm these expectations (Figure 8b), but the differences are not significant. The decreased tree-ring width in groundwater table zone 1 is probably due to occasional flooding.

Conclusion

The reported results indicate a variable response in diameter growth to increasing groundwater table. In most of the cases the response (positive/negative) was generally predictable as key site requirements were known from the literature. The actual values do indicate that the influence of adjacent rice fields is noticeable. These conclusions should be regarded with some caution: the number of samples (groundwater table measurements) was relatively limited, and the measuring activity was limited in time. However, the results show that with relatively unsophisticated methods, and over a relatively short time, indications of changing growth patterns could be assessed. The findings can be important and useful for spatial planning of reafforestation, in view of particular site conditions and selection of species for specific tree products.

Acknowledgements

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Forests and Climate Change Response

CHANGING FIRE REGIMES IN THE COTE d'IVOIRE SAVANNA: IMPLICATIONS FOR GREENHOUSE EMISSIONS AND CARBON SEQUESTRATION

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Abstract

West African savannas are depicted in the climate change literature as the "burn center" of the planet. This paper suggests that this representation is based on a misunderstanding of burning intensity and the nature of savanna environments. It is argued that burning is not as destructive as perceived and that its effects on vegetation change are more complex than believed. The case study of Katiali examines how farmers and herders use fire as a tool for Sudanian savanna management, and how these practices modify burning regimes and savanna ecosystems over time. The study also investigates the implications of changing burning regimes and vegetation dynamics on greenhouse gas emissions and sequestration of carbon. The theoretical framework of this research builds upon political ecology, which examines the natural resource management practices of ordinary farmers and herders with emphasis on historical-geographical patterns of environmental change, local knowledge, and local specific ecologies. The research was conducted during one dry season from late October 2007 to May 2008 in the Sudanian savanna of northern Côte d'Ivoire. Data were collected through field observations, individual and group interviews, and household surveys. Weather station data were recorded daily. Findings reveal that the Sudanian savanna is a complex environment composed of a mixture of trees, shrubs, grasses, and crops. This diversity is important to recognize in modeling the impact of savanna burning on greenhouse gas emissions. Results also show that farmers and herders increasingly set fires earlier in the dry season to protect orchards and to promote grass regrowth for grazing. Early dry season burning favors the expansion of trees in the Sudanian savannas. The transition demonstrates a shift to a more wooded vegetation cover that could potentially sequester more carbon dioxide than is presently attributed to the system.

Introduction

Climate change is a major environmental challenge facing the world today. The literature strongly links human activities such as greenhouse gas emissions with global warming (Crutzen and Andreae 1990, Levine *et al.* 1995, Liousse *et al.* 2004, Koppmann *et al.* 2005, Reid *et al.* 2005, Longo and Freitas 2006, Tunved *et al.* 2006). Global warming scientists consider biomass burning as an important contributor to atmospheric greenhouse gases and particulate matter (Levine *et al.* 1995, NASA 2005). Tropical Africa is widely viewed as a "fire center" or as a "burn center" of the planet (Levine *et al.* 1995, Hayhoe *et al.* 2002, Small *et al.* 2002, Ludwig *et al.* 2003, Liousse *et al.* 2004, Koppmann *et al.* 2005, Reid *et al.* 2005). There are two recurring themes in the literature regarding fire and the Sudanian savanna (Crutzen and Andreae 1990: 1670, Cros *et al.* 2000: 29, 348, Mbow *et al.* 2000: 565, Brown and Gaston 2001, Van der Werf *et al.* 2003: 552, Liousse *et al.* 2004: 78, Jain and Young 2005: 3). Firstly, savanna fires are considered to be intense and highly destructive. Secondly, savanna ecosystems are discussed as if they were homogeneous landscapes.

It is argued here that climate change scientists need to recognize the diversity of savanna landscapes comprised of different vegetation communities, including grass savannas, shrub savanna, savanna woodlands, dry forests, and gallery forest, and a variety of annual and perennial crops, including tree crops (Hoffmann 1985, Riou 1995, Bassett and Koné 2008). This plant community diversity is important when examining the effects of fire on vegetation cover, greenhouse gas emissions during burning, and the potential for carbon sequestration. Climate change scientists should also consider the diversity of fires (Monnier 1968, 1975) and burning regimes and their transformation under changing social, political and ecological conditions. In West Africa, the timing of burning is extremely important in terms of the effects of a fire on land cover change and greenhouse gas emissions. Dry season fires are commonly divided into three periods: early, middle and late dry season (Monnier 1968, César 1990, Mbow *et al.* 2000, Bassett *et al.* 2003, Koné *et al.* 2008). But the climate change literature rarely considers the temporal dimension of burning (Nguyen *et al.* 1993: 209-210, Cros *et al.* 2000: 29, 348). Only general information is available on burning frequency (Crutzen and Andreae 1990: 1670, Goldammer 1990, Mbow *et al.* 2000: 575, Abbadie *et al.* 2006: 51). Combustion efficiency in savanna landscapes also remains unclear. Previous studies provide several ranges of combustion efficiency (Ward and Hardy 1991, Koppmann *et al.* 2005). The literature indicates that combustion efficiency differs according to vegetation type and combustion stage. These gaps in the literature call for further research on burning regimes and land cover change.

This paper examines the burning practices of local people, their perceptions of biomass burning and vegetation dynamics. It also analyzes the implications of changes in burning regimes and vegetation dynamics on greenhouse gas emissions and carbon sequestration. The study takes an interdisciplinary political-ecological approach to the study of human-environmental relationships that integrates social, political, cultural and biophysical processes in order to deepen our understanding of environmental and social change (Zimmerer and Bassett 2003). The approach examines the long-term human-environmental interactions based on local history, local knowledge, and local ecologies (Blaikie 1994, Peet and Watts 2004) with the goal of contributing to knowledge about global environmental change (Bryant 1992, Blaikie 1994, Forsyth 2002).

Materials and Methods

Study area

The research was conducted in the Sudanian savanna of northern Côte d'Ivoire (Figure 1). The climate is characterized by one rainy season (June to October) and one long dry season (November to May). Average annual rainfall is between 1,100 and 1,500 mm (IFFN 1999). The Ivorian savanna ecosystems are characterized by widespread biomass burning during the dry season. Farmers, herders, hunters and honey gatherers all set fires. Fire is facilitated by the existence of a more or less continuous grass layer.

Ecologists use several parameters to define savanna vegetation at the local and regional scales. At the regional level in West Africa, the savanna vegetation is divided into the Guinean savanna, the Sub-Sudanian savanna, and the Sudanian savanna ecosystems (Figure 1). These definitions are based on rainfall, topography, soil characteristics, and vegetation. The Sudanian savanna ecosystem is composed of gallery forest, dry forest, savanna woodland, shrub savanna, grass savanna, fallow field and croplands (Figure 2). At the local scale, Hoffmann (1985) defines savannas based on floristic composition (dominant grass and/or tree species), ecological criteria (water, soil, types of rocks, position on the slope), and structural parameters (tree height and cover). Riou bases his typology of savanna vegetation types on tree height. Grass savanna has either no trees or a few trees of <2 m height; shrub savanna has trees of 2 to 8 m; savanna woodland is characterized by trees of 8-15 m; dry forest is made up of trees of 8-20 m with a closed canopy; and gallery forest is composed of big trees of > 20 m along rivers (Figure 2).

The locality selected for the research is Katiali (Figure 1). Katiali is located 55 km northwest of Korhogo, the main regional city. More than 3,000 people composed of the Senufo, Jula and FulBe ethnic groups inhabit the village. Agricultural activities focus on cotton, the main cash crop, food crops, tree crops, hunting and honey gathering. Livestock raising is an important land use activity for especially FulBe households who practice a highly mobile form of cattle raising. Agricultural polices dating from the 1960s and 1970s have emphasized the development of cotton and livestock raising (Bassett 1986, 2001, Bassett and Koné 2008). Farmer and herder responses to these policies have transformed the land cover of the Sudanian savanna into a patchwork of fields and fallows that are successively farmed and grazed. Biomass burning in Katiali begins early in the dry season between late October and early November when FulBe herders burn lignified grasses to encourage fresh grass regrowth for cattle grazing.

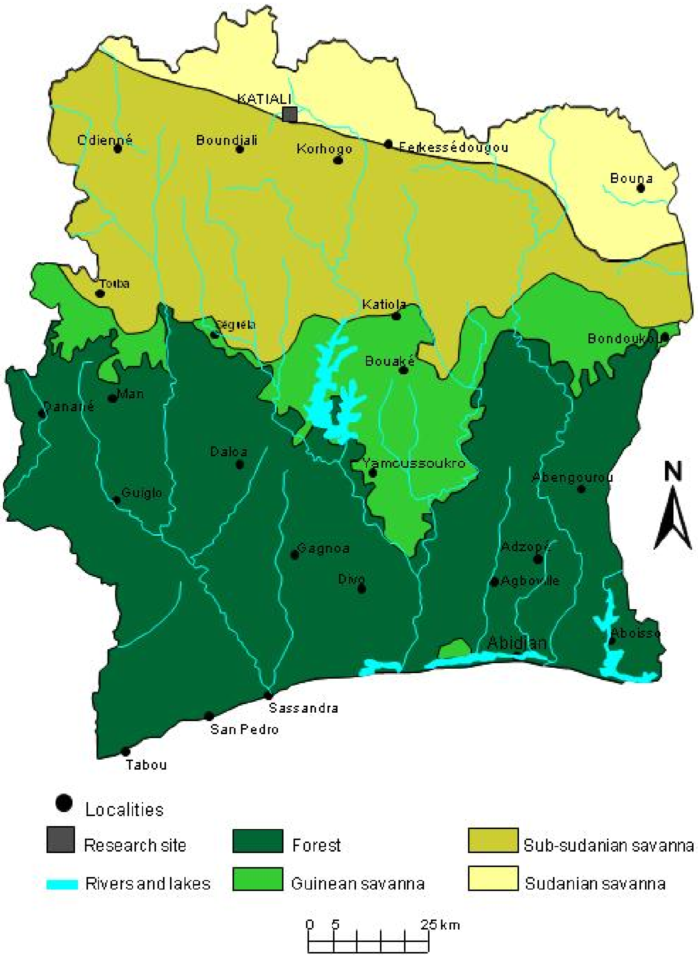

Figure 1: Vegetation zones and research site in Côte d'Ivoire (Source: Monnier 1974)

Figure 2: Fallow field, grass savanna, and savanna woodland vegetation types in the Sudanian savanna zone, Katiali

Methodology

The research was conducted during one dry season from late October 2007 to May 2008 to examine burning practices in different vegetation types throughout the Katiali region. The study involved document collection, direct observation, household surveys, and interviews with individuals and groups. A census of all the inhabitants living in Katiali was conducted at the beginning of the study. The census revealed different actors involved in burning and was used to select a more representative sample of 40 households for subsequent surveys. Household heads were surveyed on different uses of fire, reasons for burning, different periods at which fires are set and why at those periods, and on fire management practices used by farmers and pastoralists. Village leaders (men and women), farmers, pastoralists and hunters were interviewed about specific burning practices and motivations, and their perceptions of savanna fires (Figure 3).

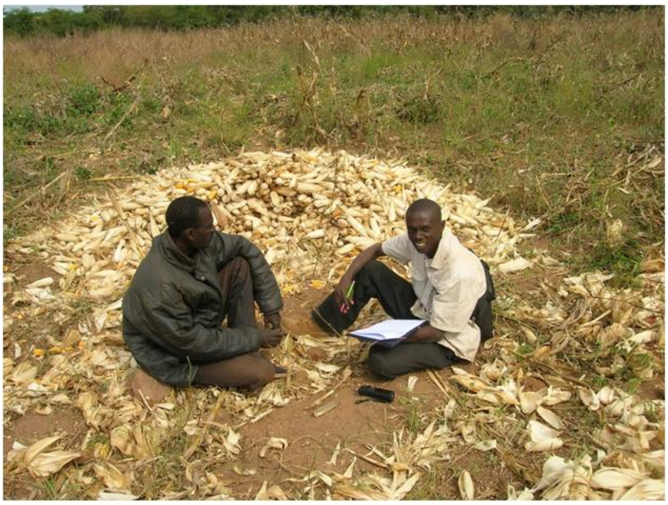

Figure 3: Interview with a farmer in his field

Weather station data, including wind speed and direction, ambient air temperature, relative air humidity, and rainfall were recorded daily (Figure 4). These data provide information necessary for burning regime analysis. The location of fires in the Katiali region was recorded using a global positioning system (GPS) device.

The land cover change study analyzed three plots of 10 x 10 m in each vegetation class to determine tree and grass species, perennial versus annual grass species, height of trees and grasses, and measured available biomass load likely to burn during bush fires (Figure 5). The study also recorded the historical understanding of vegetation dynamics of local people through transect walks, oral histories, and group discussions.

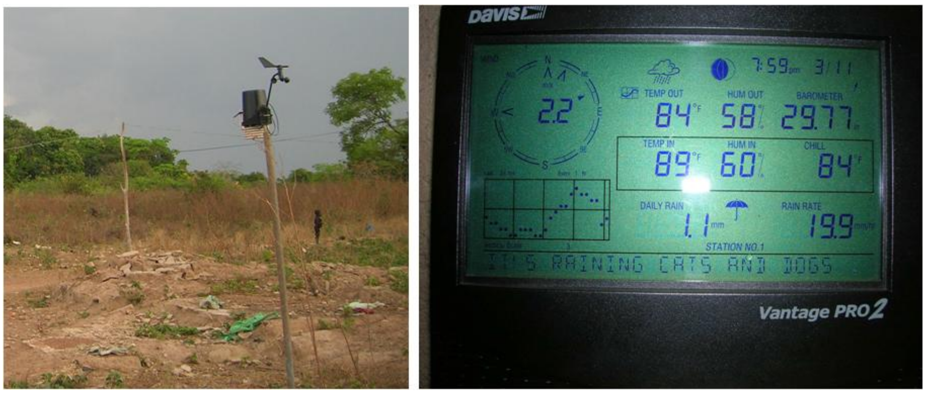

Figure 4: The portable weather station and console used to collect climate data

Figure 5: Experimental burning plot (10 x 10 m) for the grass savanna vegetation type

Results

Burning regimes study

The study of burning regimes consisted of the analysis of burning practices, different burning periods and their effects on fire intensity, burning frequency, and on combustion efficiency.

The results reveal that the main actors involved in biomass burning in the Katiali region are farmers, herders, hunters, and honey gatherers. Local resource users increasingly use fire early in the dry season as a management tool. Farmers set fire to protect their cashew and mango orchards, and herders burn for new grass growth that is more palatable to cattle (Figure 6). Hunters set fires in the middle of the dry season during the months of January and February to flush out game, while honey gatherers extract honey late in the dry season.

Figure 6: (a) Left: Fire set by a farmer in the evening of 9 Dec 2007 to make a fire break around his mango orchard; (b) Right: Grass regrowth from early burning (7 Dec 2007).

The case study of Katiali shows that burning intensity varies during the dry season (Figure 7). Burning is less intense at the beginning of the dry season (late October-December), very intense in the middle of the dry season (January-February), and less intense at the end of the dry season (March-April) (Monnier 1968, César 1990, Bassett and Koli Bi 2000, Mbow *et al.* 2000, Koné *et al.* 2008). Informants declared that fire flame height has declined over time and is not as high as 30 years ago because of the impact of grazing pressure on the height and load of grasses.

Figures 7: Biomass burning from left to right: early dry season (22 Nov 2007), mid dry season (10 Jan 2008), and late dry season (6 Apr 2008).

The study also shows important daily patterns in fire intensity due to the interactive effects of ambient air temperature, relative air humidity, and wind speed. Three periods stand out. Fires are set in the morning before 9 am, between 9 am and 6 pm, and after 6 pm, depending on the purpose of the burning. Farmers set fires either before 9 am or after 6 pm to protect their tree plantations. Such fires are controlled to burn small areas around the plantations with less intensity in relation to the influence of the harmattan. The harmattan is a continental dry and hot air mass of the northern hemisphere blowing southward and covering the whole of West Africa from December to March during the dry season (November to May). It leads to hot and dry weather conditions during the day and cool and humid weather conditions during the night. Generally the ambient air temperature between 6 pm and 9 am is low (13^{o}C to 17^{o}C), the relative air humidity is high (43%-54%) and the wind speed is very low, around 0 m/s (Figure 8). Herders ignite the bush as well during the months of November and December, and either before 9 am or after 6 pm to avoid intense fires that could result in crop damage or negatively affect underground grass roots.

In contrast to farmers and herders, hunters prefer very intense fires that could “clean” the landscape. Therefore they usually set fire between 9 am and 6 pm. Such fires are very intense because the ambient air temperature increases (23^{o}C to 33^{o}C) while the relative air humidity decreases from 23% to 13%. The increase in temperature and the decrease in relative humidity increase the ignition potential of grasses during this period of the day. The higher daily wind speed between 9 am and 6 pm (from 3.1 m/s to 8 m/s) also increases fire intensity.

In short, the study reveals that farmers and herders generally burn the savanna early in the dry season. They typically set fires early in the morning or late in the evening, which results in less intense burning and a mosaic of burned and unburned patches in the landscape (Figure 7). In contrast, hunters typically burn during the middle dry season. This practice results in very intense fires. But these middle dry season burns are not as destructive because they are preceded by early dry season fires that have reduced biomass loads and created fire breaks in the landscape.

Field trips throughout the village territory during the dry season demonstrate that bush fires are currently more frequent and smaller in size compared to 30 years ago. Contemporary bushfires start at the beginning of the dry season in late October when grasses are not very dry. This results in a patchwork pattern of small burned and unburned areas in the landscape (Laris 2002; Mbow 2000; Koné *et al*. 2008). Results from this study show that the burning efficiency declined during the period 1975-2008. Burning efficiency varies over time because of the availability of grass biomass and relative humidity during the period of bushfires. Fires set at the beginning of the dry season do not burn all the available grasses because of the humidity contained in the air, soil, and plants. Fires during the middle of the dry season are very efficient and burn all the available grass. Late dry season burning is not as efficient because there is less available biomass left to burn at that period (Figure 7).

Land cover change analysis

This study showed a decline in the grass biomass load likely to burn and that the Sudanian savanna ecosystem has become more wooded over the past 30 years. The use of fire to protect cashew and mango orchards, for grass regrowth, and for land clearing, mainly at the beginning of the dry season, leads to less intense and inefficient burns. Grazing pressure and the expansion of cultivated areas diminish grass cover. The study of Bassett and Koli Bi (2000) in the Katiali region also consider several human and biophysical factors that influence the distribution of the savanna vegetation including “shifting cultivation, grazing, and fire, as well as topography, soils, and rainfall”. They identify fire as one of the important factors that refashion savanna ecosystems. Burning regimes (timing of burning, burning frequency, combustion efficiency and fire intensity) constitute the key factor of savanna ecosystem dynamics (Gillon 1983, Bassett and Koli Bi 2000).

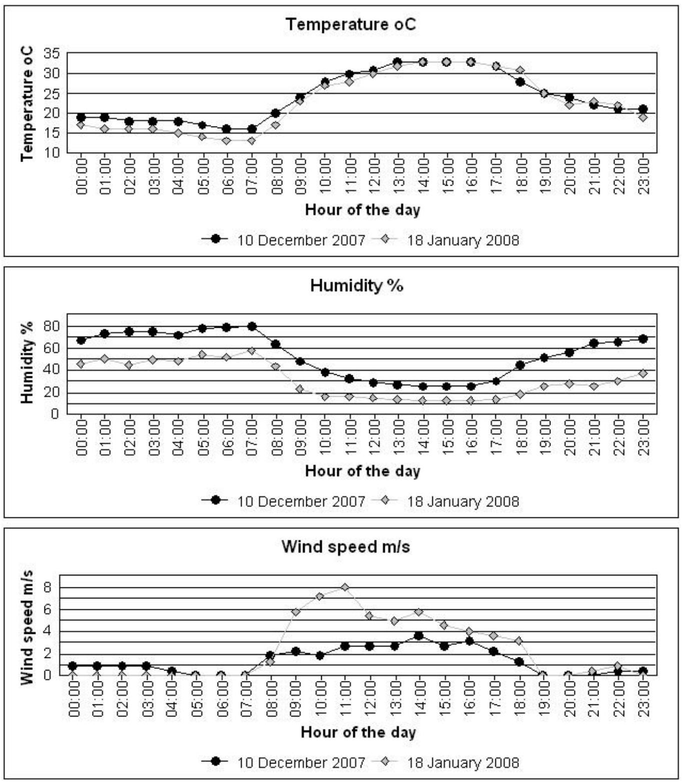

Figure 8: Changes in temperature, humidity and wind speed for 10 December 2007 and 18 January 2008 as recorded at the weather station.

Informants over 30 years of age indicated during interviews that when they were young there was more grass organic matter than currently and the landscape was not covered with as much woody species as today. Currently the major tree species of the Katiali region are *Isoberlinia doka, Daniallia oliveri, Vitellaria paradoxa, Pericopsis laxifora, Piliostigma thonningii, Entanda africana, Afzelia africana, Ficus capensis (sur)* and *Parkia biglobosa*. Farmers and herders protect most of those tree species because of their economic value. Women use *Vitellaria paradoxa* to produce shea butter and herders cut down *Afzelia africana* trees to feed their cattle in the middle and late dry season when there is no grass to graze (Figure 9). Farmers consider the increase in the number and size of *Isoberlinia doka* and *Daniellia oliveri* trees as an indication of fertile land and the presence of *Pericopsis laxifora* as an indication of poor soil. There is also an increase in the area of tree plantations. Farmers are expanding the area of mango and cashew orchards to diversify agricultural production (Bassett and Koné 2008).

Figure 9: A FulBé herder cutting branches from an *Afzelia africana* tree to feed his cattle

In short, the use of fire earlier in the dry season, increased grazing pressure, the expansion of tree plantations, and the existence of fire breaks have modified burning regimes in the Sudanian savanna. The new burning regimes are creating more wooded landscapes that have positive implications for climate change.

Implications for climate change

The environmental change literature assumes that farmers and herders set intense and highly destructive fires during the middle and late dry seasons. This widespread burning is believed to contribute to significant amounts of greenhouse gases and particulate matter to the atmosphere (Levine *et al.* 1999, Hayhoe *et al.* 2002, Small *et al.* 2002, Ludwig *et al.* 2003, Liousse *et al.* 2004, IPCC 2005, Koppmann *et al.* 2005, Reid *et al.* 2005). In contrast to these common assumptions, the observed trend in changes in vegetation cover is likely to be beneficial for carbon retention and the sequestration of carbon dioxide from the atmosphere. The results of this research are useful to analyze the impact of agricultural and pastoral land use systems on greenhouse gas emissions and carbon sequestration potentials in West Africa. The resulting increase in vegetation cover will potentially sequester more carbon dioxide than is presently attributed to the system. In addition, the new burning regime conditions and the decline in the availability of the biomass likely to burn produce fewer greenhouse gases into the atmosphere.

Conclusion

The case study uses a political-ecological approach to reveal the emergence of new burning regimes and to provide a more accurate assessment of land use and land cover change in the Sudanian savanna. Local resource users increasingly burn the savanna in the early dry season to protect their cashew and mango orchards and to encourage new grass growth for their cattle. This early dry season burning is less intense and less efficient and favors the expansion of diverse tree species such as *Isoberlinia doka, Daniellia oliveri, Vitellia paradoxa* and *Afzelia africana*. The less intense and less destructive burning also produces lower gas and aerosol emissions into the atmosphere. The resulting increase in vegetation cover is also an important carbon sink, which potentially sequesters and retains more carbon dioxide than is presently attributed to the system. This research results are very important to climate change scientists who seek environmental change information at the local and regional scales and for environmental policy makers involved in negotiations in the carbon market. Updated and accurate environmental information and insights, will better inform decision makers in formulating more appropriate environmental policies.

Acknowledgement

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THE SUSTAINABLE FOREST MANAGEMENT PUZZLE: POLICIES, LEGISLATION, DEFORESTATION AND THE CLIMATE CHANGE ISSUE IN GHANA

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Abstract

Forests have influenced climate, soil and water resources which have supported Ghana's agriculture, the backbone of her economy. In less than 50 years, Ghana's primary rain forest was reduced by 90%; even in this era of sustainable forest management. This paper presents a review of major forest policies and legislations since the beginning of the 20th century, and their implications for forest management and climate change. Extensive desk study and survey of literature were undertaken on forest policies, legislation and enforcement in Ghana. Two major policies and several legislations have been passed in the forestry sector in Ghana since colonial times, with major improvements since 1990. Unfortunately, week capacity, inadequate resources, poor supervision, the justice system and corruption continue to hamper effective implementation of forest policies and enforcement of regulations. All the policies and legislation enacted have no direction on climate change and as it stands now, cannot help in mitigation and/or adaptation to climate change. Between 1990 and 2005, Ghana lost 26% (1,931,000 ha) of its forest cover, at 2% annually. Between 1990 and 2000, Ghana lost 135,000 ha of forests annually, and a further 115,000 ha annually between 2000 and 2005. Ghana's CO_2 emissions have, accordingly, increased steadily from 0.2419 to 0.3075 and to 0.326 metric tonnes per capita, for 1990, 2000 and 2004 respectively, with resultant changes in climate. Climate change will in turn affect the remaining forests through increasing damage to forest health through proliferation of forest fires, pests and diseases.

Introduction

Ghana is endowed with several natural resources including tropical rainforests, which has been a major source of revenue for the country. Forests have also influenced climate, soil and water resources which have supported Ghana's agricultural sector, the backbone of the country's economy. However, sustainable management of Ghana's forest has been a major issue for successive governments since colonial times. At the beginning of the last century, a third of Ghana's total land area of 238,540 km^2 was covered by high forest whiles the remaining land was covered by savanna woodland (Antwi 1999). In the last 50 years, Ghana's forest cover has shown drastic reduction; even in this era of sustainable forest management.

It is impossible to think about sustainable forest management without policies to guide decision making on the use of the resource and legislation to provide legal backing to those policies (Owusu 1999). Ghana is not new to forest policies. As early as 1908, a report on Ghana’s forests was presented to the colonial government by H.N. Thompson in which he recommended establishment of a Forestry Department; creation of forest reserves; and some regulation of timber felling and exports. This report formed the basis for the colonial government’s forest policy. After the recommendations from Thompson, there has been several interventions in the form of ordinances, policies and legislation all aimed at regulating activities in the forest sector but little seems to have been achieved. Some have attributed the reduction of Ghana’s forest to the failure of Ghana's forestry policies and strategies to ensure that forest resources were managed on economically viable, socially beneficial and environmentally sound principles.

Ghana has had a fair share of global environmental problems. Change in weather patterns and recurrent droughts, severely affect agricultural activities. Soil erosion and habitat destruction with resultant water pollution threatens biodiversity. Decreasing river discharge and inadequate supplies of potable water are major issues in Ghana. The relationship between these environmental problems and deforestation is well established. In this paper, major forest policies and legislations and their implications for forest management in Ghana in relation to current climate trends are presented and discussed.

Materials and Methods

Extensive desk study and survey of literature were undertaken on the forest policies and legislations in Ghana. Documents were gathered from the Forestry Commission of Ghana; Resource Management Support Centre (Ghana); Ghana Meteorological Agency; Environmental Protection Agency of Ghana; Faculty of Renewable Natural Resources of the Kwame Nkrumah University of Science and Technology, Kumasi Ghana; Ghana Archives; and the Internet. The documents reviewed include forest ordinances and laws passed in Ghana from colonial times to date and other literature on forests in Ghana. The study examined existing information and data on forest policies, acts, decrees and legislations, enforcement of legislations and how they address or relate to climate changes.

Results

Review of forest policies in Ghana

A review of Forest policies in Ghana are presented in the sections that follow.

1948 Ghana forest policy

There is a long tradition of government interventions at different times all aimed at sustainable management of Ghana's forest estate. The very first formal National Forest Policy on forests was adopted in 1948 following the visit and Report on Forests by H. N. Thompson, Conservator of Forests in southern Nigeria, in 1908 (Owusu 1999). Thompson's report convinced the government of the need to take control of forests following a series of failed attempts by the colonial government to properly manage the forests of Gold Coast (now Ghana). The key issues in the policy were to reserve sufficient forests and forest lands to supply the benefits needed by the people; manage the reserved forests for sustained yield of timber; conduct research to support utilization and forest management; utilize resources on non-reserved forest lands fully before their liquidation by farming; promote local administration of forest and educate the local people to understand the value of forests; and train staff or develop Africans to higher positions.

This policy directed forestry activities in Ghana over a long period of time. Among all the key issues in the 1948 policy, the colonial government and subsequent governments after independence in 1957 seem to have focused more on the exploitation of forest resources, mainly timber. Promotion of local administration of forestry, for example, received very little attention though it was seen as very crucial to the sustainable management of the forests. The economic benefits of forests were actively pursued and the ecological importance was sidelined. Research to support utilisation and forest management received little attention. Research was focused more on economically viable tree species to be harvested for export. The direction of this policy led to increasing emphasis on central government administration, control and ownership of the country's forests. Local people's involvement in forest management was not pursued as the policy had stated. According to Owusu (1999), there was an increasing marginalisation and even alienation, of local communities in the administration of forests; a trend towards forestry being practised only by foresters for the nation's benefit; and a trend towards the "timberisation" of forestry. This was the state of Ghana's forests from the post-independence period to the late 1980s.

1994 Forest and Wildlife Policy

By the late 1980s and early 1990s, Ghana's forests were under excessive exploitation, illegal harvesting led by chain saw operators was flourishing excessively and prescribed harvesting procedures were being flouted with impunity. Worst of all, forestry institutions had become demoralized and inefficient because of continued underfunding. Concerns and agitations from major stakeholders and growing global interests in forest loss culminated in the revision of the old forest policy and eventually, the new Forest and Wildlife policy in 1994 (MLF 1994).

The overall aim of the Forest and Wildlife Policy of 1994 is conservation and sustainable development of the nation's forest and wildlife for maintenance of environmental quality and perpetual flow of benefits to all parts of society. The two fold aim of environmental quality and sustainable benefits had the following specific objectives:

- Management and improvement of Ghana's permanent forest estate for preservation of soil and water, conservation of biological diversity, environmental stability and sustainable production of domestic and commercial products;
- Promotion of efficient forest-based industries, in secondary and tertiary processing, to use timber and other products from forests and wildlife and satisfy domestic and international demand with competitively priced products;
- Promotion of public awareness and involvement of rural people in forest and wildlife conservation to maintain life-sustaining systems, preserve scenic areas and enhance potential for recreation, tourism and income generating opportunities;
- Promotion of research-based and technology-led forestry and wildlife management to ensure forest sustainability, socio-economic growth and environmental stability;
- Development of effective capacity and competence at district, regional and national levels for sustainable management of forest and wildlife.

Pre-independence forestry sector legislations and regulations in Ghana

Policies without backing legislation are as good as not existing. The legislation provides enforceable rules which when broken will attract lawful sanctions. This gives life and meaning to the policy and also ensures a successful implementation of the policy.

Historical background

The first enactment with a bearing on forests was the Native Jurisdiction Ordinance of 1883, which empowered traditional councils to make bye-laws to protect water courses and conserve forests (Agbosu 1983). A report of the Commission on Agricultural Potential of the Gold Coast, published in 1894, first drew the colonial administration’s attention to the need and urgency to protect the forest resources. Sensing the likely threat of restrictions on forest harvests, the timber merchants responded with an immediate large scale increase in timber harvest for use as fuel and props in the mines and for export to Europe.

The Forest Reservation and Water Courses Protection Ordinance was enacted by the colonial administration in 1889 to protect forests but according to Agbosu (1983) it never came into force because of objection from timber firms, the middle class and traditional authorities. Other ordinances that followed such as the Concessions Ordinance to govern the acquisition of timber concessions, and the abortive Timber Protection Ordinance which sought to regulate some aspects of the timber trade, were also vehemently objected to by both the British merchants and the local middle-class because they foresaw a negative effect on their business and profits. Agbosu (1983) also argues that the colonial government was interested in the revenue to be gotten rather than protecting the forests, judging from the provisions in the ordinances they sought to introduce.

Forest Ordinance, 1927 – Cap 157

It was not until 1927 that the first forest statute was passed. This ordinance led to the creation of forest reserves and vested power in an appointment of a Reserve Settlement Commissioner (RSC). The commissioner had the authority to listen and judge on claims of rights over a proposed area. The judgement of the RSC informed the government in publishing the final order making an area a forest reserve.

Forests (Amendment) Ordinance, 1954

This ordinance was an amendment to Cap 157(Government of the Gold Coast 1954). It concerns the procedures in an enquiry by the RSC in respect of rights of a proposed Forest Reserve and procedures with a Native Court. The amendments included an introduction of a "Native Appeal Court". The ordinance provided for dispute resolution with respect to ownership of land in reserves and differentiated the roles of the Native Court, Native Appeal Court and the RSC.

Post-independence forestry sector legislations and regulations in Ghana

Forests Amendment Act, 1957

This is a further amendment to Cap 157, after independence. It amended section 34 of Cap 157 (Government of Ghana 1957). The amendment of the principal Act concerns regulation-making powers of the Governor in Council and the extension of that power so as to apply regulations to areas constituted as Forest Reserves by by-laws made by the appropriate local authority. In the case of conflict between local by-laws and a regulation, the provisions of the regulation prevailed.

Forest Protection Decree, 1974 (NRCD 243)' and 'Forest Protection (Amendment) Act, 2002 (Act 624)'

'The Forest Protection Decree, 1974 (NRCD 243)' declares any specified damaging of trees, cultivation, creating fires, obstructing of water flows, hunting or fishing or grazing or trespassing of cattle in a Forest Reserve without a written permission of the competent forest authority to be an offence. This decree mainly replaced the offence creating sessions of the Cap 157 and, for the first time, took a serious look at persistent offenders and forest officers who took part in forest offences by conniving with law breakers. Under this decree, duties and powers of Forest Officers were specified, persistent offenders were banned from engaging in timber business and forest officers found culpable were summarily dismissed. The NRCD 243 was a major step to ensure a strict protection of Ghana's forest.

After almost thirty years of the Forest Protection Decree of 1974, the Forest Protection (Amendment) Act, 2002 (Act 624), was passed to amend the Forest Protection Decree 1974 (NRCD 243) to provide for higher penalties for offences therein and to provide for related purposes (Government of Ghana 2002a). For example, subsection (1) of section 1 of the NRCD 243, which is on forest offences, was amended as follows: "any person who in a Forest Reserve without the written consent of the competent forest authority fells, uproots, lops, girdles, taps, damages by fire or otherwise any tree or timber; makes or cultivates any farm or erects any building; causes any damage by negligence in felling any tree or cutting or removing any timber; sets fire to any grass or herbage, or kindles a fire without taking due precaution to prevent its spread; makes or lights a fire contrary to any order of the Forestry Commission; in any way obstructs the channel of any river, stream, canal or creek; hunts, shoots, fishes, poisons water or sets traps or snares; subjects any forest produce to any manufacturing process or collects, conveys or removes any forest produce; or pastures cattle or permits any cattle to trespass, commits an offence and is liable on summary conviction to a fine not exceeding 500 penalty units or to imprisonment not exceeding 2 years or to both, except that for a second or subsequent offence under this section the offender shall be liable on summary conviction to a fine of not less than 250 penalty units or to imprisonment not exceeding 3 years or to both".

'Concessions Act 1962 (Act 124)'

The Concessions Act 1962 (Act 124), prohibited the creating of forest reserves by local governments; it removed the role of courts in granting timber concession and transferred that role to a Minister of State, and vested all timber rights in the president acting as a trustee for the owners. This law was deemed appropriate by the government of that time when it wanted to control the commanding heights of the economy.

'Trees and Timber Decree, 1974 (NRCD 273)' and 'Trees and Timber (Amendment) Act, 1994 (Act 493)'

The Trees and Timber Decree, 1974 (NRCD 273) aimed at protecting trees and timber and regulating their cutting, transportation and export. It required timber merchants to register property marks with the office of the Chief Conservator of Forests (Government of Ghana 1974). Timber merchants were required to mark the stump of each tree they felled and the logs with their unique registered property marks. Areas outside forest reserves but having a good stocking of timber were declared temporarily protected areas until the timber was harvested.

Twenty years later, the Trees and Timber (Amendment) Act, 1994 (Act 493) was passed to amend the Trees and Timber Decree, 1974 (NRCD 273), aiming at encouraging development of the local timber industry through processing of harvested logs beyond the saw-milling stage by placing punitive levies on the export of certain timber species in log form and on the export of air-dried lumber. It was expected to add value to the logs before export and also to create employment (Government of Ghana 1994). This act supports the objective 2 of the 1994 Forest and Wildlife Policy.

'Forestry Commission Act, 1980 (Act 405)' and 'Forestry Commission Act, 1999 (Act 571)'
The Forestry Commission Act of 1980 (Act 405) provided for the establishment of the Ghana Forestry Commission (Government of Ghana 1980). The functions of the Ghana Timber Marketing Board, the Forest Products Research Institute of the Council for Scientific and Industrial Research, the Forestry Department and the Department of Game and Wildlife were to be exercised under the supervision of the Forestry Commission.

In 1999, after an assessment of the operations of the Forestry Commission, which had been in existence for almost two decades, the Forestry Commission Act, 1999 (Act 571), was passed to re-establish the Forestry Commission in order to bring under the Commission the main public bodies and agencies implementing the functions of protection, development, management and regulation of forests and wildlife resources and to provide for related matters (Government of Ghana 1999). The re-established Forestry Commission is a corporate body responsible for the regulation of the utilization of forest and wildlife resources, the conservation and management of those resources and the co-ordination of policies related to them.

'Timber Resource Management Act, 1997 (Act 547)', and 'Timber Resources Management Regulations, 1998 (L.I. 1649)'

This act streamlined the process for granting rights to harvest trees and extract timber (timber rights) to ensure the sustainable management and utilization of timber resources. Harvesting timber without obtaining a Timber Utilization Contract (TUC) was made an offence which attracted a fine of 1000% of the value of the timber or imprisonment for 6 months to 2 years, and confiscation of the timber, tools, equipment and machinery. The Timber Resources Management Regulations, 1998, (L.I. 1649) provided rules and regulations to guide the implementation of Act 547. Under Act 547, the contract holder enters into a contract with the Government to utilize and manage the timber resource on stated Terms and Conditions (Government of Ghana 1998).

'Timber Resources Management (Amendment) Act, 2002 (Act 617)'

This act is an amendment of the Timber Resources Management Act 1997 and is to exclude from its application land with private forest plantations, to provide timber rights for the maximum duration, and maximum limit of area. It also provides for incentives and benefits applicable to investors in forestry and wildlife and to provide for matters related to these (Government of Ghana 2002b).

'Forest Plantation Development Fund Act, 2000 (Act 583)', and 'Forest Plantation Development Fund (Amendment) Act, 2002 (Act 623)'

Act 583 established a Forest Plantation Development Fund to provide financial assistance for the development of private commercial forestry plantations, to provide for the management of the fund and to provide for related matters such as research and technical advice to persons involved in commercial plantation forestry on specified conditions (Government of Ghana 2000). Funds for this fund were to be generated from the proceeds of the timber export levy imposed under the Trees and Timber Decree 1974 (NRCD 273) as amended by the Trees and Timber (Amendment) Act, 1994 (Act 493), from grants and loans for encouraging investment in plantation forestry, from grants provided by international environmental and other institutions to support forest plantation development projects for social and environmental benefits, and from money provided by the Parliament of the Republic of Ghana for private forest plantation purposes.

Act 623 was enacted to amend the Forest Development Fund Act, 2000 (Act 583) to enable plantation growers, both in the public and private sectors, to participate in forestry plantations and to provide for related matters (Government of Ghana 2002c).

Discussion

Major policy and legislation challenges in managing Ghana's forests

To start with, historical assessment points out that forest administration in Ghana did not start on a good footing, i.e. on the basis of sound national land or forest policy. According to Agbosu (1983), the colonial government left the administration of forest lands to the traditional authorities (as seen with the Native Jurisdiction Ordinance of 1883), subject to such controls as might be imposed by statutes and regulation. These traditional authorities were mainly illiterates, relatively ignorant and not adequately equipped to efficiently manage the forests. This was a great incentive to timber merchants who exploited the nation's timber resources. Some British businessmen together with their local middlemen, educated elite, lawyers and merchants even rallied the traditional authorities to oppose the colonial government's decision to create forest reserves to be administered by trained personnel. This fact became evident during the period of the mining boom and of the increase in timber trade in the first decade of the 20th century (Agbosu 1983).

After a shift in policy from total state control to active participation of local communities in the management of forests, there was the need to enact relevant literature to back the new policy and give life to it. Weak capacity, inadequate resources, poor supervision, the justice or court system and corruption, in particular, have continued to hamper the effective implementation of forest policies and enforcement of regulations aimed at sustainable forest management. These problems started long ago and there is recorded evidence (as indicated in Agbosu 1983) of communications by Mr. Giles Hunt, writing on behalf of the West African branch of the Liverpool Chamber of Mines. Mr Hunt complained about the manner in which timber firms were allowed to operate freely in the forest reserves without any adherence to the ordinances, the cutting of smaller trees and excessive destruction caused to the forest in the course of harvesting a single tree. These concerns were being expressed as early as before 1910 and, unfortunately, they still sound very relevant in 2008. Mr. Hunt went on to propose the setting up of a Forestry Department of suitably trained and qualified personnel to properly administer the forest estate of Ghana.

It is fair to say that in the last decade, there have been improvements in forest legislation with the passing of some acts which have, in some cases repealed or amended wholly or sections of previous laws to make them more potent, recommend stiffer penalties to serve as a deterrent and meet current needs. Examples are Act 493 and Act 624.

Deforestation in Ghana and forest policies and legislation

Ghana has one of the highest deforestation rates in Africa and the world — at 2% annually. Whilst the whole world lost 3% of its total forest area, averaging 0.2% every year between 1990 and 2005, Ghana lost an average of 135,000 ha of forest per year between 1990 and 2000, amounting to an average annual deforestation rate of -2% (FAO 2007). Between 2000 and 2005, Ghana's forests decreased by a further 115,000 ha, with a rate of forest change of -2% per annum. In total, between 1990 and 2005, Ghana lost 26% of its forest cover, or around 1,931,000 ha (UNEP 2008). Measuring the total rate of habitat conversion (defined as change in forest area plus change in woodland area minus net plantation expansion) for 1990-2005, Ghana lost 27.6% of its forest and woodland habitat.

Deforestation is top on the important environmental issues in Ghana, according to UNEP (2008). Deforestation in Ghana is primarily driven by slash-and-burn agriculture, timber harvesting, wildfires, mining, and rising demand for fuel wood. In the cocoa growing regions of Ghana, which also happen to be in the forest areas, large tracts of tropical forest have been cleared to support increasing cocoa cultivation which is a major contributor to Ghana's agricultural-based economy. Currently, Ghana is the world's second-largest producer of cocoa beans (FAO 2007) and when world cocoa prices are low, Ghana's foreign exchange earnings are significantly affected and is often compensated for by increasing timber and mineral exports. Thus, cocoa farming is both a direct and indirect driver of deforestation (UNEP 2008).

The Ghana government, since the 1980s, has provided generous incentives to attract investments in the mining sector and have even given mining concessions within some of Ghana's forest reserves, eg. Afao Hills Forest Reserve (UNEP 2008). This poses a serious threat to Ghana's remaining forests. Over 60 per cent of the Wassa West District in western Ghana is now under concession to large-scale gold mining companies, the greatest concentration of mining in a single district in Africa (UNEP 2008). The large footprints of these open-pit mines directly result in significant forest loss. In addition, related infrastructure and associated population growth indirectly drive even greater land cover conversion. The latest findings, according to "Africa: Atlas of Our Changing Environment" released by the United Nation's Environment Programme in June 2008, indicate that significant portions of Wasa West tropical rainforest have been degraded by or lost to this gold mining boom since the 1980s. In addition to the threat from mining, shifting cultivation, uncontrolled logging, charcoal production, and increasing population, place enormous pressure on the remaining of Ghana's tropical forests.

According to UNCCD (2002), one-third of Ghana's land is already affected by desertification. The land is becoming increasingly arid and this is evidenced by lowered water tables, siltation of rivers, and increased flooding; rapid deforestation and poor cultivation practices are largely responsible for this (UNEP 2008).

There is no doubt that Ghana's forest policies, legislations and lapses in enforcement has highly contributed to the rate of deforestation in the country. Until 1994, detailed clearly defined forest policies specifying goals, objectives and strategies for development of forest and the future direction of the timber industry were not in existence (MLF 1996) despite the 1948 forest policy. This is surely a recipe for disaster in forest management. Boateng (1994) concluded that forest degradation intensified through illegal cutting and encroachment for agricultural purposes. Due to the lack of proper policy direction on tree harvesting, timber firms and concessionaires were selectively felling only preferred commercial timber species.

Another major contributor to Ghana's deforestation has been the alienation of forest communities from policy formulation although such communities were expected to help in protecting the forests (MLF 1996). The lack of legal sanctions, and where available, it not being deterrent enough, for example low fines, has encouraged illegal forest harvesting. It is therefore not surprising that in less than 50 years, Ghana's primary rain forest has been reduced by 90% (UNEP 2008).

Deforestation, forest policies and legislation and climate change in Ghana

Removal of forests will undoubtedly cause a change in climate by affecting the amount of carbon dioxide in the atmosphere. Due to the ability of forests to absorb and store carbon over an extended period of time, they serve as "carbon sinks". In effect, when forests are removed, this unique role that they play to keep CO_2 concentrations in the atmosphere at normal levels is lost and rather the carbon stored in them is released into the atmosphere as CO_2 gas upon burning. The world's forest ecosystems are estimated to store more carbon than the entire atmosphere (Greenfacts 2007).

From 1990 to 2000 and to 2004, CO_2 emissions in Ghana have increased steadily from 0.2419 to 0.3075 and to 0.326 metric tonnes per capita, respectively (UNEP 2008). This is very much expected in a country where deforestation rate is high and slash-and-burn agriculture is widely practiced. Climate change will in turn affect the remaining forests profoundly through increasing damage to forest health through proliferation of forest fires, pests and diseases (FAO 2007). Unfortunately, both the "1948 Forest Policy" and the "1994 Forest and Wildlife Policy" have no direction on climate change. This means at it stands now these policies can not help in mitigation and/or adaptation to climate change which is a major environmental issue.

Conclusion

Poverty and ignorance are major factors contributing to countries not achieving sustainable forest management. No matter the correctness and effectiveness of the policies and legislation formulated and enacted, respectively, human beings are to implement them. With high poverty levels, people such as forest guards who patrol the forests, lawyers and judges, security officers like the police who are to enforce laws, professional foresters or forestry officials who make decisions, can be influenced and corrupted by money to compromise on the right thing to be done to the detriment of our forests. Despite seeming improvements in the legal and policy environment, progress towards sustainable forest management in Ghana is difficult because beneath such nice policies and legislation lies a substructure of exploitative and repressive relations between the corporate timber industry and the state on the one hand and forest-dependent communities and the public on the other (FERN 2006). This, unfortunately, is the real situation on the ground since colonial times.

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REFORESTATION AND AFFORESTATION FOR ADAPTATION AND MITIGATION IN BURKINA FASO: LIMITS, BENEFITS AND SYNERGIES

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Abstract

Afforestation and reforestation (AR) initiatives through large and small scale plantations by government, private entities and communities have been put in place as a major adaptation measure since the Sahelian drought of the 1970s. The depletion of forest and other natural resources in Burkina Faso have been accelerated due to the impacts of recurrent droughts and desertification coupled with human activities such as deforestation, causing environmental degradation and sometimes leading to poor soil and reduced crop productivity, famine and extreme poverty that increase the vulnerability of ecosystems and communities. These AR activities have registered some successes and failures as well as some challenges. Many goods and services have been provided by these AR activities that benefit the society directly or indirectly. Unintentionally, these AR activities also increase existing carbon sinks even though not meant for carbon sequestration and are eligible activities under the Clean Development Mechanisms of the Climate Change Convention. With the mitigation and adaptation debate coming up strongly within the Climate Change Convention, there is a need to explore the potential of AR for adaptation and mitigation. This study therefore examines the opportunities for and barriers to AR and the likely synergies and future perspective for adaptation and mitigation in Burkina Faso.

Introduction

Views on afforestation and reforestation (AR) activities for decades have been and are still enjoying great popularity in different ways in many households, communities, sectors, governments, non-governmental organizations and development agencies as they are linked to different environmental, economic and subsistence purposes. Properly designed, implemented and managed, AR in Burkina Faso and many other countries has the potential to serve many intended as well as unintended purposes that include poverty reduction and livelihood improvements, forest-based adaptation to climate change, carbon sequestration, rehabilitation and restoration of degraded lands, and the provision of raw materials for forest-based industries and sectors. AR activities and their related products (fruits, fodder, improved soil fertility, medicinal plants, firewood, construction wood) are used in Burkina Faso in various locations and ways to adapt and reduce vulnerability to impacts of climate variability and change (Kalame *et al.* 2008a). Most of the AR activities in Burkina Faso have been and still are a huge source of carbon sequestration which is a potential with a growing market worth exploiting for the benefit of the community and sector involved, especially through both voluntary and non-voluntary markets of the Clean Development Mechanisms (CDM) of the Climate Change Convention.

Afforestation and reforestation activities in Burkina Faso are in most cases intended to replenish the fast depleted and degraded capital and wealth of forest and savanna ecosystem goods and services to meet their different uses. This reduction of quality and quantity of forest resources due to the impacts of climatic hazards, notably recurrent droughts since the 1970s (SP/CONEDD 2007) and desertification coupled with human activities such as deforestation, is causing environmental degradation leading to poor soil, crop and forest productivity, famine and extreme poverty that increase the vulnerability of ecosystems and users of forest and tree resources (Kalame *et al.* 2008a). Under increasing conditions of climate variability and change (e.g. more recurrent droughts, temperature peaks, wild forest fires, windstorms), the growth and productivity of forest ecosystems in Burkina Faso that provide communities with various goods and services will be badly affected with a likely southward shift of forest ecosystems (Gonzalez 2001, SP/CONEDD 2007).

Considering, from a climate change perspective, the numerous purposes and stakeholders involved in AR activities in Burkina Faso for many decades (Table 1), we sought to explore pertinent questions in this paper: (i) When can AR activities be used for adaptation, mitigation or both? (ii) How and when can AR activities increase adaptation and reduce vulnerability of forest-savanna ecosystems and their users to the impacts of climate variability and change? (ii) How can carbon sequestration through AR activities in Burkina Faso benefit communities under the CDM? The objectives of this paper are therefore to (i) Investigate AR projects in Burkina Faso since the Sahelian drought of the 1970s, and (ii) Analyze the potential of these AR activities regarding carbon sequestration and adaptation of ecosystems and communities to the impacts of climate change.

Materials and Methods

Analysis of major past and present AR projects in Burkina Faso since the Sahelian drought of the 1970s was carried out using literature review, consultation of experts and field visits. Government policy documents on AR, project reports and documents on AR projects in Burkina Faso, empirical studies on vulnerability, adaptation and CDM including other relevant case studies were analyzed. For further analysis, different resource persons and experts both at local and national levels were consulted for specific issues in AR activities in Burkina Faso. A better understanding of AR activities and its potential role in climate change adaptation and carbon sequestration was further attained through personal observations and discussions with knowledgeable resource persons in the communities during visits to several sites in Sapouy, Bougnounou, Ouahigouya and Zinaré with past or present AR activities.

Results

AR projects in Burkina Faso since 1970

Climate change, desertification and environmental degradation in the Sahel region are strongly linked to drought. Most AR activities in Burkina Faso and the Sahel at large have for the past four decades been put into place to combat drought, desertification and environmental degradation (Table 1).

AR as an adaptation strategy

Adaptation represents ways of reducing vulnerability (Smith and Wandel 2006) through a response to actual or expected climate stimuli or their effects, to moderate harm or to exploit beneficial opportunities (IPCC 2001). Adaptation can be passive, reactive, or anticipatory as well as spontaneous, economic or planned (Smith *et al.* 2000, Klein 2001), depending on the timing, available resources and purpose of the adaptation. Adaptation can be implemented by public actors such as government bodies at all levels and also private actors such as individuals, households, communities, commercial companies and other actors, such as NGOs. Most government AR programmes (Table 1) are anticipatory and planned adaptation strategies (Table 2) with the aim to reduce the impacts of drought on natural resources and communities in Burkina Faso. They are carefully planned with a long term perspective, backed by policies. Many other AR schemes carried out in Burkina Faso as an adaptation strategy by the government, individuals, communities, Non-Governmental Organizations (NGOs), private companies, donor agencies often involve different adaptation options at different temporal scales (see current, medium and long term adaptation options in Table 2) to reduce the impacts of climate hazards, be it reactive (fast and immediate response), economic (income generation), autonomous (independent response), technological (management skills) or planned (but not legally backed by government policies). Most of the AR activities carried out by agencies other than the government are however in most cases, activities under the broader government AR programme such as the ongoing ‘National Reforestation Programme’ that is being held every year with participants ranging from households, development agencies, community and NGOs.

Table 1: Some AR activities in Burkina Faso to fight drought (climate impact), desertification and environmental degradation

AR Projects in Burkina Faso	Implementing Actors
National AR schemes by the Government	
Prospect, harvest and distribute across the Sahel project (1984)	National Forest Seed Centre (CNSF)
National programme to fight desertification (1986)	Communities, civil society
National village forestry programme (1986, 1991)	Village communities
8,000 villages, 8,000 forests (1994-1997)	Village communities
National reforestation programme, (2003-2012)	Farmers, communities, civil society, donor agencies, students, non-governmental organizations
Small AR schemes by NGOs, Donor Agencies and Inter-governmental organizations	
Integrated management project of the Sabcé-Boussouma region (1984-1998)	SOS Sahel and Agro Action Allemande
Small scale reforestation project in Arbolle (1988)	TC-Dialogue Foundation
Reforestation project in the Silia village, Bam Province (1989-1992)	SOS Sahel, SOSSI-F, Band AID
Reforestation activities in Burkina Faso in Zoula, Réo, Gui, Latou, Toega, Kamedji, Kamsi, Villy, Ramongo et Sinthiou (1992-2007)	Defi Belgique Afrique (DBA)
Reforestation programme in 30 schools and villages in the Bazèga province (1996-1999)	Eau, Agriculture et Sante en Milieu Tropical (EAST)
Tree planting project Comoé, Yatenga and Kadiogo provinces (1997-2002)	Green Cross Burkina Faso
Green points of the Sahel, Burkina Faso (1998)	Sahel DEFIS
Reforestation projects in Didyr, Ouagadougou and Nayala (2000-2005)	Nature Solidaire
Regional world environmental initiative and desertification control in Sahelian Africa, IREMLCD, (2003-present)	Permanent Inter-States Committee for Desertification Control (CILSS)
Reforestation, tree nursery, and family reforestation in villages (2005-2007)	Nouvelle Planéte
Let’s re-green Burkina Faso, Fada, 2006	Union des Jeunes pour le Développement FADA
Land and livelihood Séguénéga (2007-2012)	TreeAid

AR activities especially the “forestry zai and assisted natural regeneration” are used in two major ways as an adaptation strategy to benefit the environment and population of Burkina Faso (Table 2). Firstly, they provide environmental services to combat drought-induced environmental degradation and desertification (SP/CONAGESE 2001, SP/CONEDD 2007). Secondly, they replenish the depleting forest- and tree-based assets communities act upon (e.g. non-timber forest products [NTFPs], construction poles, firewood etc) to increase their adaptive capacity and to reduce their vulnerability to the impacts of climate hazards such as recurrent droughts and flood events (SP/CONEDD 2007, Kalame *et al.* 2008a). Most of the adaptation options listed in Table 2 are activities that have been existing in Burkina Faso for decades. To be considered as an adaptation strategy or option, AR activities in Burkina Faso must be intended to improve the adaptation and resilience or reduce the vulnerability of an ecosystem (e.g. forest, savannah or agroforestry landscape) or a human system (household, community, sector, etc) to a particular climatic event such as drought, flood, bushfire, high temperature, hot weather, etc. Most vulnerable communities to climatic hazards are mostly interested in AR for income generation (EA as shown in Table 2) especially through the sales of construction poles and firewood. Various NTFPs are used both for income generation (e.g. shea butter and "soumbala" which is made of fermented seeds of *Parkia biglobosa*) and subsistence (e.g. baobab leaves, medicinal plants). Most of the tree species planted however are fast growing and sometimes introduced such as *Eucalyptus camaldulensis* as demonstrated in the ongoing national reforestation Programme in Burkina Faso (Figure 1).

Table 2: AR adaptation strategy with different steps and options that benefit the environment and the population in response to different impacts of climatic events (recurrent drought, extreme temperature, windstorms, flood events, bushfires)

Steps/options for environment and population benefit	AR as an adaptation strategy	
	Provision of environmental services	Restocking depleted and degraded forest- and tree-based resources
Vulnerability to be addressed	- increased aridity and degradation of soil - reduced productivity of trees - accelerated degradation of forests and trees - soil erosion on farmlands and around water courses	- wilting and reduced productivity of crops - destruction of crops during flood events - destruction of NTFPs by forest fires - accelerated degradation of forests and trees
Current and mid-term adaptation options	- identify suitable and adaptable tree species that are indigenous, fast growing and multipurpose (TA) - identify suitable land for planting (PA) - take intensive care to prevent any destruction by fire and animals (TA) - take intensive care until the root systems of trees are well established (TA) - use forestry zai to capture water (TA)	- skilful harvesting of fast growing trees like *Eucalyptus* to promote fast coppicing (TA, EA) - sale of construction poles for income generation (EA) - harvesting of forest fodder (EA, PA-NP)
Long-term adaptation options	-sand dune stabilization (PA, PA-WP, RA) -soil stabilization, restoration and increase fertility (PA, PA-NP) -improved modification of microclimate (PA, PA-NP) - protection and reduced sedimentation of water courses (PA)	- commercial harvesting for construction poles (EA, RA, AA) - commercial firewood harvesting to complement low crop productivity and other household needs (EA) - harvesting of forest food to cope with flood-induced crop destruction (RA, AA) - income diversification through commercial harvesting of NTFPs (EA) - increased reliance on forest for fodder during drought periods (EA) - increased biodiversity and reliance on forest for medicinal plants (AA, RA)

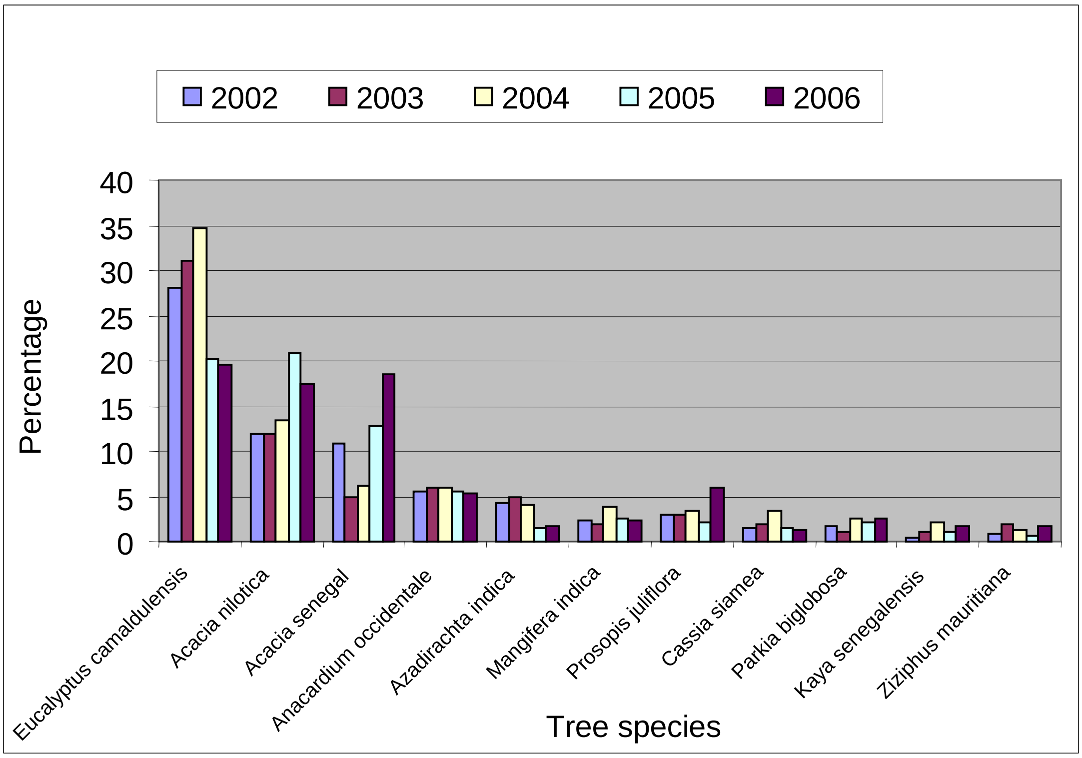

Figure 1: Changes in percentage contribution of different tree species produced for planting during 2002-2006 afforestation and reforestation campaigns in Burkina Faso (MECV 2006)

AR projects for mitigation

AR CDM projects are still very new in Burkina Faso and Africa at large with the Permanent Secretariat of the National Council for Environment and Sustainable Development (SP/CONEDD) being the Designated National Authority for CDM projects. Burkina Faso defines a forest under AR CDM as having an area of 1 ha, a crown cover density of 30% and a height of 5 m. At the moment, JICA's Mitigation Measures is operating a project (still at initial stage) on 'participatory and sustainable forest management in the Province of Comoe' in Burkina Faso that will run from June 2007 to May 2012. Major activities regarding AR CDM projects in Burkina Faso at the moment focuses on project development, trying to address issues of baselines, suitable areas for AR CDM projects, and meeting the various conditions and steps to operationalize AR CDM projects both under the Kyoto Protocol and the voluntary carbon market.

The low biomass stock of the extensive vegetation of sandhills, shrub steppes, savanna grassland and wasteland found in the northern part of Burkina Faso, having a Sahelian climate with an annual rainfall of about 600 mm, makes this a potential AR CDM area in Burkina Faso under the Kyoto Protocol (JOFCA 2007). This area has an extra advantage of 'additionality' due to its high climatic, economic and technical barriers coupled with the absence of any industrial AR. These areas in northern Burkina Faso include the administrative units of Sanmatenga, Namentenga, Soum, Seno, Yatenga, Bam, Yagha, Poni, Bazèga, Bougouriba, Boulgou, Boulkiemdé, Comoé, Ganzougou, Gnagna, Gourma, Houet, Kadiogo, Kénédougou, Kossi, Kouritenga, Mouhoum, Nahouri, Oubritenga, Oudalan, Passoré, Sanguié, Sissili, Tapoa and Zoundwéogo (JOFCA 2007). The voluntary carbon market does not follow the strict procedures of the Kyoto Protocol. The Forest Department of Burkina Faso has therefore extended suitable forest, shrub and savanna areas as potential AR CDM areas, such as 'savanes arborées', 'savanes arbustives', 'steppes arborées', 'savanes herbeuses', 'steppes arbustives', and 'steppes herbeuses'. Baselines will vary for different vegetation and landscape types such as agricultural areas alongside natural areas, shrubby and grassy vegetation, agroforestry areas, forest, open space with no or little vegetation, and inland marshes.

Suitable species for AR CDM projects in Burkina Faso, according to the Forest Department, include *Acacia senegal, Acacia nilotica, Eucalyptus camaldulensis, Faidherbia albida, Vitellaria paradoxa* and *Azadirachta indica* with *Acacia senegal* having the highest preference because of the gum arabic it produces that has a high market value.

It is expected that any AR CDM project must contribute to the sustainable development of Burkina Faso. Local communities should actively participate and benefit as well from any AR CDM project in their area. These however raise many questions such as the nature and extent of participation, the sharing of benefits from such projects and issues of land ownership and usufruct rights.

Major limitations to AR CDM projects under the Kyoto Protocol include complexity of the methodology, modalities and procedures stipulated in Decision 5 from CMP 1 with unclear meaning of terminologies (such as leakage, carbon pool and additionality), limited project scope, lack of technical skills and financial resources, temporal nature of AR credits and perception of risk (IISD 2007). Voluntary carbon markets however, provide another opportunity for AR CDM projects which is being explored at the moment in Burkina Faso. Other limitations of AR in Burkina Faso have been discussed above under the section on AR as an adaptation strategy.

Limitations to and challenges of AR

In situations of successful AR activities in Burkina Faso, especially at the household and community levels, many benefits have been obtained. Many AR activities, however, have had a very weak success rate both at the government and non-government levels due to various reasons:

i. In general, very little is done at large scale or national level AR activities by the government to protect planted seedlings against browsing, drought and other forms of human and animal encroachment. A successful AR activity as an adaptation strategy highly depends on successful regeneration (Kalame *et al.* 2008b) rather than the quantity of tree seedlings planted, as the latter is often used to score political points by the government and other parties involved.

ii. Constant efforts are needed to protect young vulnerable trees to various climatic and anthropogenic disturbances until their root systems are well established. When disturbed, tree regeneration by root suckers is one of the most important reproductive mechanisms that occur in the Sahel and Sudan zone in West Africa, as they occupy more area for water and nutrient uptake (Bellefontaine 1997, Ky-Dembele *et al.* 2007). The work of Ky-Dembele *et al.* (2007) in the Nazinon forest of Burkina Faso showed that most trees under disturbance may take 5 to 10 years to properly establish their root systems for long term survival.

iii. Non consideration of required species by the public during seedling cultivation especially in roadside nurseries. About 93% of the seedlings planted (Figure 1) come from private nurseries mainly along the road in urban centres while only 7% is provided by the National Forestry Seed Centre (MECV 2006) because the cost of the seeds is not affordable by farmers and private actors in the sector.

iv. Lack of technical support by forestry staff to the population concerned. The government lacks human, financial, material and logistical resources to support the annual nation-wide reforestation campaign, let alone providing resources for future tree protection and management after the campaign. The government partly blame communities for their insufficient management effort to protect planted trees.

v. Limited lands for AR activities and limited AR due to insecure land tenure (Bertault 1992). Farmers are not sure to be the beneficiaries in the future because planted areas belong to the whole community and not to individuals - the tragedy of common goods.

vi. The more intense and frequent extreme climatic events of high rainfall variability (both at spatial and temporal scales), with recurrent droughts, make tree regeneration very difficult in some areas. The very long dry season (6-8 months) is a major constraint in the absence of irrigation schemes.

vii. Realization of economic adaptation in some areas by farmers and communities through the sale of construction poles from their *E. camaldulensis* and *A. indica* plantations is not always guaranteed due to lack of markets, which become a major disincentive to some farmers to plant trees.

viii. Farmers lack finances to buy tree seedlings for AR activities as most farmers in Burkina Faso rely on assisted natural regeneration on their farmlands (Reij *et al.* 2005).

ix. Trees need a long time to reach maturity and this is a disincentive for some people to engage in AR. This can be solved however through techniques such as grafting. It has also been shown that many local species can grow fast if they are protected. Some people however, engage in AR because of their offspring, the future generation and the overall protection of the environment.

x. The free grazing system causes the destruction of young trees by livestock especially during the dry season when fodder supply is limited.

Synergies between adaptation and mitigation using AR

More and more studies are increasingly recommending the need to take into consideration the various synergies between adaptation and mitigation activities especially in the forestry sector (Ravindranath 2007, Verchot *et al.*2007, Guariguata *et al.* 2008, Nkem *et al.* 2008). In this study, synergy is considered to be elements or issues that are common or connected in one way or the other to both adaptation and mitigation. There are many common elements and characteristics of AR projects for adaptation and mitigation purposes that includes

i. AR in degraded lands which reduce vulnerability by providing environmental services e.g. sand dune stabilization, soil restoration, water infiltration improvement, microclimate modification in the case of adaptation while in mitigation, they are suitable area for CDM under the Kyoto Protocol especially in northern parts of Burkina Faso.
ii. The use of multipurpose, indigenous and fast growing trees in AR are commonly used for adaptation purpose as well as being recommended for CDM project amongst which are *Eucalyptus camaldulensis*, *Acacia nilotica*, *Acacia senegal* and *Azadirachta indica.*
iii. Livelihood benefits from AR will reduce the vulnerability of communities through economic adaptation e.g. sales of firewood, fruits, and construction poles while CDM projects will allow the extraction of firewood, crop cultivation, sales of AR credits and gum Arabic.
iv. Sustainable forest management practices such as harvesting techniques (technological adaptation), fire protection and participation of communities especially in the management process.

Discussion

The world is inevitably moving towards a low carbon economy despite the political, economic and scientific challenges to curb green house gas emissions. Some countries will be winners while others will be losers in terms of exploring emerging opportunities such as the carbon markets (e.g. past experiences with CDM projects), transfer of technology and pursuing a development path that will increase the adaptive capacity of vulnerable communities, sectors and ecosystems especially in Africa and Burkina Faso in particular. Following about three decades of AR activities in Burkina Faso, a lot of experience has been built (both positive and negative) which should be capitalized on, with the growing importance of trees and forest in the climate change discourse.

Due to their daily encounter with extreme climatic conditions for decades, smallholder farmers and communities in Burkina Faso have a very high level of environmental literacy and innovative technologies (e.g. zai, half moon, seed selection and storage techniques). They have a lot of experience in planting and managing trees under harsh climatic and anthropogenic conditions either in woodlots, plantations, community forestry, forest management for firewood production or conservation of protected areas. Through AR activities, many communities in Burkina Faso have seen the re-establishment of forest in their environments with enormous gains in biodiversity especially medicinal plants and small rodents that disappeared decades ago. On the other side, there are many areas where farmers and communities have cleared extensive forest lands for cultivation of cash crops. In some cases, selected tree species of subsistence and economical importance such as shea butter (*Vitellaria paradoxa*), mango (*Mangifera indica*), baobab (*Adansonia digitata*) and néré trees (*Parkia biglobosa*) are protected and left on farmlands. With all these practices, farmers have a good understanding on where, when and how to carry out a long term successful AR project that will serve as an important input to inform government policy and strategy on AR for climate change adaptation and mitigation.

To improve the potentials of AR in Burkina Faso for adaptation and mitigation, the government and other key donor agencies will however, need to

- assess the impacts of past AR activities to the environment and livelihoods in Burkina Faso in order to enhance AR as an adaptation strategy that is more resilient, lasting and responsive to the needs of communities and ecosystems under a changing climate;
- clearly link the relevance of past AR activities to present response strategies and update policies with a clear climate change perspective.

In the case of AR for CDM projects, a successfully exploration of future opportunities to develop and implement AR CDM projects in Burkina Faso will entail issues of

- good governance through improved transparency and accountability especially on the sales of carbon;
- enabling trade environment for non voluntary carbon markets that will encourage the private sectors to invest;
- capable human resources and institutions to handle AR CDM projects that are often viewed as complex to handle;
- using research to develop techniques such as grafting and scientific data on the growth of local species allowing the quantification of the biomass accumulated according to the age of the plantations (allelometric equations); and
- raising awareness on the potentials of AR CDM projects in Burkina Faso using efficient communication mechanisms.

Conclusion

This paper explains how AR is useful in the ongoing efforts to help communities and ecosystems to adapt to the impacts of climate change and at the same time to explore the opportunities emerging from the carbon markets through carbon sequestration activities in the Clean Development Mechanism. Almost all AR projects in Burkina Faso in the past decades were more or less seen from an adaptation point of view. The government is more concerned about the rehabilitation of degraded lands and the protection of the environment. More focus has been laid by the government on reducing the vulnerability of ecosystems through the provision of environmental services to reduce the impacts of drought and stop the expanding desert from the north. Communities are however, more concerned with the livelihood benefits associated with AR which has led to the highly recommended use of multipurpose, indigenous and fast growing trees in order to promote co-benefits in AR projects. Most of these benefits are realized in the medium to long term at a time when the trees have grown to maturity depending on the species.

Just like many other developing countries, Burkina Faso is still in the process of exploring the carbon markets under the CDM schemes, thus there is a need to create the necessary environment for the carbon market that promotes good governance, more involvement of the private sector, and capacity building of institutions and human resources.

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FOREST GOODS VULNERABILITY TO CLIMATE CHANGE IN WEST AFRICA: VOICES FROM LOCAL COMMUNITIES ON MEDICINAL PLANTS AND PRESCRIBED ACTIONS FOR ADAPTATION

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Abstract

In recent years, the debate about climate change and variability have shifted from the possible negative consequences on ecosystem function, livelihoods and economies to a deliberation about actions that could be taken to avert a complete disruption of ecosystem functions and how to cope or adapt to potential negative impacts. Hitherto, climate change dialogues over forest ecosystems have been largely restricted to conference rooms, expert contemplations and media speculations with little involvement of forest dependent communities. Forests remain a veritable source of livelihood: income, food, medicine, fodder and recreation opportunities for the rural population that is often overlooked during deliberations about finding adaptation strategies. Current concerns about the limited space for popular participation by ostensibly the most vulnerable communities whose livelihoods are directly linked to forest ecosystems increased the need to solicit this perspective. A case study was carried out to highlight the perception of inhabitants of eight rural communities in Ghana and six communities in Burkina Faso on the vulnerability of forest goods particularly medicinal plant species (natural pharmaceutical products for the poor) to climate change and their inputs on adaptation actions in the sector. The result shows a connection between climate change, human pressures and species degradation.

Introduction

Forest ecosystems are a primary resource base for the provision of all medicinal plants, including plants used for traditional medication in local communities and also harbor a huge amount of known drugs in daily use (Colfer *et al.* 2006). Seters (1997) described the forest as an important store house of medicinal plants. Over 80% of people whether in the rural or urban areas consult traditional medical practitioners or depend on medicine from the forest ecosystem for health problems (Cunningham 1993, SP/CONNED 2007)) and this figure is expected to rise in West Africa with increasing high cost for health care. Medicine from the forest is culturally preferred because it is seen as God’s given pharmaceutical company to the poor in which all that is demanded is an indigenous knowledge of identification and user right which is sometimes complicated. This knowledge is passed on from one generation to another. This role of the forest is one basis for many arguments for forest conservation and management especially with global environmental changes (Seters 1997). Despite this, their importance to rural livelihoods is frequently overlooked by policy makers because these products are not traded through formal markets and in many instances are directly consumed by household members (Falconer 1992).

The IPCC forecast of impacts of climate change in general points to the tenderness and vulnerability of the forest ecosystem and increased diseases that are prevalent in Africa. Some researchers have also pointed out that future climate change will have significant consequences for the distribution, condition, shifts in species composition, erosion of biodiversity, and productivity of forests (Aber *et al.* 2001). In addition, vector-borne diseases such as malaria, meningitis and rift valley fever, will be controlled by the extent of temperature, rainfall and humidity (Githeko and Ndegwa 2001, Van Lieshout *et al.* 2004). This means that climate change may both increase the incidence of diseases and limit or erode the availability of known species used for treating common ailments.

Policy, economic and physiological factors may also determine the vulnerability of medicinal plant (Brown 1992). Many studies (Anyinam 1995, Bhattari 1997, Chivian and Sullivan 2002, Rao *et al.* 2004, UNCBD 2007) have reported the threats to medicinal plants from habitant destruction, over harvesting, increasing commercialization, and loss of indigenous knowledge, as well as population increase, forest fires, shifting cultivation, over grazing and impeding impacts from climate change. In addition to the above, the use and sale of medicinal plants are intimately connected with the threats to their survival. Though these other factors cannot be discounted, it is supposed that climate change impacts will further provoke changes in supply. Yet, the base for non-timber forest products (NTFPs) which include medicinal plants, food, on which the poor depend on for health and livelihood is neglected as policies and strategies for their management and development are lacking (Kalame *et al*. 2008a). This coupled with other shocks and stresses already in play, makes the poor more vulnerable to potential impacts of climate change.

Potential impacts of climate change on forest ecosystems in the region

A recent ecological simulation by McClean *et al.* (2005), using climate models developed by the UK Meteorological Office's Hadley Centre, compared the climate in 1975 to future scenarios predicted for 2025, 2055 and 2085 coupled with three distinct computer models to predict which plants would be affected by changing climate. They examined a total of 5,197 species of African plants and concluded that changes in climate conditions are likely to affect between one-quarter and one-half of the species. Life zones in which nearly all these species can live would either shrink or shift, often to higher altitudes as a result of anticipated changes in Africa's climate. The work of Gonzalez (2001) also demonstrated that there is already a gradual southward shift of vegetation in West Africa from Sahelian zones to Sudano-Guinean zones. Productive land which formerly provides subsistence needs has declined through the process of desertification, defined by the United Nations Convention to Combat Desertification (UNCCD) as ‘land degradation in arid, semi-arid and sub-humid areas resulting from several drivers that includes climate variations and human activities. Higher temperatures will increase the rate of evapo-transpiration, thereby reducing soil moisture availability for a given rainfall regime. Increases in rainfall may or may not be enough to compensate for increases in surface temperature. Land degradation resulting from human activities around forest communities may exacerbate species erosion under a variable and changing climate.

Projections from the Ghana, Burkina Faso and Mali National Communication Documents indicate that by 2050, annual average temperatures could be 2ºC to 6ºC higher over Burkina Faso, Ghana and Mali. Analysis of currently observed temperatures in these countries has increased by 1ºC. One consequence of climate change in the region is an increase in extreme weather events which can affect forest ecosystems by causing significant loss in tree and animal species. Aside from such direct impacts, floods and storms can also alter water flows on which trees depend, thereby hurting forest health. A changed climate also opens the way for non-native, harmful species to invade disturbed ecosystems. Changes in temperature and rainfall could favor outbreak of insect-pest infestations. The anticipated changes in the ranges of tree species, in forest composition and in the size and occurrence of insect populations will also affect the dynamics of forest communities. Certainly, regional droughts seem to have a clear link with the frequency and intensity of fires (Hansen *et al.* 2001, Biringer 2003). The implications of these potential climate change impacts on the forest will affect the provision and quality of forest goods and services essential for livelihood and national development.

Materials and Methods

This study formed part of a regional study on the vulnerability of West African forests to climate variability and change, which is conducted in three countries: from the coastal forest zone of Ghana, through the Guinea-Sudan savannas of Burkina Faso to the dry Sahelian woodlands of the northern borders of Mali. The case studies reported here were conducted in eight rural communities (>20 villages) within two ecological zones, i.e. of high rainforest and savanna zones of Ghana; and in four communities (>12 villages) within three ecological zones of Guinea-Sudan savanna to southern Sahel zones in Burkina Faso (Figure 1). The communities were purposefully selected based on historical evidence of high exploitation and sales of forest-based products for medicinal and other purposes from the areas. Village level meetings were held to apply participatory action research tools such as resources mapping and problem tree analysis to solicit community perceptions on the impact of climate variability and change on forest ecosystem goods and services (FEGS). In one major village in each of the study sites, perceptions on changes in the demand and supply of FEGS, particularly their seasonal cycle of flow and trends, were assessed. This was followed with focused group discussions of some very knowledgeable local and research individuals who helped match local names of trees to scientific names or their local uses. Through a stratified random sampling, interviews were conducted using structured questionnaires with 20 persons per community in Burkina Faso and 10 persons per community in Ghana, giving a total of 160 interviewed respondents. Another set of interviews was conducted with local forest and extension staff but this was not systematically structured since some areas do not have forest and extension staff on the ground. In each of the communities special groups of actors like herbal medicine practitioners and herb sellers were particularly targeted for interviews.

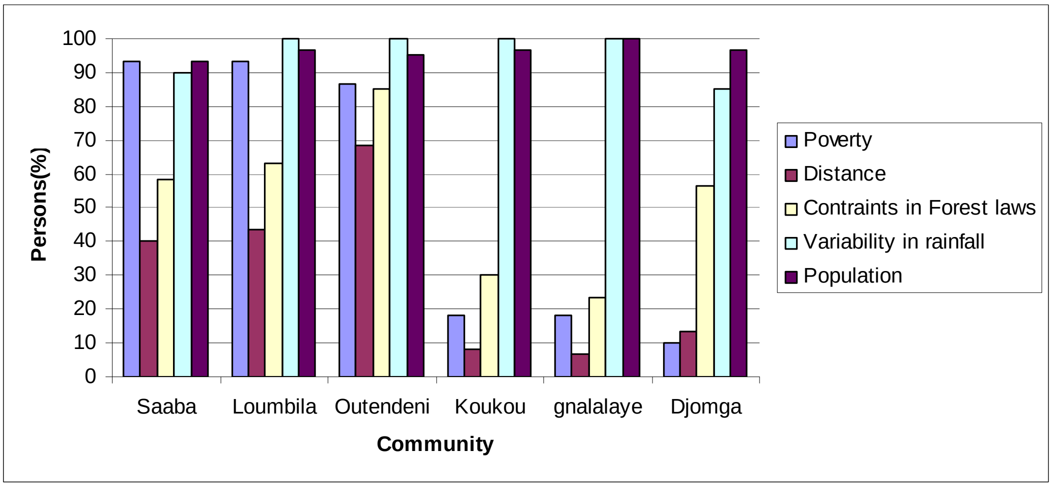

Figure 1: Indicators for observed changes within the forest sectors by communities

Results and Discussion

Importance of forest medicinal plants to the population in West Africa

The importance of forest medicinal plants on the health sector and livelihood of rural people was evident from primary data from the studied sites. The list of locally known and used forest medicinal plants is inexhaustible (Table 1). As already reported by FAO (2004), over 2,000 forest plants are used in traditional medicine around West Africa. The indigenous communities in the study area do know and understand the usefulness of plants and depend so much on them wherever the local knowledge persists. The slogan destroy the forest and destroy the poor is much viable in the region. The traditional application of medicinal plants has high socio-economic value and importance in the studied communities. All (100%) interviewees indicated they are aware that people do use medicinal plants as against 95% of them agreed to have actually treated some ailments at one time using traditional knowledge of medicinal plants. This is higher than the 85% reported by (SP/CONNED 2007) for Burkina Faso, where people regularly use medicinal plants. Medicinal plants are used by the general population at personal and household levels as well as by specialized traditional healers. The importance of traditional medicine is highlighted by the number of traditional healers as opposed to that of western-trained medical doctors in some communities, because almost every family has someone who has a fair to good knowledge for identification and what plants should be used for particular purposes. In Ghana, for example, the ratio of medical doctors to traditional healers is estimated to be 1:92. Traditional healers in these countries are officially registered; about 3,360 healers are registered at the national level in Ghana, with about 300 traditional healers registered in Burkina Faso (Zida and Kolongo 1991).

Medicinal plants and climate change: what are the people saying?

Burkina Faso

In Burkina Faso, the majority (77%) of respondents attributed changes in plant resources to several years of droughts which many simply referred to as “changing weather or times”. Though the people did not label it ‘climate change’ per se but they understood and recognized that at some point in time, the weather is no longer what they used to know, rainfall has decreased and according to them this is one of the reasons for changes in forest products (Figure 1). There was a general belief that in the past ‘many ailments, almost every disease, or children diseases’ are cured by medicinal plants. Now they are treated in combination with modern medicine, especially when the plant species needed for such disease is difficult to come by. The traditional medicine practitioners are recognized to provide primary health services; they are believed to have the knowledge of medicinal plants which is gotten by traditional heritage or by learning and these people are respected in their communities. The use of medicinal plants by local communities is not due to the absence of modern heath centre in any locality, but it is rather a habitual cultural practice on which locals place so much value and confidence. Some of the local communities interviewed insisted that these days some diseases cannot be cured traditionally as new diseases which they did not know, emerges and interest in local knowledge declines.

The local communities attested that forest medicinal products like many other forest goods are on the decline in Burkina Faso. On how they are able to judge and measure decreased availability of FEGS, they affirmed that decrease in the availability is explained by the difficulty and time spent looking for particular species. There is extinction of some species which used to be available in the environment but no longer found around Djomga and Gnalalaye villages in northern Burkina Faso, tree species such as the *Adansonia digitata* (baobab), *Diospyros mespiliformis* and *Anogeissus leiocarpus* have completely “disappeared” or are “disappearing”. The long time spent in looking for particular species have increased the cost of treating the ailment by traditional medicine. This fact was highlighted by 93% of all traditional medicine dealers interviewed in the different counties. Irregular production of some plant species was also mentioned by local communities as indicator of change in the availability of medicinal plants. Further probing on their perception on what could have led to this changes; the local communities include impacts of past droughts, migrations, annual bush fires, population pressure, expansion of agricultural fields and the over-exploitation of natural resource in that order, as the major drivers. These clearly indicate the vulnerability of the communities coupled with likely increases in diseases in the context of climate change and the impacts of climate change on forest ecosystems.

This corroborates the findings of Kalame *et al.* (2008b) in the drought-prone central Sudanian region in Burkina Faso, where many important trees used as medicinal plants are, or almost, extinct due to poor / over harvesting coupled with unsuccessful tree regeneration hit by impacts of recurrent drought. Frequent droughts in West Africa have reduced the distribution of *Bombax costatum* in some countries, frequent fires are causing degradation of *Vitellaria paradoxa*, *Parkia biglobosa* and *Balanites aegytiaca* stands in the Sahel, while over exploitation have been reported for a wide range of products.

Shea butter nuts are over harvested in the Sahel region due to increasing population of interested collectors and traders. Other conflicting use of forest species may reduce the continual supply of medicinal species. In some countries, it may be the high demand for fuel wood which sometimes is indiscriminately harvested due to limited knowledge of medicinal species by the younger population who often are charged with collection of fuel wood for the family.

Ghana

The status of some known tree species within the two ecological zones (high rainforest and Guinea savanna) in Ghana in the last 40 years, and projection for the next 20 years (Table 1) is indicated by the local communities to be on a faster degree of degradation now than it has ever been. This state of decline is very much likely to intensify in the future with changes in land use cover and climate change impacts. Drivers of the dynamics in species composition and availability in the humid forest area are mainly human induced. Such human activities include a spontaneous rise in the population of settler farmers who are themselves second and third generation of the first generation of migrant farmers from the drier area of the country and beyond, the high demand for land for cocoa plantations which is influenced by international trade opportunities, increased mineral explorations and surface mining, slash-and-burn farming methods, and illegal harvesting of natural resources through uncontrolled felling of trees. In the savanna zone, human induced factors mentioned as main drivers are high population numbers, migration of Fulani herdsmen engaged in over-grazing of available fodder, slash-and-burn agriculture, bushfires and high livestock populations. Also the intensity of the droughts of the 1970’s coupled with these drivers has made the regeneration of new species slower and some became extinct as a result. Although the community in Ghana perceived changes to be mainly as a result of human induced changes, they however do not rule out the fact that climate variability and change may also have had an impact, because respondents could easily enumerate the observable differences in weather conditions between what they used to know and what it is currently, and the fact that species/herbs are already scarce. What the local community can observe, scientists could empirically verify. Van Dijk (1999) from studies in Cameroon noted that many known forest species are scarcer than in the past for several reasons, with irregularity in production of number of (fruit producing) species as main cause of change in their availability. This can be associated with climate variability and change, conversion of forest land for agriculture, increase in demand as a result of increasing population and increased logging activities.

The situation of decrease attested by the communities will likely continue if action is not taken to preserve the forest from adverse effects of global environmental changes. The question then is what is the hope of the ordinary people in the region and pharmaceutical companies who depend on these resources? The fact that local communities could easily identify shortfall in availability of forest ecosystem goods and services that are known or used by them does not only indicate elements of vulnerability of these goods but it also highlights the urgent need to adapt forest ecosystems and adapt the community livelihoods to climate change impacts.

Prescribed actions by the local communities

Burkina Faso

According to local communities, strategies to cope with observed changes in the availability of medicinal plants have been ranked in two categories: (i) short-term unsustainable strategies; and (ii) long-term sustainable strategies. Short-term actions being implemented by local communities include decrease in the frequency of bush fires, multiplication of sacrifices/ prayers and the decrease in cutting trees for fuel wood. These strategies are partially implemented at individual level based on personal conviction about environmental degradation but need to be fully backed by government policies for them to be effective. As long-term local actions (Figure 2), communities cited migrations of communities from degraded land to favorable land, reforestation and the techniques of water and soil conservation to rehabilitate degraded land. There is no guarantee however, that migration itself is a sustainable action because it is a transfer of the problem from one place to another, and it is usually at the root of social conflict when pressure on fertile agricultural lands and declining forest resources increases. About 80% of the population were of the opinion that reforestation may be a better option.

Table 1: Some commonly used forest medicinal plants in West Africa

Botanical name	Part used[1]	Local name (Ghana)	Ailments/conditions treated[1]	Status of species *=poor; *** = good		
				Last 30 years	Now	Next 20 years
Alstonia boonei	bark root bark / leaf leaves latex	Sinuro	-measles, intestinal,worms, asthma, fractures, jaundice, lactogenic, wounds and cuts -rheumatism -swellings -purgative / laxative, yaws	**	**	***
Albizia adianthifolia	bark	Pampena	anthelmintic (expulsion of tapeworms)	***	***	**
Alcornea cordifolia	stem/Leaf	Gyama	-bronchial problems, leprosy, piles	**	**	***
Allanblackia floribunda	bark	Sonkyi	-analgesic diarrhoea/dysentery			
Afromomum spp		Fam wisa	-piles, fever, boils	**	***	***
Combretum smeathmannii	bark	Kokrodosa	-ulcer, boils, guinea worm sores			
Borassus aethiopum	root	Maakube	-asthma	**	***	***
Garcinia kola	fruit, fruit, root, bark & stem	Tweapea	-anthelmintic , -aphrodisiac	***	***	***
Griffonia simplicifolia	leafy stem/leaf	Kagya	-aphrodisiac, kidney diseases	**	**	**
Ficus exasperate	leaf	Nyankyerenee	-cold	**	**	***
Hoslundia opposita	root leaf and leaf sap leaf and flowers	Asifuaka	-antiseptic, colds, purgative/laxative, sore throat, gonorrhoea, wounds and cuts -convulsions, sore eyes /conjunctivitis, Mange, jaundice, cholagogue (stimulating liver and bile production), stomach pain (purgative), vertigo, snakebite antidote and preventative -ringworm and parasitic skin diseases	**	**	***

Botanical name	Part used[1]	Local name (Ghana)	Ailments/conditions treated[1]	Status of species *=poor; *** = good		
				Last 30 years	Now	Next 20 years
Lophira lanceolata	root shoot	Sereso-Kaku	-asthma -bronchial problems	*	*	*
Mallotus oppositifolius	root/leaf	Anyanyanforowa	-anaemia	*	**	**
Monodora myristica		Widiaba	-stomach problems	**	**	***
Morinda lucida	leaf root	Konkroma	-blood purifier -chest pains, menstrual troubles	**	***	***
Newbouldia laevis	roots bark leaf	Sesemasa	anthelmintic diarrhoea/dysentery , catarrh, syphilis toothache (caries) -impotence (with clay and red pepper), colic, catarrh, earache, hepatitis, piles, purgative/laxative, sinusitis, snuff/sneezing, styptic (arrest bleeding), wounds and cuts, menstrual problems, -amenorrhoea, dysemorrhoea, conjunctivitis, sore eyes, heart disease, heartburn, palpitations (leaf ash and salt), in difficult labour, to facilitate birth, lactogenic, febrifuge	**	**	**
Nauclea latifolia	bark	Sukisia	-anaemia, cough and whooping cough, measles, menstrual troubles			
Paullinia pinnata	root and leaf-tips	Toantini	-aphrodisiac, boil	**	*	**
Picralima nitida		Kanwono	-weaning			
Piper guineesis	seed	Esro wisa, Ashanti pepper	-convulsions, stomach, purgative, flatulence	***	***	***
Rauwolfia vomitaria	stems and roots	Kakapenpen	-fever, piles, stomach problems, asthma, cancer, measles	**	**	**

Botanical name	Part used[1]	Local name (Ghana)	Ailments/conditions treated[1]	Status of species *=poor; *** = good		
				Last 30 years	Now	Next 20 years
	root		-aphrodisiac			
Spathodea campanulata	bark	Kokoanisuo	-backache, bladder trouble/kidney diseases	**	***	***
Sterculia tragacantha	shoots	Sofo	-anthelmintic (expulsion of tapeworms)	**	**	**
Strophanthus hispidis	stem and root	Maatwa	-headache			
Tamarindus indica		Samia	-stomach problems			
Voacanga africana	seed extract	Ofuruma	-general cases of cancer, toothache			
Xylopia aethiopica	seed	Hwentia	-boils, anaemia, diarrhoea, purgative, kidney diseases, bronchial problems, cancer, flatulence, hepatitis	**	**	***
Zanthoxylem xanthoxyloides	bark	Kanto	-stomach problems, cough, impotence, paralysis	**	**	***

[1]Sources of information: Ayensu (1978), Abbiw (1990), Asante *et al.* (1992),

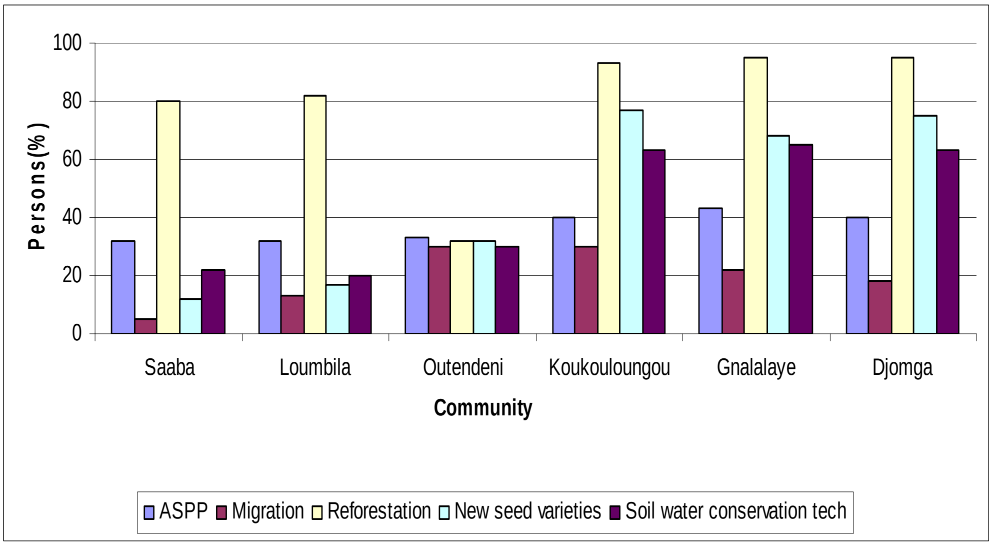

Figure 2: Long term adaptation practices to forest resource scarcity by communities

Ghana

The local communities in Ghana would like to have the government or a similar body to regulate the sale of such herbs so that they can buy these herbs at controlled prices. Some species are particularly found near water bodies and there must be a comprehensive programme to protect riparian vegetation to help to prevent riparian herbs of medicinal quality from becoming extinct. There should be greater protection of forests and sacred groves since these are places they usually get their herbs. The activities of timber companies, in the opinion of the herbal medicine practitioners, constitute a very serious threat to the availability of herbs. They advocated that government should pay a closer attention to this by balancing the need to harvest timber and the conservation of other forest resources. Their main argument is that if the government pays more attention to the activities of herbal medicine practitioners and recognise them as very important in health delivery, this group with knowledge of medicinal plant species will have a voice to advocate that the destruction of their herbs be discontinued. They would work in partnership with government to ensure the sources of their livelihoods were protected by all stakeholders. In their opinion, this needed recognition and promotion from the government seem to have eluded practitioners of traditional healing and some are gradually losing interest in practicing herbal medicine. Development of the herbal medicine industry in the country is not receiving good attention. They do not get support from private investors, banks or other agencies to improve on what they are doing; rather there is more emphasis on importation of herbal drugs from China to the detriment of the local industry and practice. This creates disinterest in the local herbal industry and indirectly works against deliberate attempts to either domesticate, regenerate or a plan to stop medicinal plants from getting extinct.

A possible pathway to the restoration of forest-based resources, especially under current high deforestation and climate change variability as suggested by some respondents, is that the village chiefs, district assemblies, government, forestry commission, etc. should help set aside areas noted for trees, plants or herbs of medicinal value and prevent farmers, timber companies and other developers from degrading those areas. This has become particularly important as many developers are now moving into the rural areas and also timber companies are now exploring the non-traditional or lesser known timber species which have usually served as medicinal plants in the past years.

Species that are not currently cultivable but vulnerable should be domesticated; however, the opinion of local communities was that they were not well resourced to embark on the planting of such species on a large scale. They should be supported to cultivate the species that they know are easy to cultivate. The universities and research institutes should also research into the adaptation suitability of other trees which the herbal medicine practitioners do not yet know if they are cultivable so that they can domesticate some when possible. It must be noted that there is some suspicion when researchers come closer to these practitioners who are usually not educated. They claim that the researchers come to learn from them, steal their preparations and go out to register the products and claim ownership of such drugs or treatments since they can read and write. It was also proposed that the government should help to make a nationwide collection of some of these species that are getting extinct for preservation so that practitioners can go to a particular point where they can get these herbs to purchase when the need arises. This will cut down the time and cost of travelling around looking for particular herbs for medicine.

Recommendation

The rural poor become especially vulnerable to the loss of essential goods such as medicinal plants when natural and human systems are impacted by climate change. The foundation of long-term good health of the population relies on the stability of ecological and physical systems (McMichael *et al.* 2003). Therefore, the overall success of any intervention depends on the level of involvement of the multiple forest stakeholders, including the local communities. Necessary steps to be taken include:

- Assessment and understanding of socio-economic and climate related vulnerabilities of both the population and the health sector in West Africa.
- Analysis and documentation of existing adaptation options in the indigenous health sector in West Africa.
- Documentation and integration of indigenous knowledge on medicinal plants during the planning and implementation of natural resources management.
- Formulation and mainstreaming, amid uncertainties, of “no regret” proactive and reactive adaptation strategies and policies on climate-induced health hazards into development activities at different spatial and temporal scales.

- Build a multi-stakeholder institutional platform and mechanism that focus on achieving a realistic and synergic integration of traditional and modern medicine for the overall benefit of national health care improvement.
- Improve management of health-supporting systems such as water catchments, forest and other agro-ecosystems.
- Raising awareness on disease prevention through environmental education on the benefits of a healthy living environment.
- Valuation of the commercialization of medicinal plants through improved storage and packaging.
- Promotion of traditional rules, bye-laws and harvesting practices of medicinal plants that ensure a sustainable supply.
- Conservation of genetic resources of medicinal plants both in-situ and ex-situ through herbariums, herbs gardens, agroforestry parklands, forest reserves and sacred groves.
- Formulation of a multi-stakeholder, multi-sectoral and locally supported land use planning and policies to avoid indiscriminate deforestation and degradation of natural resources, including medicinal plants.
- Encouraging artificial and assisted natural regeneration of medicinal plants in different ecosystem landscapes.
- Restoration of degraded lands using adapted multipurpose indigenous and introduced tree species taking into consideration local tree preferences.

Conclusion

With climate change coupled with other anthropogenic activities, very important indigenous forest species used in the past for healing have disappeared from the forest in some locations and will continue to do so if actions are not taken to preserve these forest species from adverse effects of global environmental changes. This study has given a clear indication that the local people are concerned about the increasing loss of forest goods and services; in this case medicinal plants. Natives and the traditional healers indicated that previously, they could collect whatever species they needed for any particular ailment but now it is no longer the case, and for some species, it may take between 2 to 3 months to find.

This paper is a call for collective sustainable adaptation actions in addition to what the communities have prescribed, to slow down the negative impacts of global change on both the health of the population and on ecosystems that provide medicinal plants.

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TOWARDS SUSTAINABLE FOREST MANAGEMENT IN GHANA: UNDERSTANDING THE CLIMATIC RISK AND ADAPTATION MAZE

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Abstract

Forest management in Ghana dates back to pre-colonial times. Forest management during this era of democracy has experienced a number of interventions in response to new challenges. For example, there are increasing livelihood challenges in forest areas in Ghana under the intensity of climate change impacts in recent times. Different forms of adaptation to climatic risk ranging from indigenous to acquired techniques are coming up in almost every sector of the economy. These adaptive strategies are diverse and sometimes complex especially among forest-dependent communities. In this study, attempts were made to trace the complexity of climatic issues and adaptation trends in southern Ghana and linking the knowledge to the resilience of current strategies employed for sustainable forest management in Ghana. It is suggested that, among other things, a review and adjustment of the annual allowable cut in Ghana would be a major step in responding to climate change which would in turn affect certification and levies on logging and sustainable use of forest goods and services.

Introduction

Some 50% of the Gross Domestic Product (GDP) in Ghana is derived from harvesting of renewable natural resources in agriculture, fisheries and forestry sectors and over 100,000 people are directly involved in the forestry sub-sector (Aryeetey and Dzanku 2008). Since the 1950s, more than 50% percent of the original forest area had been converted to agricultural lands. Yet demand for forest goods and service has increased significantly over time as a result of population growth. Following the reported alarming decline in the forest base in Ghana and other African countries (FAO 2005) coupled with its concomitant impact on the quest for improved livelihood, its sustainable use has been at the heart of discussions in recent times.

In Ghana, for example, pre-independence strategies were aimed primarily at cocoa production in southern Ghana (Kotey *et al.* 1998). Since that period the trend of forest management has changed drastically in form and composition and varies in different ecological zones. The evolution of forest policies, strategies and conditions that characterized the phase of administration of the forest estate in Ghana from 1870s to date have been graduated as the Formal forestry period/consultative phase (1874-1939), the Timberization phase (1940 to 1953), the Diktat phase (1954 to early 1990) and currently the Collaborative phase (late 90s to present) (Kotey *et al.*1998). At each stage, new strategies were devised to meet emerging challenges and thus the challenges were addressed, though in most cases, incompletely. Despite the existence and implementation of a legislative framework, destruction of Ghana's forest continues at an unsustainable rate. In most African countries, similar trends have been recorded (ITTO 2005).

Current forest management strategies, backed by amended regulations like the Timber Resource Management Regulation, were basically aimed at ensuring 'social satisfaction' to different stakeholders in the timber industry. The perpetual flow of optimum benefits to all stakeholders was seen as essential to this process; a characteristic of participatory forest management. Despite these efforts, illegal logging, which may be an important indicator of "social dissatisfaction" and/or perhaps greediness of the survival of pre-colonial beneficiaries,, has resulted in the decline of the original forest base to about 11-14% (Poorter *et al.* 2004).

Suffice to imply that efforts targeted at addressing the challenges have not completely eradicated the problems. A further stress is envisaged as a result of climate change which will further compound the situation in forest management. Climate change and envisaged surprises will hit many forested communities in southern Ghana, and other African countries. The impact on the quality and quantity of forest goods and services will be enormous if measures are not taken to cope effectively with this situation since proper forest management has the potential to reverse the climatic variability and its impacts.

As efforts are made to address the challenges to sustainable forest management, it is acceptable to call for a review of current practices towards sustainable forest management in Ghana. In the context of the climate change discussions, mitigating and adaptive strategies need to be implemented that will ensure the survival of forest dependent communities and its associated forest functions and services. This paper, aims to examine efforts towards sustainable forest management in Ghana and analyze the resilience of current strategies employed to some current and projected climatic stresses in order to predict the impacts for the forest goods and services in Ghana.

MATERIALS AND METHODS:

Study area

The research was conducted in the tropical high forests of southern Ghana (Figure 1) which cover about 7% of the Ghana land area (MLF 2004). Three Forest Service Divisions in two ecological zones (moist semi-deciduous and moist evergreen forest types) in southern Ghana were used for the study. Specifically, the study was conducted at Akim Oda, Assin Fosu and Asankragua.

Stratified random sampling was used for the study. Desktop search and interviews were conducted in the selected forest areas. Three district forest managers, seven technical officers and eleven forest guards in the study areas where interviewed.

Results and Discussion

Knowledge of climate change in the forest districts

All personnel in the study areas, managers and technical officers, were well informed about climate change with some local indicators like intensity of sunshine, irregularities in season and erratic rainfall. However, the lack of empirical evidence shows almost no relevant research with a major gap the design of location-specific and forest-dependent and acceptable adaptation strategies with moderate financial demand - a maze in itself. These findings are consistent with results from elsewhere in Africa (AIACC 2007). The difficulty in monitoring even the current regulations and strategies put in place in forest reserves and off-reserved land, is that the zones imply stress, which is a threat to effective implementation of any strategies, no matter how innovative this could be. The threat to addressing climatic risk in this area is whether it will be based on 'expensive' reliable data and information upon which appropriate adaptation strategies can be developed in southern Ghana.

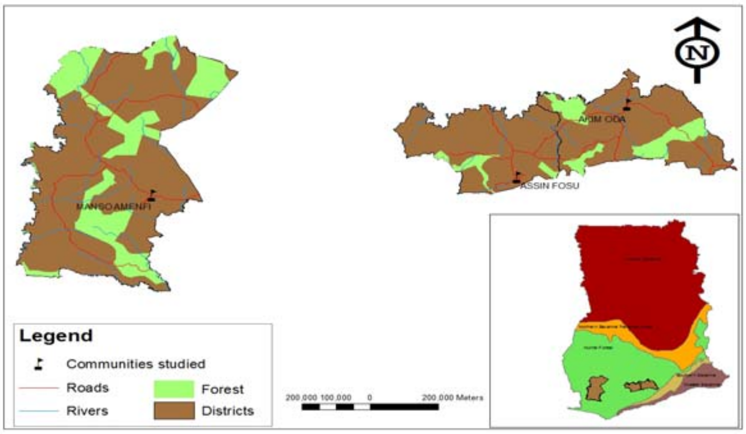

Figure 1: Location of the selected study areas in southern Ghana

Current strategies adopted in sustainable forest management in Ghana

The personnel in the studied districts are seen as agents to ensure proper implementation of forest policies and strategies either as Forest service, Timber industry or Wildlife service. Ghana has introduced a new timber utilization contract system to improve efficiency, transparency and accountability in forestry, particularly in forest production activities (MLF 2004). This is to ensure that sustainable timber yield and plan towards it is easily monitored and strictly adhered to in Ghana. There are also manuals for production, management and planning, which set out the obligations of logging contractors. The silvicultural system used in natural forests is a polycyclic selection felling system using a cutting cycle of 40 years, a national annual allowable cut of approximately 1.2 million m^3 (Oteng-Amoako 2008). Recent reports on world forests placed Ghana's forest management in a good position. It is reported that about 270,000 ha of natural production forest of the original 1.60 million ha Production Forest Estate are considered to be managed sustainably; with an estimated 108,000 ha of the Protection Forest Estate are so managed (ITTO 2005)

Aside the efforts in maintaining the natural forest estate, Ghana is establishing a sizeable plantation estate of teak (*Tectona grandis*) on degraded forest lands (Oteng-Amoako and Sarfo 2003). Vigorous teak plantations in logged forest land currently cover an estimated 124,000 ha (personal communication). As part of collaboration or participatory forest management, fringe communities in the forest areas have been regarded as part of the management of forest resources. Community participation in forestry is being facilitated through community forest committees (CFCs) and there were some 100 CFCs (MLF 2004).

Climatic change/ stresses and sustainable forest management

The climatic debate is definitely geared towards one major conclusion: that average weather conditions over the past decades are changing significantly in most regions of the world and its impacts will be more severe in developing countries of the world (AIACC 2007, IPCC 2007). Considering the low level of literacy, high poverty rate, population dynamics, heavy dependence on declining forest resources and the effort of government to move Ghana to a middle Income status make tracing of climate change and impact extremely complex and difficult. The situation further suggests that forest ecosystems will face new challenges with great implications for the livelihoods of thousands of households and national economic development. It is therefore important to promote technical and scientific information exchanges on both the implications and applications of innovations in sustainable forest management especially for adaptation to climate change without compromising forest ecosystem resilience.

The services provided by forests may face interesting challenges; therefore the call for developing and implementing immediate adaptation strategies by all. Forest goods and services will be 'scarce' and probably more valuable, with the likelihood that people will pay more for such services even in tourism. Climatic change may also affect the regeneration cycle of forest species which had been the basis for determining the annual allowable cut in Ghana. In plantation forestry, as in the afforestation programme in the country, maturity and species survival may also be significantly affected.

Adaptation maze in sustainable forest management

The complex mass of facts that influence adaptation processes has a great impact on how sustainable Ghana's dwindling forest will be managed in the next decade and beyond. According to IPCC (2007) adaptation to climate change is a process by which strategies to moderate, cope with and take advantage of the consequence of climate events are developed and implemented. In many sectors of Ghana's vulnerable economy, attempts that have been made to estimate the impacts of climate change has been impressive but because of the complexity of developing and properly implementing adaptation strategies, there is a widening gap of adaptation deficiency in areas. The recent case studies in some African countries confirm this (AIACC 2007). Adaptation strategy is a policy making process. This is an area dominated by competing priorities and frequently by antagonistic groups. Adaptation strategies are better implemented if they are location-specific and have some cultural and geographical tones. Furthermore, it should include flexibility mechanisms to address the climate "surprises' that will almost certainly occur in the future. It must also account for the new technologies and findings in the field of climate change.

Adaptation is a long, continuous and dynamic process which requires patience and succession planning. It is a mixture of different "sectoral permutations", i.e. sectoral measures, multi-sectoral measures and cross-sectoral measures. Which of these measures should be taken for Ghana and at what level of administration in forest management? It is also about prioritization with a wide array of stakeholders with different interests using different decision making tools such as cost-benefit analysis (CBA), cost-effectiveness analysis (CEA), multi-criteria analysis (MCA), and expert judgment (UNFCCC 2005). The identified factors in adaptation strategies are shown in Figure 2.

Conclusion

Efforts aimed at ensuring sustainable forest management in Ghana are remarkable although plagued with unintended hiatus. Undoubtedly, Ghana has favourable conditions for the achievement of sustainable forest management, such as well trained human resources, including a strong Forestry Commission, and a long history of forest management. Nevertheless, many challenges must be met. Climatic risk in sustainable forest management aside illegal activities such as chainsaw lumber production and poaching that are thought to be widespread. In the wake of the threats imposed by climatic change in Ghana, a number of climatic related innovations are needed to respond effectively. District specific adaptation strategies are needed along the generally accepted ones.

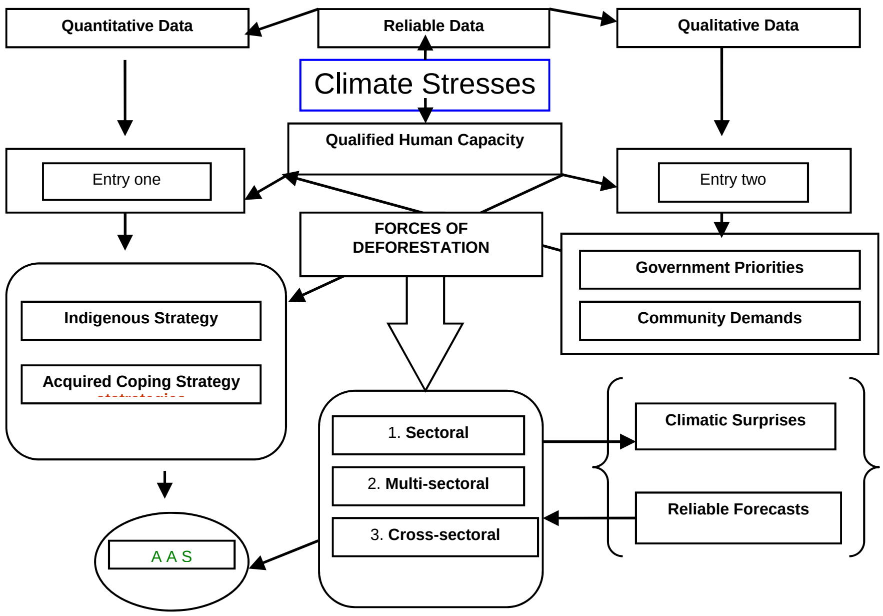

Figure 2: Schematic diagram of the adaptation maze (AAS = Acceptable Adaptation Strategies)

Recommendations

It is recommended that the annual allowable cut (AAC) be reviewed to incorporate an estimate of the impacts of climate change. This will ensure that the annual volume increment of wood in the productive area that can be removed annually without jeopardizing the future productivity of the residual growing stock (the AAC) will reflect current and projected climatic variability in Ghana's response to climate change.

With the promotion in Ghana of the use of non-timber forest products (NTFPs), particularly bamboo and rattan, the use of resources of relatively shorter development period and carbon sequestration ability are envisaged. These resources could be explored to reduce the pressure on timber species in the natural forest and its attendant impact from changed climate conditions in the tropics.

The adoption of a special rating of trees based on their climatic adaptation potential rather than the current use of their biological rarity index (IUCN 2004) should be considered.

Better supervisory and monitoring of existing rules and regulations are needed. It is important that this be based on sound financial and ample human resources to help achieve the strategies towards sustainable forest management in Ghana.

Acknowledgements

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COMMUNITY FOREST MANAGEMENT: A STRATEGY FOR SAFEGUARDING THE DRY NATURAL FORESTS IN THE CONTEXT OF CLIMATE CHANGE IN BURKINA FASO

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Abstract

Natural resources management in general and particularly from forests, constitute a key issue of development policies in Sahelian countries. These countries tried to prevent the catastrophic consequences of the exponential reduction of their forests. Since 1985 Burkina Faso made a serious effort to develop a national policy for sustainable management of its dry forests, with implementation through many projects. The local population participated in the implementation of the forest management plan, and there were certainly positive aspects recognized by all the actors. But after 15 years of community forest management within the context of a negative climatic trend over the years, it was considered relevant to investigate impacts of this management. A forest inventory and questionnaire surveys amongst the villages allowed measuring the effect of ecological and socio-economic impacts in protected forests of Bougnounou. An improvement of population incomes through the harvesting of wood and non-timber forests products (NTFPs) is one of the main results which support sustainable forest management efforts. Forest management activities by direct seeding and planting with local species best adapted to human disturbance and the present climate conditions have allowed to preserve forests and increase vegetation cover, flora and fauna. This community organisation for local forest management is enhancing the creation of local groups. Recommendations were made to overcome some difficulties encountered and mainly to integrate actions of adaptive management in order to control the effects of climate change and variability. These actions have to be considered in the forest management plan for the next rotation.

Introduction

Like other Sahelian countries, Burkina Faso is subject to an increased dependence on traditional energy sources, primarily fuel wood, which constitute 90% of the total energy consumption of the country (Kabore 2005). This need for fuel wood increases more and more because of population growth and the strong concentration of the population in the large urban centres. This situation coupled with the great droughts of the seventies (CILSS 2004, Kabore 2005) were the reason for the focus on natural forest management in Burkina Faso. The great droughts and the desertification of the seventies caused the huge migration of people from the north to the more fertile land of the south with associated increased anthropogenic pressure on the forest resources. The negative effects of bush fires, the land grabs and the increasing demand for fuel caused the Burkina Faso government and its development partners to develop since the eighties a forest management program to fight against the degradation of the natural ecosystems (PAFN 1993).

The dual objective of the forest management program was to integrate the ecological and socio-economic aspects of natural forests which before was under the exclusive management of the forest administration. The management of natural forests falls under the national forest policy in Burkina Faso and its basis was to give local communities a sense of responsibility (MECV 2003). The management of many forests throughout Burkina Faso was set up. Very few studies have been done on the impacts of this system of forest management. This situation raised some questions about the impacts and the sustainable management of such forests in the context of climate change scenarios.

Promotion of sustainable forest management (SFM) requires the reconciliation and combination of the environment and development, and to adopt a multiple vision of the forest functions (Zida M 2004). A study of the classification and dynamics of the natural woody vegetation of Maro forest showed an improvement of stand density and recolonisation of cleared areas (Zida D and Ouadba 1998). Similar results were obtained by Zare *et al.* (1998) in the province of Bazèga and Savadogo (2007) when studying the dynamics of Sudanian Savanna-Woodland Ecosystem in response to disturbances. This study contributes to the evaluation of the impacts of community forest management of the CAF (forest management area) of Bougnounou in order to identify measures of adaptation to climate change.

The specific objectives for this paper are to

- evaluate the impacts of community forest management on the dynamics of woody vegetation of the CAF of Bougnounou;
- evaluate the impact on community livelihoods;
- identify the criteria and indicators for adaptive forest management.

Materials and Methods

The site retained for the data-gathering is the CAF of Bougnounou in the Ziro province. The CAF forest covers 24,093 ha, is subdivided into 11 forest management units (FMUs or UAFs) and managed over a 15-year harvesting cycle (rotation), i.e. an UAF was subdivided into 15 annual firewood harvesting blocks.

Inventory of the woody plants of the protected area

Two of the 15 FMUs were randomly selected for the inventory: UAF 5 and UAF 6. In each selected FMU, 5 of the potential 15 harvesting blocks were randomly selected, i.e. blocks 1, 5, 6, 7 and 11 (Figure 1). Within each selected block, transect lines were systematically located 400 m apart, and circular plots were sampled at points 400 m apart along each line. Each plot covered 1,250 m^2, i.e. with radius of about 20 m. On each plot each woody stem with a minimum stem circumference of 10 cm at 1.3 m height from the ground (suitable for harvesting), was recorded by species, circumference and height. In addition, the following data were recorded (using ordinary tapes):

- the number of sprouts, the height of cut, the height of dominant sprout and the health condition, for the individuals which had been cut.
- vegetation and soil type.
- location of each sampled plot, using a GPS.

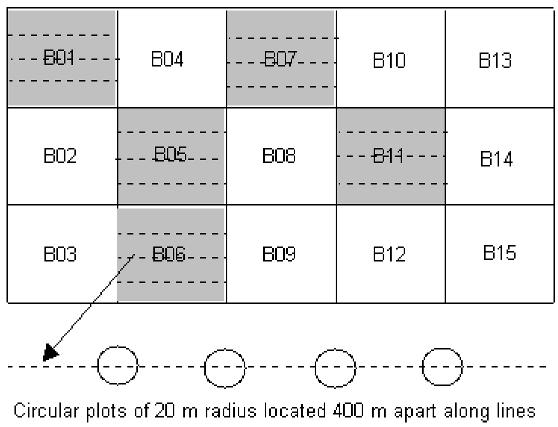

Figure 1: Schematic sampling design within one selected UAF. The shaded annual harvesting blocks were selected for sampling. Two or more parallel transect lines were systematically located 400 m apart within each selected block. Circular plots of 20 m radius were sampled every 400 m along each line.

Investigations of the populations surrounding the forest

Two types of questionnaires were used: a random selection of 16 Forest Management Groups (GGFs or associations); and 34 people from members of the GGF and particularly those that harvest the available resources, living around the managed forests. Data were collected through MARP methods (ISS, focus groups).

Data processing

The collected data were analysed using Excel and SPSS 15.0. The importance values (IV) of the different species were calculated as IV = (RF+RD)/2 where

> *RF = Relative frequency* = number of plots (frequency) in which the species was present in a FMU, expressed as percentage of the sum of all frequencies of all species in the FMU;
>
> *RD = Relative density* = number of stems of a species in a FMU, expressed as a percentage of all stems of all species in the FMU

The structure of the woody stems was expressed as histograms (stem density per hectare for stem height and diameter classes for the two FMUs. Variables such as stem density and index of diversity of the stands were calculated.

Results

Stem density and species composition of the vegetation

The types of vegetation currently present in the area are woodland, tree savanna, shrubby savanna and some dense areas of riparian and gallery forest.

Mean stem density for the study area was 120.8 stems/ha but ranged between 108.4 and 153.1 stems/ha for UAF 5 compared to a much wider range between 76.0 and 173.3 stems/ha for UAF 6 (Table 1). A total of 46 woody species were recorded with 38 species in UAF 5 and 41 species in UAF 6 (Table 1). Two plots had no trees. The species diversity ranged between 2.99 and 7.76 (Table 2), which represents a good diversity of the woody flora of the CAF of Bougnounou.

The top 10 woody species (represented by 11 species), based on their importance values, show that eight of the overall top 10 species are also among the top 10 in each of UAF 5 and 6, but their relative position vary between the two UAFs. This suggests that even though the two UAFs generally have the same composition of woody species, the relative importance of the different species show much variation between the two areas.

Table 1: Species richness and stem density for the selected harvesting blocks in the selected two forest management units (FMUs or UAFs) of the forests in the CAF of Bougnounou

UAF	Harvesting block	Number of plots	Number of species	Number of stems	Total plot area (ha)	Block stems/ha
5	1	6	22	83	0.750	110.7
	5	4	17	73	0.500	146.0
	6	6	19	82	0.750	109.3
	7	7	21	134	0.875	153.1
	11	9	21	122	1.125	108.4
6	1	8	20	110	1.000	110.0
	5	6	13	57	0.750	76.0
	6	5	14	62	0.625	99.2
	7	6	19	98	0.750	130.7
	11	6	27	130	0.750	173.3
Total		**63**	**46**	**951**	**7.875**	**120.8**

Table 2: Index of diversity of the vegetation of the CAF of Bougnounou

UAF	**Harvesting block**	**Shannon Index (H')**
5	1	3,99
	5	3,99
	6	3,60
	7	7,76
	11	3,75
6	1	3,85
	5	2,98
	6	2,99
	7	2,99
	11	4,02

Table 3: The top 10 woody species, overall and per each of UAF 5 and 6 (see shaded IVs), based on the calculated importance values (IV) based on the mean of Relative frequency (RF) and Relative density (RD) of all 46 woody species recorded in the CAF of Bougnounou.

Species	Overall			UAF 5			UAF 6		
	RF	RD	IV	RF	RD	IV	RF	RD	IV
Detarium microcarpa	9.5	14.2	11.8	7.0	10.9	9.0	8.4	12.6	10.5
Anogeissus leiocarpus	4.5	9.1	6.8	11.4	16.8	14.1	7.4	12.8	10.1
Vitellaria paradoxa	8.1	8.7	8.4	10.1	9.0	9.5	9.0	8.8	8.9
Combretum micrantum	6.3	9.1	7.7	7.0	8.1	7.5	6.6	8.6	7.6
Combretum molle	9.0	10.3	9.7	4.4	2.8	3.6	7.1	6.7	6.9
Combretum glutinosum	8.6	8.7	8.7	1.3	1.5	1.4	5.5	5.3	5.4
Acacia dudgeonii	4.1	2.0	3.0	5.7	5.0	5.4	4.7	3.5	4.1
Crossopteryx febrifuga	2.3	1.6	1.9	4.4	7.0	5.7	3.2	4.2	3.7
Burkea africana	5.4	4.5	4.9	1.9	0.7	1.3	4.0	2.6	3.3
Terminalia macroptera	2.3	2.2	2.2	2.5	5.7	4.1	2.4	3.9	3.1
Acacia macrostachya	4.5	3.2	3.9	2.5	1.5	2.0	3.7	2.4	3.1
Terminalia avicenioides	3.6	5.3	4.4	0.6	0.7	0.6	2.4	3.0	2.7
Maytenus senegalensis	2.7	2.4	2.6	2.5	2.6	2.6	2.6	2.5	2.6
Gardenia erubescens	3.6	3.4	3.5	1.3	0.4	0.9	2.6	2.0	2.3
Strychnos spinosa	2.3	1.2	1.7	3.2	2.0	2.6	2.6	1.6	2.1
Piliostigma thonninghii	0.9	0.6	0.8	3.2	3.9	3.6	1.8	2.2	2.0

Horizontal and vertical stand structure of the vegetation

The horizontal stand structure is represented by the stem diameter class distribution, which is very similar for the two UAFs (Figure 2). There is a relatively high stem density in stems <10 cm diameter at breast height (DBH), which suggests a good recruitment of the stems in relation to the relatively low level of stems >10 cm DBH.

Vertical stand structure represented here by the stem height class distribution (Figure 3), shows a different pattern between the two UAFs. UAF 5 shows the highest stem density for stems <3.5 m high, and a decreasing stem density in subsequently taller classes. UAF 6 has the highest stem density in stems 3.5 to 7.0 m high. Both areas show a low stem density for trees >7 m height, with more such trees in UAF 6.

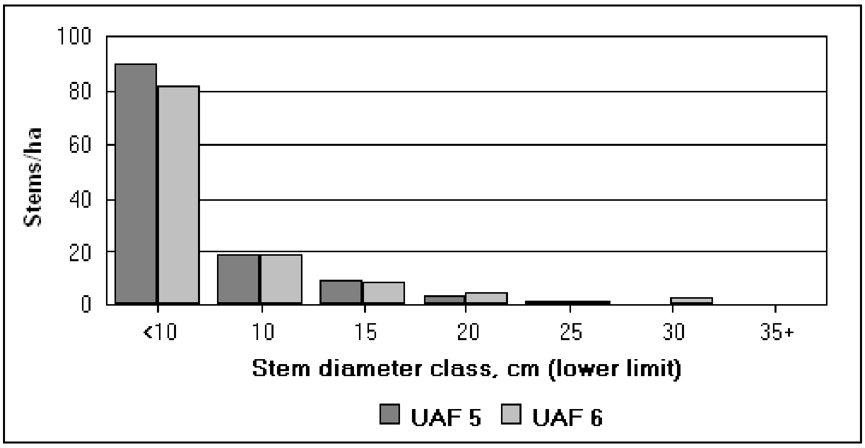

Figure 2: Stem density by stem diameter classes in the two forest management units (FMUs or UAFs)

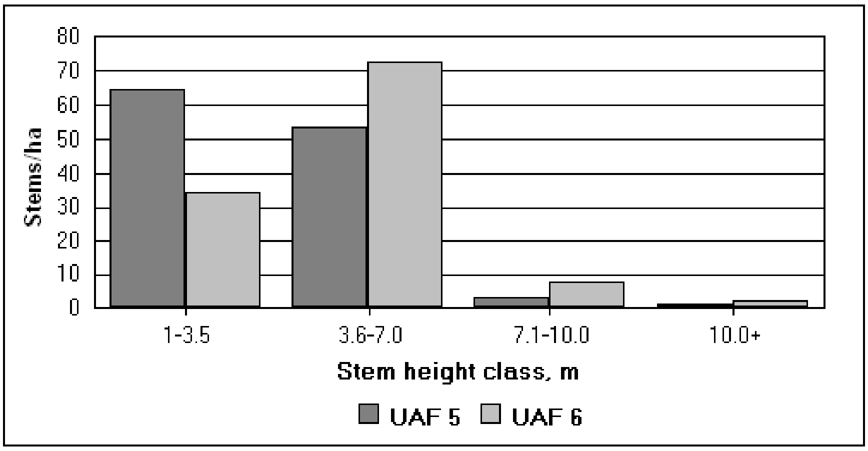

Figure 3: Stem density by stem height classes in the two forest management units (FMUs or UAFs).

Forest harvesting and vulnerability

The products exploited in the forest are fire wood, charcoal, bush meat, medicine and other non-timber forest products (NTFPs), mainly leaves, flowers, fruits, seeds and honey.

Satisfying the population needs through sustainable harvesting of forest products is part of the objectives of community forest management. It is important to note that the whole population in the study area uses fire wood as their main source of energy, and it is also sold for additional revenue. The needs for services and wood working are also associated with additional income. The various uses of NTFPs (Figure 4), as harvested from the forests by local members of the forest management associations (GGF), constitute a source of vulnerability. Firewood, the NTFPs and pastures are the important forest products and need to be incorporated into the management of the forests.

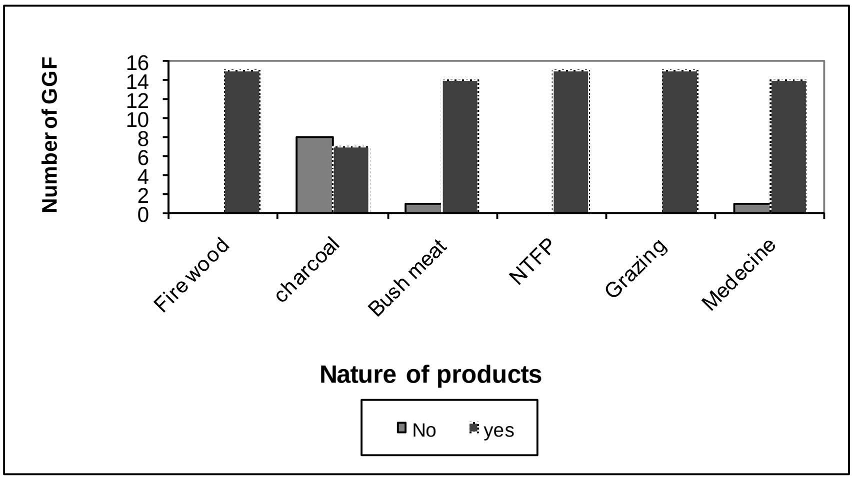

Figure 4: Forest products harvested by the local population from the forests

Other vulnerability factors influencing the ecosystems include the following: Frequent bush fires are not always controlled in spite of the practice of fire management by the local populations. Their fire impacts are visible in all the types of vegetation through destruction of plant litter and debris, fruit and seed. Population growth, the extensive agricultural practices and livestock breeding are at the base of the strong demand for products from the forests. This situation is shown by the frequent conflicts and the illegal occupation of the protected forests.

Incomes resulting from community management

Income from the community management of the protected forests primarily come from firewood, charcoal and other NTFPs. Only firewood is organised with a functional distribution chain. Harvesting firewood provides income to the communities, the State and the wholesale and retail traders in the urban areas.

Firewood production over the first harvesting cycle of the management plan shows a general increasing trend but with inter-annual variation (Figure 5). This production curve represents the firewood that is transported to Ouagadougou and excludes that part that is consumed locally. The income from the sale of firewood is shared between the Forest Management Associations (GGFs) groups (Working capital [FDR] and Returned from the Logger), the State (forest tax for allowable cut) and the forest (Funds of Forest Installation [FAF]).

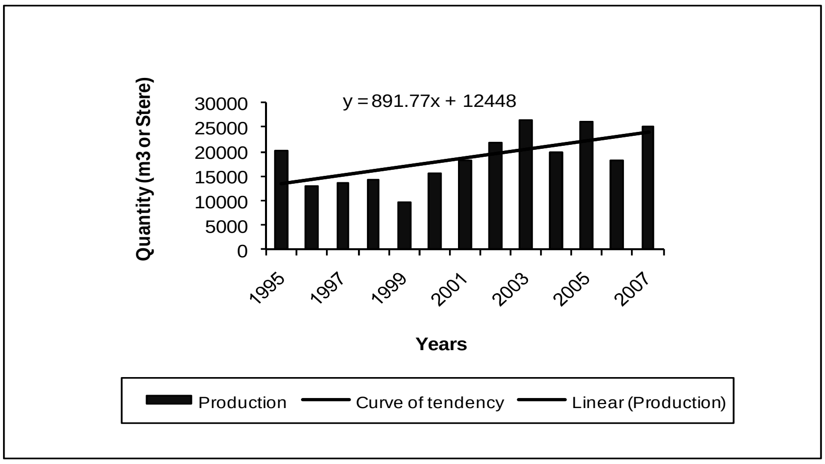

Figure 5: Quantity of firewood produced and marketed for the city of Ouagadougou during the first harvesting cycle of the management plan

In general, the evaluation of different states of the forest, before (Figure 6) and after (Figure 7) the implementation of the management plan by the GGFs, shows an improvement of the measured variables. The evaluation (excellent, good and weak) in general go from excellent to good.

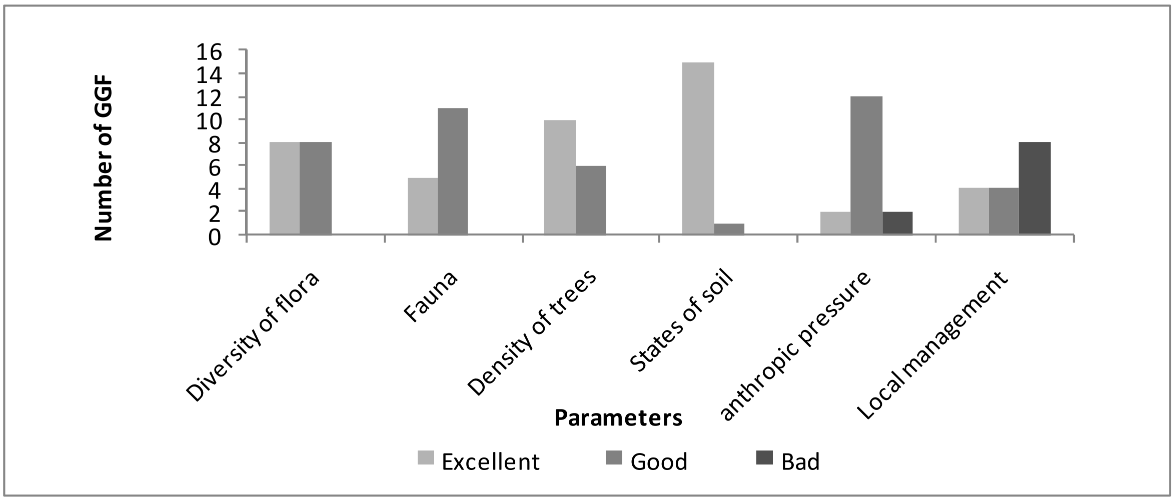

Figure 6: Evaluation of the state of the forest before implementation of forest management through the 16 GGFs

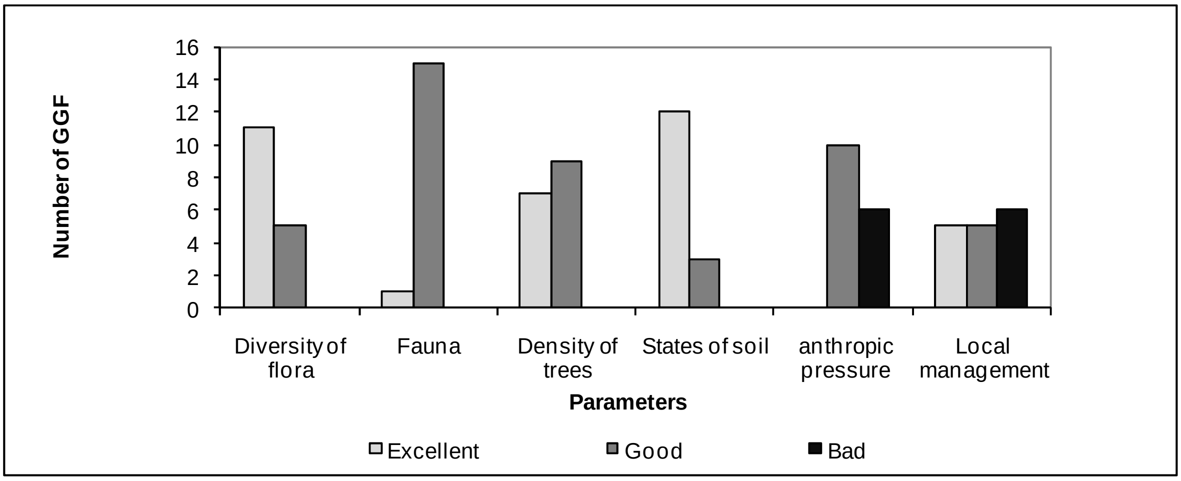

Figure 7: Evaluation of the current state of the forest after the implementation of forest management through the 16 GGFs

Discussion

State of vulnerability of the forest ecosystems

The vulnerability of the forest ecosystems is summarised with various pressures on them, either by the local populations or by climatic factors (temperature and rainfall). The human and animal pressures accentuate the impact of overexploitation of the vegetation resources on desertification (National Action Plan of Adaptation to the Climate changes [NAPA] of Burkina Faso [MECV 2007]). Bush fires, the wasteful cutting of firewood (for 84% of the population), deforestation of natural vegetation for farming, overgrazing by livestock cause a decrease in the natural vegetation resources. The level of the various pressures has increased in the forest formations of Bougnounou.

This situation constitutes a threat to the protected forests because of the land area is becoming too small and of too low quality because of overuse and of the slash-and-burn agriculture by the local populations. The described pressures increased as a result of the variations and changes in the climate as observed through the decreasing rainfall (Figure 7), a rise of the temperature and consequently an increase in the evapotranspiration. The rainfall patterns show a shortening of the wet season, a different temporal distribution of the rain, and more frequent floods and periods of drought.

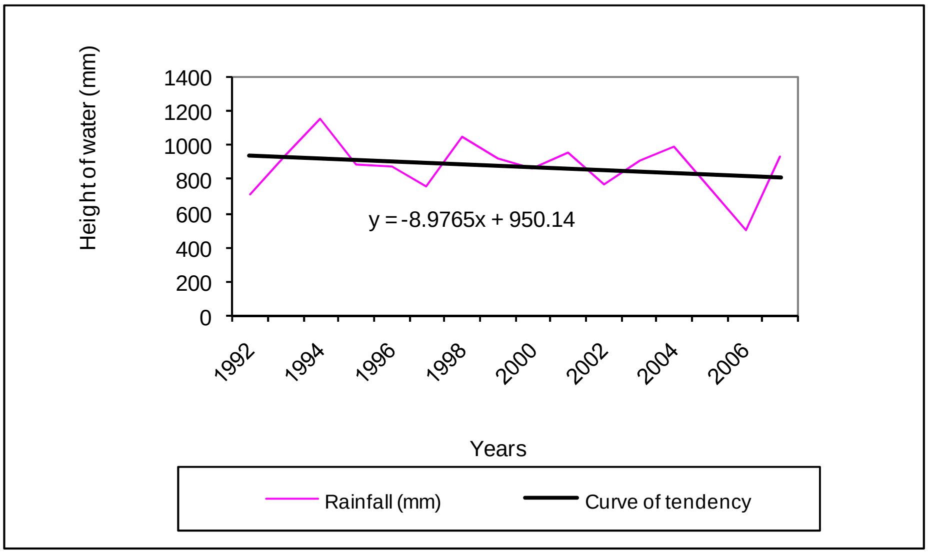

Figure 7: Annual rainfall in the Sapouy area during the period 1992 to 2007

Ecological aspects of the community management of the protected forests

In Burkina Faso, the implementation of the policy for the management of the natural forests marks the start of the setting up of participatory projects with the local population since 1985. Today the managed forests constitute the primary source of firewood for the rural and specially the urban populations.

The results of the forest inventory 15 years after implementation of controlled harvesting through the GGF community management of the forests show the current ecological condition of the forests. The horizontal structure of the vegetation, as shown by the stem diameter class distribution for the woody species, shows a high density of stems <10 cm DBH compared to those >10 cm DBH. The managed forests show a good regeneration capacity and stocking to provide a good basis for sustainable resource management. This result of good regeneration, synonymous with enrichment and a perpetuation with the forest vegetation, is demonstrated by the inverse J-shaped stem diameter curve (Kabore 1995). Similar results were obtained by Zida (1998) for the Maro classified forest (CNRST 1998). The high density of stems with a low DBH was also observed by Sawadogo (2007) for the majority of the woody species in the UAF of the CAF of Nazinon after the first 20 years of controlled harvesting.

The vertical structure of the vegetation, as shown by the stem height class distribution for the woody species, shows a similar high prevalence of stems in the class of stems <3.5 m high in UAF 5, and a prevalence of stems in the class 3.5-7 m high in UAF 6. This also demonstrates a good regeneration capacity with a better forest recovery in UAF 6.

The average density of the woody plants is 120 stems/ha stems with 10 cm or larger circumference at 1.3 m. This density was influenced by the clearings and abandoned fields.

The surveyed resource users and the GGFs noted the improvements in the vegetation and the value of reforestation through direct seeding, rational harvesting practices and protective actions. But difficulties exist in terms of the various current pressures on the forests, and especially the need to improve aspects of the current community management system. The immediate causes of the degradation of the vegetation are the farming techniques based on clearing, the bush fires, the system of livestock management which requires the stripping and severe cutting of trees, abusive destruction of trees, and climatic disturbances (Guinko 1984). These elements causing the vulnerability of the vegetation sources need to be controlled to ensure sustainable management of the protected forests of this zone. Suitable (monitoring) measurements at local, regional and national level must be developed and implemented to address the sources of vulnerability, particularly in relation to the perceived climatic changes and variability. In Burkina Faso, climatic variability is a reality and generates many risks with severe consequences (Simonsson 2005, MECV 2007). Members of the GGFs have adopted methods to address adaptation through their activities of planting and seeding with adapted species to face the effects of climate change.

Socio-economic impacts of community management of the protected forests

The implementation of community management of natural forests in Burkina Faso is generally positively appreciated especially due to the remarkable impacts at the socio-economic level. The people experience direct benefits individually and collectively which justify their appreciation.

The production of firewood and charcoal provide substantial income to the population that enable them to obtain agricultural equipment and to improve their living conditions (DREDCO 2003). The production of the firewood marketed by the CAF of Bougnounou gets on average FCFA41,118,169 per annum (about US$78,245 based on US$1=FCFA525.5, November 2008) of which only 9% return directly to the State as taxes. Honey and other NTFPs are similarly marketed but that small business is not organised and experience problems of capitalization. Other wood and medicinal/therapeutic species are preserved in these forests.

The reduction of the conflicts between the farmers, the livestock herders and users of NTFPs will have to be actively addressed in the management of the forest areas. The forests constitute the primary source of pasture for all seasons and are the reason for the high concentration of the cattle, as in the majority of the managed zones of the south and south-west of Burkina Faso.

Conclusion

The setting up of natural protected or classified forests, practised in Burkina Faso since 1985 provides a basis and tools for sustainable management of the forests by local populations. They create jobs and generate income which improves the livelihood of rural people, i.e. an effective means of fighting poverty in rural areas. In the managed CAF forest area of Bougnounou, after the first 15 years cycle which ended in 2007, there were assets to preserve or improve in order to allow sustainable forest management, i.e. the global objective of forest governance. The assets to be preserved include the organisation of the population in functional forest management groups, the integration of forest management into the rural activities, improvement of the vegetation condition through education, and the adoption of forest management as a way of life of the population.

All of these activities proceed in the context of climatic change and variability, and are necessary to account for through better adaptive management of the forest ecosystems. As mentioned earlier, the high temperatures, the decreasing rainfall, the uncontrolled bush fires, and the extensive agriculture are sources of negative ecological impacts on the natural forests. The adopted attitudes of the people towards adaptation to the impacts of climate change include the choice of adapted species for sowing and reforestation and the integrated management of livestock and forestry. The implemented participatory community forest management through forest management groups is one of the solutions in the fight against desertification in relation to the population growth pressures and climate change. This requires the implementation of adjustments in the harvesting and use of the ecological systems in response to the threats and impacts of climate change. Although the forest ecosystems have an autonomous system of adaptation, their importance for the society leads us to influence this adaptation (David and Robert 2003).

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CLIMATE CHANGE IMPACTS ON LOCAL COMMUNITIES IN THE CONGO BASIN FORESTS: PERCEPTIONS AND ADAPTATION STRATEGIES

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Abstract

The drying up of some watercourses, the shift in forest cover, the reduction in wildlife populations and soil fertility are all manifestations of ecosystem vulnerability caused by climate change in the Congo Basin. This coupled with the projected increase of annual rate of deforestation in the Congo Basin from 0.5% to 1% and a shift in forest cover from 46% to 27% will slow down the availability of goods and services derived from the forest ecosystem. This may further reinforce the already existing conflicts among various stakeholders who rely or depend on forest resources for their livelihoods. This paper examines the local community perception of the reduction of forest resources with climate change in addition to other human pressures and their coping strategies. It shows that climate change is an added stress to already existing cultural damage, break out of conflicts over forest resources, food insecurity and health, and impoverishment of local communities. The paper further demonstrates that coping strategies vary according to how different communities perceive climate change. It further highlights the urgent need to take into account local communities' perception of climate change and their coping strategies in any development plan and climate change adaptation policy in the Congo Basin forests.

Introduction

The scientific explanations advanced by intellectuals on climate change integrate less of cultural considerations of local communities. The requirements of modern life which contrast with cultural values worry farmers and lead them to provide other explanations to climate change and adapt to it according to their available opportunities (Barbaut 1987).

The Congo Basin geographically includes the Central African Republic (CAR), Democratic Republic of Congo (DRC), Republic of Congo (RC), southern Cameroon, Gabon, Equatorial Guinea, Rwanda and Burundi (Figure 1). This is the second largest tropical moist forest area in the world after the Amazon Basin in terms of its importance to the climate balance of the earth. The Congo Basin constitutes a vital space where about 20 million people benefit from it for their livelihoods (Yalibanda 1999). These people rely entirely or to some extend on the forests for their livelihoods (Table 1). Increasing population growth and high demand for forest resources coupled with the effects of climate change put the livelihood of local communities at risk (Bastin 1996).

This study was initiated within the framework of highlighting socio-cultural data of the Congo Basin forest communities which are likely to change vis-à-vis their fragile environment (Kalck 1992). These data will be used in the formulation and the implementation of adaptation strategies to climate change which will probably become extensive in the future. The goal of this paper is to analyse the real and potential effects of climate change on local communities in the Congo Basin. It examines perceptions and adaptation strategies of these communities with regard to the reduction of forest resources that are caused or can be caused by climate changes. Their adaptation strategies pertaining to these modifications can vary according to the perception they have of climate change. The development plans and the policies to fight against climate changes must take into account the perception and the coping strategies of forest communities of the Congo Basin (Notre Monde 1978).

Table 1: Basic facts on the Congo Basin forests

Item	**Number**
Plant species	20,000
Reptile species	400
Amphibian species	336
Bird species	1300
Mammal species	100
Human population	100 million inhabitants
Swampy forests	20 million ha
Humid forests	204 million ha
Timber annual allowable harvest	12 million m^3/year
Countries	DR Congo, Congo, Cameroon, Gabon, CAR, Equatorial Guinea, Rwanda and Burundi.

Source: Doumenge *et al.* 2003

Figure1: The location of the Congo Basin within central Africa.

Perception of climate change by local communities:

The perception of climate change by local communities in the Congo Basin forests is important in scientific debates. “Biological diversity” was at the centre of the discussion of the “Earth summit” of Rio de Janeiro in 1992. In 2002, in Johannesburg, the attention of scientists was drawn on “cultural diversity” with regard to the issues related the management of the environment. It is therefore very important to review the culture of people, especially Congo Basin forest communities when we reflect on climate change. Forest communities have their own explanations to the problems which relate to them even if they are not harmonized with what science accepts (Leclerc 1999). They all know that the time, the climate and the resources of their environment have been subject to many changes. Their perception is harmonized with their socio-cultural habit. For some, it is a divine curse, for others, it is the abandonment of the culture of the ancestors following modernism which is the origin of climate change (Caldecott 1988).

Climate change: A curse by the gods

In local communities in CAR for example, climate change is considered a curse from the gods. In most communities all natural resources such as water and the forest are cosmogenic and religious. The spirits of the waters and the forest are intermediaries between the gods and the people (Ngana 2004). For water needs, the habitat is generally set up near a water source and a sacred forest. They believe that it is the god of water who provides water to the population and ensures that it is potable and permanent.

Each clan ensures the “sacredness” of these spaces included in its sphere of influence by erecting altars. The habitat, the space for gathering and hunting has a spring arranged and made sacred so that this god can continuously provide drinking water and goods from the forests. On these altars sacrifices made using eggs, pastoral goods, pieces of meat and a white chicken. Children can only go to these springs if they are accompanied by adults. The aquatic animals of the spring are hardly fished. Throughout the track that leads to it, sacrifices are made on altars, announcing to users that they are in a sacred area. The god of water, the forest and the spirits (mamiwatas) never leave any person unpunished who soils this place of worship. The belief in these spirits is very widespread according to the notion people have of their environment (Roulon-Doko 1996).

Distance from the spirit of the ancestors following the abandonment of customs

Burial rites around resources are not practiced any more as in the past to preserve the spirit of the ancestors in the Congo Basin. Today the villages have a modern and common cemetery. However, in the past, the deaths were buried behind houses and the chiefs in front to make it possible for passers-by to venerate them. These are the practices which maintained the spirit of the ancestors (Vergiat 1981a). Forest resources were not subject to any problems since the Dead were helping the Living by providing food and water all year round. The problems of villages were solved according to mythical processes. Water and plants garnered early in the morning and late at night were used to prepare sacrifices for the ancestors and drugs for the sick.

Pourtier (2001) had pointed out that “the statute of the ground and these resources rather belongs to the spiritual sphere than the juridico-economic sphere”. These resources therefore deserve respect, such as the assignment of sacred forests, places of worship or initiatory forest. A precondition ritual was obligatory before the harvesting of the resources, whether it was for hunting, fishing and collecting caterpillars. The ritual makes it possible to request the mercy and the blessing of the divinity. For local communities in the Congo Basin, climate change and its consequences are perceived as consequential of the deconsecration of the forest, the manifestation of the anger of the gods on local communities because of their transgression of mythico-religious norms and the purification rituals seem to be the provisions to attenuate this anger (Vergiat 1981b).

The perception of atmospheric manifestations

Atmospheric manifestations such as lightning, wind, rain receive a geo-cultural explanation. Traditional meteorology is used to figure out the daily weather in order not to be surprised in the course of the day. These facts known in the Congo Basin are evidence of the existence of a local knowledge in climatology. Lightning is a supernatural phenomenon that some people use to kill and to be avenged. In the Congo Basin, communities possess knowledge at the meteorological level thanks to certain climate facts and manifestations. The base of this knowledge is the daily real life weather observable in the clouds, the songs of certain birds and the position of certain plants and their fruits. In the socio-cultural habits of some communities, there are practices that can prevent or cause precipitation. It is from the rain that rural activities are organized and that the calendar for the harvesting of Non-Timber Forest Products (NTFPs) are also worked out or established. By regarding climate changes as a divine curse, any effort of adaptation is likely to be a waste of time and effort. However, the populations do not remain indifferent vis-à-vis this situation (CARPE 2001).

Impacts of the vulnerability of forest ecosystems on local communities

The forest ecosystems of the Congo Basin underwent a real modification in recent years. More than 50% of the forest is located outside of protected areas including 80% in Cameroon, with many under logging concessions. In addition, nearly 14% of the forests were converted into arable lands (Pnue and Omm 1990a). The protected surfaces cover only 6% of the forest (Wilkie 2001). The clearing of the forest over the next 50 years will cause the reduction of 41% of the current forest cover because of slash-and-burn agriculture, logging, the opening of roads, urbanization and the increase in the population (Kiken 2007).

There is therefore a great vulnerability of forest ecosystems and there will be consequences for the livelihood of local communities of the Congo Basin. The loss of forest cover causes a reduction in the fertility of soils and a big decline in agricultural production. The harvesting of NTFPs is facing unprecedented problems and the resulting food insecurity is a recent challenge in the forest community. Climate change, population growth and poverty are at the base of the overexploitation of forest products such as consumable plants (Nguimalet 2008). The degradation and deforestation of forest ecosystems constitute a loss for the pharmacopoeia, one of the virtues of the Congo Basin. Local communities become therefore vulnerable to new outbreaks of some little known diseases. Since the Congo Basin forests represent an embodiment of a whole civilization (past and present), its reduction is inevitably accompanied by a cultural vacuum that the current world cannot fill. The impoverishment of local communities is a subject of concern with regard to climate change (Martin and Pernet 1987).

Conflicts in the use of forest resources

Climate change causes an increasing scarcity of forest resources. This scarcity creates conflicts in the use of natural resources between actors in the Congo Basin. Conflicts between farmers and livestock grazers have become typical today. The world now witnesses new forms of conflicts. The case of the conflict between the peulhs' stockbreeders and the Pygmies in Béa-Panzi in the 1990s in the region of Sangha-Mbaéré in the south of the CAR is one of the many examples that exist on the subject. Also, there is an increasing shift of isohyets towards the south by several hundred km (Pourtier 2001). This shift of isohyets results in the reduction of rainy periods in the Sudano-Sahelian region (Vennetier 1984). With regard to the rainfall deficit in this area, pastoral resources (water and grazing) become progressively rare (Falconer 1990).

To adapt to this situation, livestock grazers tend to move more and more into forest areas already occupied by some communities such as the Pygmies and logging companies. In the east of the CAR, livestock grazers have problems in their descent into the forest of Bangassou. Foresters estimate that the presence of cattle in this forest presents perverse effects for the fauna and tourism. The forest that is transformed into savanna and through clearings attracts livestock owners. This situation was the reason for the organization of a round table talk in May 2008 in Bangui by the International Foundation for the Management of Fauna (IFMF) and the National Federation of Central African Stockbreeders (NFCAS)).

The scarcity of resources generates conflicts between humans and wildlife. When the forest is no more able to feed them, wild animals revert to finding food in farmed areas. Monkeys are the biggest destroyers of corn and groundnut fields. The wild pigs attack cassava farms for their tubers. Birds cause the destruction of some grains such as rice, millet, sorghum, corn and sprouts. This competition is strong when some wild animals directly attack humans (boa, elephant) according to a local study in CAR and a study in progress. The existence and the safety of families living in the forests are threatened and that can lead to a negative response by humans and a massacre of elephant, buffalo, wild boars which are regarded as harmful for crops.

The recent introduction of pastoral activities in forest areas because of the insufficiency of resources in savanna areas caused by climate change is a source of tension between the local communities and the aliens. The report of the Congolese observatory of human rights indicated a negative assessment of the legal consequences of climate change on marginalized local communities.

Risks of food insecurity and health

The advantages of the Congo Basin forests are not solely limited to the climate balance of the earth. This forest is a source of food for local communities (Tisserand 1961). It is a natural resource pool and provides medicinal plants for the populations living in the area. Climate change causes the barrenness of soils. Soils are appropriate to a given climate and vegetation (Ndjendole 2001). When a modification occurs on the vegetation for example, the balance of the unit is modified (Boulvert 1986).

The forest is a source of drugs for the people living in the area (Piri-Dejean 1997, Tchatat 1999). Deforestation in the Congo Basin and the floods which result from it favor the proliferation of mosquitoes and the emergence of epidemiologic diseases. Local communities are confronted with health problems (Ogden 1990). The fragile forest ecosystems affect the availability of medicinal plants that people rely on for treatment when they are ill. The forest does not adequately meet this need anymore; they are therefore obliged to move towards modern healthcare centers to be taken care of by aid organizations. During dry and rainy seasons, local communities are confronted by drinking water problems. These problems are truly crucial, for it is difficult to find drinking water in some places (Bouvarel 1983). The scarcity of drinking water is due to the reduction of ground water. Frequent floods during rainy seasons also lead to the scarcity of drinking water. These floods can slow down or stop human movements from 3 to 4 months depending on the area. The proliferation of tsetse flies in CAR is the cause of the sleeping sickness which prevails in some resistant pockets in the Congo Basin. The tendency of the shift in humidity contributes to the new outbreak of some infectious diseases such as meningitis and tuberculosis (CARPE 2001).

Impoverishment of local communities

Many inhabitants in the Congo Basin are not able to satisfy their basic needs. The interaction between local communities, the environment, the development and the consumption of natural resources then becomes an issue of survival. There are close connections between the concepts of basic needs and the environment. In the Congo Basin, many people are poor and the environmental degradation which is often due the absence of adequate ways of development (FAO 1992) hinders many efforts of development. Local communities are therefore constrained to destroy forest resources because they are poor and do not have other means to feed, to lodge and to meet their needs in energy. "The degradation of the natural environment" is part of the serious problems of development for which it would be necessary to find solutions (Koko and Runge 2004).

Disturbance of the water cycle is not only of chemical consequence. The deforestation and the erosion of soils amplify the frequency and the amplitude of floods. Climate modifications introduced by the changes in the composition of the atmosphere induce not only deforestation and tornadoes, but also a slow rise in the level of rivers. With regard to this natural disaster, awareness must be raised and strategies implemented to fight global warming and the emission of carbon dioxide. Thus, the necessity to preserve the environment by concrete actions must remain at the forefront of any national development plan. Rural communities are unaware of the dangers related to development, particularly the consumption without control and reserve of natural resources by causing serious environmental imbalances, the disappearance of a number of animal and plant species (FAO 2007).

Cultural damages of climate change

By changing their habitat, forest populations change culture. The Pygmies in the Congo Basin forests are an example of a strong interbreeding when they move towards large villages. The deforestation witnessed today is due to the collective loss of cultural identity to the benefit of modernization (Ngana 2004). Since the safeguarding of the forest is accompanied by the safeguarding of the culture of marginalized populations, the absence of one will impede the existence of the other. The risks of the disappearance of a culture and the destruction of the forest are inevitable. "From one point to another, one period to another, social attitudes, ways of speaking and codes changes. Cultural realities do not represent any more the same face" (Claval 1995). "An ethnic group which disappears is a culture that goes away" (UNESCO 2002). The disappearance of a culture is the loss of a community's identity. The protection of biological diversity is therefore a vital strategy of safeguarding the culture. However, due to climate change, the forest protecting the Pygmies is shifting every year (Bahuchet 1978).

"All the authors agree on these premises that is, the possibility of comparing the communities which we would call today primitive with Western civilization" (Lévi-Strauss 1996, p365). The reduction in the vegetation cover in the face of urbanization, slash-and-burn agriculture, logging and mining and climate change undermine the culture of those who live there (Pnud 2007).

The situation experienced by local communities in the Congo Basin forests is similar to that of the Indians with the destruction of the forest in the State of California in the USA. It was also the case for the Iks people in the north-east of Uganda who were driven out of their ancestral hunting territory for the creation of the national park. These communities were obliged to confine themselves in the infertile mountains which separate Uganda from Sudan and Kenya. But incapable to maintain their farming culture, these formerly happy and prosperous hunters divided themselves into some small communities in less than three generations. The Iks children were fighting for food off their parents' mouth who in turn drove them out of the family nest for the lack of food. They became indifferent to old people, sick people and the disabled die (Turnbull 1987). That is why the Congo Basin forests in Africa are today considered as one of the most vulnerable areas to the effects of climate change.

Adaptation strategies to climate change

Adaptation strategies of local communities to climate change are closely related to the perception they have of this phenomenon. Their capacity to adapt is limited and needs to be reinforced. At the agricultural level, in the energy field and issues of health, they are able to adapt to difficult moments experienced in their region (Pnue and Omm 1990b). Deforestation in the Congo Basin goes hand in hand with the cultural vulnerability specific to local communities. The Pygmies for example have the culture of gathering and collecting foodstuffs. The forest is their resource pool. With deforestation, gathering activities are reduced. They must adapt to the culture of production, i.e. to practice agriculture and animal husbandry. The reinforcement of their capacity goes through the semi-intensive system such as the arboriculture which has mitigation effects on the reduction of the forest cover and the mobility of populations. The practice of agricultural activities by the new actors like the Pygmies and Peulhs has mixed results: increase in the agricultural production which makes it possible to ensure food safety, but accelerating the destruction of the forest because of agriculture.

Adaptation strategies with regard to food insecurity

Farmers have improved on their productivity, proceed to innovating and ingenious techniques without the participation of agricultural agents. At the level of cassava production, instead of directly inserting the cutting in the ground, farmers took the initiative to make a hillock before planting. For them, this method will have the capacity to retain water around the stems of the cassava and to accelerate its growth (Geny *et al.* 1992). This strategy had positive effects, because it made it possible for the plant to develop well by producing beautiful leaves and tubers of reasonable size and volume (between 0.5 and 1 m).

Everywhere in Africa and in the rest of the world, farmers adapt to the hostility or to natural constraints that limit the implementation of their development activities. The adaptation to climate change is not a fact particular to local communities of the Congo Basin forests. In the tablelands of Bandiagara in Mali for example, the Dogon people took refuge in the 6th century, in a hostile natural environment. Their sphere was characterized by sandy soils, lateritic, a dry climate and without water. In spite of that, they succeeded in developing agriculture, by bringing soils from the outside, by storing an important quantity of manure for agriculture, by retaining water in small dams and by practicing intensive horticulture. This strategy enabled the Dogon people to be more productive than the farmers of the Niger Delta (Brunel 2004).

The diversification of crop types seems to be the strategy to minimize risks. In order to be sheltered from climate vulnerabilities the African farmer prefers to minimize the risk rather than to maximize outputs (Brunel 2004). His strategy is to farm several fields which allow him, whatever the unforeseen climate risks, to guarantee his food (Wickens 1991). The outputs are weak, but diversity ensures a minimum loss of resources (Brunel 2004). It is with monoculture that farmers become more vulnerable to climate disturbances and the risks incurred by an identical harvest. The diversification of crop types and small socio-economic activities such as the sale of honey wax and alcoholic drink by women, ensure the food security in the Congo Basin forests. The breeding of small ruminants (goats, poultry) is expanding vis-à-vis the scarcity of bush meat (Bois 1967).

Adaptation strategies in response to the depletion of energy sources

The increasing scarcity of wood fuels obliges local communities to seek alternative sources of energy. The roots and the stems of the grass of Laos represent alternatives following the crisis of wood fuels in the Congo Basin. This plant is starting to colonize old forest spaces. In addition, other fuels substitutes are: fibers from palm nuts, residues of harvests, shelled ears of corn, the bark of coconut and some tree species (Wilkie 2001). The responsibility for the collection of these substitutes falls on women. With regard to the shortage of the wood fuels, it is the woman who invents and suffers at the same time from the consequences resulting from the use of these substitute sources of energy. They have always proven to be resourceful; an example is the tested fuels of substitution in response to the shortage of wood fuels. In large villages, the shortage of wood fuels is very striking. To save energy and to avoid the wastage of wood, the adopted strategy consists in using improved hearths manufactured from recovered metal materials (Raponda-Walker and Sillans 1961). For example, in some West Africa countries, cow dung is used as sources of energy with all the health consequences affecting households.

Reinforcement of the adaptation capacity of local communities

The vulnerability of forest resources is accompanied by some development actions to the benefit of populations affected by the effects of climate change. Governments in all the countries of the sub region made provisions to provide the population with drinking water through the opening of bore holes. Bore holes along to the fields provide for drinking water in large villages. Religious organizations have strongly contributed to the popularization of bore holes in most of the villages. Moreover, modern equipment provided for springs secured water for the villagers. But the transport of water remains an issue for women. They are obliged to care water from bore holes to water for their cassava and wild tubers (Barthe and Hancock 2005).

For any development program to succeed, it is inevitable to consider the perceptions of the people who will benefit from the program (Figure 2). The success of the project depends on it, since the difference between old perceptions and current perceptions of atmospheric manifestations and its effects on the ecosystems is great. This is why creating awareness will make it possible for communities to adhere to what actors of development will propose to them. The opening of bore holes is a success story in spite of the strength of some customs. It is now indisputable the idea of moving towards the domestication of NTFPs. *Gnetum africanum* (Koko) can be farmed in order to avoid its final destruction under the pressure which this plant is subjected to today. The trees with caterpillars can be domesticated and farmed in the vicinity of villages and cities. The popularization of mushroom plantations is on the increase and a guaranteed source for food security (FAO 1981).

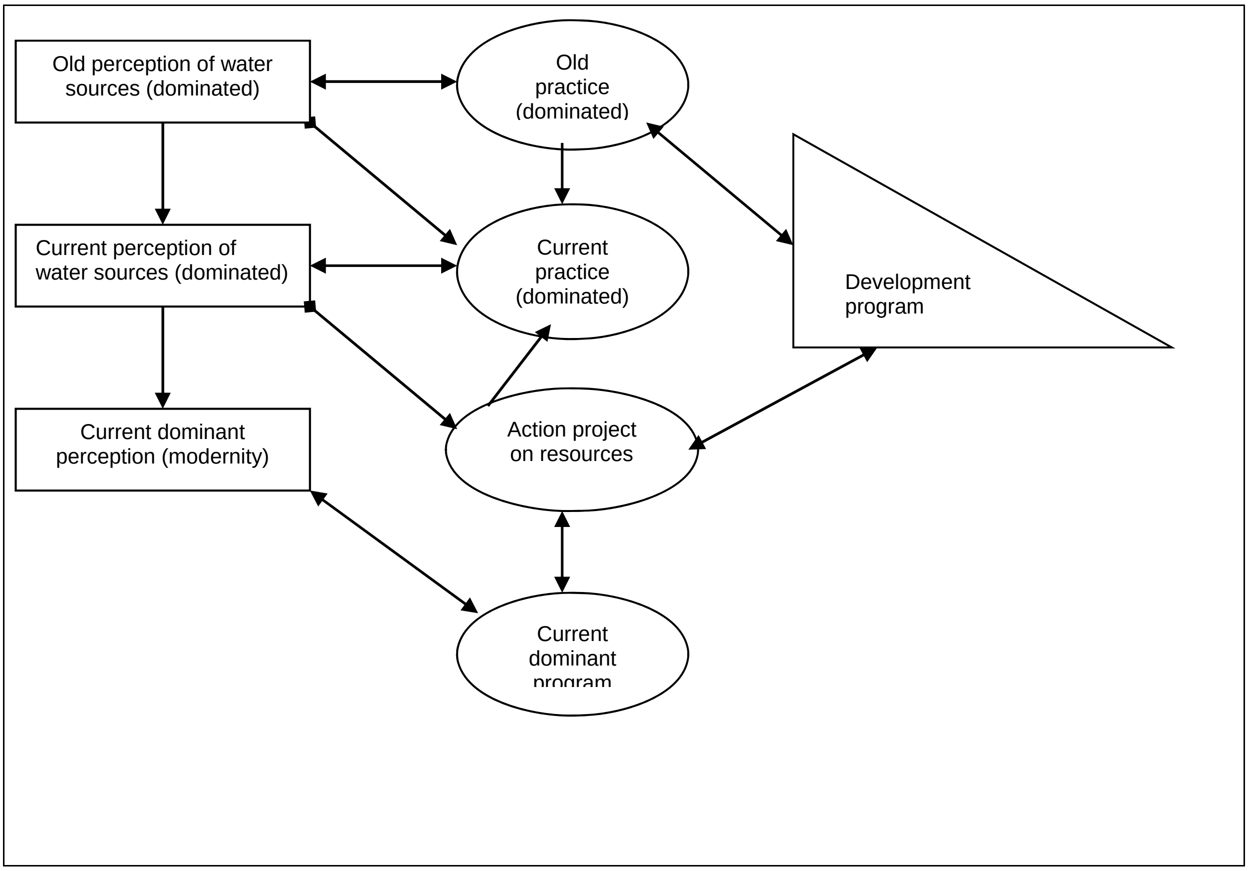

Figure 2: Relations between perception and development programs

Conclusion

Global warming is a contemporary reality which results from physical and anthropological factors. Its consequences affect local communities as well as forest ecosystems. In the context of the intensity of natural disasters, the survival of local populations is a matter of concern. Adaptation and prevention strategies are insufficient and a challenge to the international community. In the Congo Basin forests, the upheavals related to climate change upset the way of life of local communities (FAO 1978). Marginalized and minority social groups are finding it difficult to adapt and to find a balance. Constraints of a natural nature bring about adaptation strategies which are a matter of survival instinct specific to each living organism. These strategies lie within the scope of the research to satisfy food and medical needs when forest ecosystems become vulnerable. The strength of the tradition which is materialized by a religious and mythical perception of resources and climate change is at the base of incomprehension between actors fighting against climate change. The characterization of local communities will make it possible to identify those who adapt better compared to those who suffer more from the effects of climate change.

Information, education and communication (IEC) is a tool for the reinforcement of the adaptation capacity of local communities. Technical and institutional support is essential using warning messages to help the population to be awakened, to avoid being overwhelmed by natural disasters. The support of partners should allow for the structuring and organization of communities into groups or associations. They will therefore constitute a force to better adapt to the unforeseen risks impose to them by climate change. Through a decentralization policy, the State could grant financial support to local communities (Gaza 1994). These communities must be able to set up reliable development projects in their neighbourhood and to have access to these funds. They can be projects on the domestication of edible plants and the modernization of garnering activities such as the cultivation of mushrooms. In connection with taking into account socio-cultural realities, Diallo (1998) stressed that local knowledge has an importance as regards development, and that local communities have varied knowledge which would be necessary to integrate into adaptation strategies to climate change.

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FORESTRY, CLIMATE CHANGE ADAPTATION AND NATIONAL DEVELOPMENT IN CAMEROON

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Abstract

Climate change effects on tropical forest ecosystems are predicted to include variations in the availability of timber and non-timber forest products and reduction in water and water resources. Such effects could amplify the existing pressure on food security urging expansion of current agricultural lands at the expense of forest, biodiversity loss and socioeconomic stresses. However, forestry activities play crucial roles in reducing the vulnerability of both natural and social systems and therefore provide the opportunities for formulating adaptation strategies. In Cameroon as in many other tropical countries, forest ecosystem services provide security portfolios for over 80% of the predominantly rural communities, and are thus, highly crucial for poverty reduction and national development. The Global Forest Outlook of 2007 indicated that Cameroon and the Democratic Republic of Congo are among the leading countries in deforestation globally. Furthermore, forest receives very little attention in national planning and policies in either of these countries. This paper emphasizes that in Cameroon, climate change is an added stress to already threatened habitats, ecosystems and species, and is likely to trigger species migration and habitat reduction. In addition to a number of climate sensitive diseases such as malaria, tuberculosis and diarrhoea, the paper also points out that future climate variability in Cameroon will also interact with other stresses and vulnerabilities such as HIV/AIDS and other deadly diseases. The review highlights the point that climate change impacts and adaptation strategies in Cameroon cannot be isolated from current environmental problems and other socioeconomic challenges. Thus, adaptation would need to be integrated into national development programmes. The implementation of adaptation strategies should follow sector-based responses with a review of the existing environmental legislations and their implications on strategies for poverty reduction strategy and adaptation to climate change.

Introduction

The vulnerability of developing countries, particularly those of Sub Saharan Africa, coupled with their inability to cope with present and projected climate change scenarios have been stressed in several global assessment reports (e.g. MEA 2005, Stern 2006, IPCC 2007a). Some of the implications include the inability to eradicate extreme poverty and hunger, ensuring environmental sustainability and also promoting gender equality and empowering women. The nature of the exposure of these countries to climate change and their limited adaptive capacity determines the severity of climate impacts where poverty, food security and human adaptive capacity to climate change are intricately linked with developmental challenges (Nkem *et al.* 2007). As a conservative estimate, over half of the world's population continues to live on less than US$2 dollars a day, with a billion on US$1 or less (WRI 2005). This in fact has the potential of affecting outcomes where planning is not appropriately integrated. Large numbers of rural poor people depend on forest resources for their livelihoods. According to many global reports (e.g. WCFSD 1999, World Bank 2001, 2004, WRI 2005), 350 million people are estimated to "depend almost entirely for their subsistence and survival needs on forests" and that over 1.6 billion living in extreme poverty continues to depend to varying degrees on forests for their livelihoods. As an ecosystem providing livelihood opportunities for such a large number of people worldwide living in extreme poverty, forests are therefore an indispensable asset in designing poverty reduction strategies and contributing to the realization of some of the other global targets in developing countries. This is particularly true for tropical forests ecosystems which harbour about 410 million people (including 60 million indigenous people) living in, or at the fringes of, these forest ecosystems and who depend on forests resources for their subsistence (Wiersum *et al.* 2005). In this framework, community-based planning around shared natural resources is one way that provides an integrated approach to addressing the different aspects of the development challenge (Huq 2007).

Considering the vulnerability of forests to climate change and given their vital role in the household livelihood and food security in tropical developing countries especially in Sub Saharan Africa, climate change and climate variability measures have to be taken seriously and for adaptation strategies need to be integrated into project development planning both in the private and public sectors (Nkem *et al.* 2007). In addition, adaptation strategies defined by the UNFCC to address climate change in tropical forestry acknowledges the use of forestry activities to reduce vulnerability and variability of both natural and social systems.

Like most countries of the Congo basin, Cameroon's forest ecosystem services provide security portfolios for over 80% of the forest dwellers contributing to poverty alleviation and national development. However, the FAO Global Forest Outlook of 2007 (FAO 2007) highlights increasing deforestation in the region in spite of overall global reduction, with Cameroon and the Democratic Republic of Congo, leading in deforestation. Incidentally, the importance of forests is overlooked in national development processes such as policy dialogues on climate change and poverty reduction strategies. Therefore, the challenge is to increase both public and policy awareness of the role of forests, and to develop livelihood adaptation strategies on a framework of forest goods and services. This in fact should not jeopardize in any case the integrity of such forests to future climate impacts, in order to ensure the continuity in the provisioning of forest ecosystem goods and services that contribute to food security and poverty alleviation.

This aim of this paper was to contribute to the understanding of the role of forests in reducing poverty and in adaptation to climate change using the case of Cameroon forest sector. This was done by reviewing major forest documents and policy of Cameroon, and through interviews with forestry officials.

Cameroon forest sector

State of the resource

Cameroon is a country blessed with abundant natural resources, especially with its dense rainforests in the south that covers more than 40% of the national territory (Letouzey 1985). Cameroon's total forest area is 23 million ha representing 51.9% of the total area (Oyono 2004). It is the third largest in Africa after that of Democratic Republic of the Congo and Gabon. Relative to area, Cameroon's forests are among the top five species-rich in Africa and are home to five globally important centres of plant and bird diversity (GFW 2003). Timber production is about 3 million m^3 per year. Since 1980, timber production has increased by 35% (GFW 2003). As the country's oil reserves dry up, timber exports are projected to constitute an increasing share of foreign exchange revenue in coming years. With only 80,000 ha, forest plantations play a marginal role on the forestry sector.

Cameroon's network of protected areas covers presently 15.2% (7.2 million ha) of national territory. In the 1994 forestry law, Cameroon has committed itself to putting 30% of its land area under protection. With this proportion, Cameroon will stand as a country with the highest proportions of protected areas in the world. However, agricultural encroachment, poaching and illegal logging threaten all these areas.

As Cameroon forms part of the Congo Basin, which plays a global role in carbon sequestration and climate regulation, slowing down deforestation (~1%) is extremely important. In this light, Cameroon established in its Initial National Communication to the UNFCCC a detailed program for reinforcing national capacity, transfer of appropriate technology and putting in place mechanisms for compensation and substitution. However, currently this still remains theoretical.

Contribution of Cameroon forests to poverty reduction

The contribution towards poverty reduction, expected from forests, falls in line with avenues 2 (diversification of the economy to reinforce growth) and 3 (strengthening the private sector as the locomotive of economic growth) of the poverty reduction strategy paper of Cameroon which ended in mid-2008. In fact, it entails finding ways and means of improving the living standards of rural populations by taking into account the contribution of forest resources and the services that the forest offers. In this context, Cameroon's forests play an important economic role at the local and national level. The opening line of the 1995 Forest Policy document of Cameroon notes that "the forests of Cameroon represent one of the country's greatest riches." Cameroon's forest sector is the third largest source of foreign exchange for the State, after agricultural exports and oil, and accounts for more than 10% of GDP and 28.2 % of non-petroleum exports. It provides between 45,000 and 70,000 jobs (FAO 2003a, Amariei 2005).

Overall, national stock of commercial timber is estimated at 310 million m^3 representing a standing value of about 25,000 billion CFA francs (approximately US$70 billion) (Essama-Nssah and Gockowski 2000). The average productivity of the typical Cameroon production forest is about 260 m^3/ha of standing timber, of which 32 m^3 are composed of the 75 or so commercially exploited species with 21 m^3 exceeding the minimum exploitable diameter (CIRAD-Forêt 1997, cited in Amariei 2005). According to the national zoning plan, 6,025,000 ha are planned as production forests and it is estimated that an average of 415,000 ha of concessions were legally opened for logging from 1994 to 1996 (Coté 1993, MINEF 1996, Eba'a Atyi 1998).

Cameroon ranks among the world's top five tropical log exporter producing and exporting countries with a roundwood production of about 3 million m^3, and roundwood exports of 575,000 m^3 in 2000. Other wood-based export articles are sawnwood, with an export production of 540,000 m^3 in 2000, while the export production of wood-based panels reached 75,000 m^3 in the same year (FAO 2003a, Amariei 2005). Wood harvested for fuel is four times more than industrial roundwood (GFW 2003). Traditional fuels, including firewood and charcoal, account for roughly 80% of all energy consumption (FAO 2003b). At this rate, fuel wood supplies will become increasingly less sustainable as global warming intensifies, further jeopardizing the well-being of many already poor communities. To overcome the situation therefore, the Government and the communities should apply adaptation strategies that focus on developing small fuel wood plantations and improving charcoal production practices.

Government fiscal revenues collected from the forest sector constitute a means of converting Cameroon's forest patrimony into development for the common good. The economic importance attached to the sector by the Government of Cameroon is indicated by a Policy Framework Paper, which states: "The government expects this sector to contribute to growth and macroeconomic balance. In 2000/2001, Government revenue from direct taxes levied from the forestry sector summed up to 33 million US$" (World Bank/WWF Alliance 2002). Total penalties collected between 2001 and 2004 amount to about CFA 916,000,000 (~US$ 2,036,000). In addition there are billions in outstanding penalties not yet collected (Essama-Nssah and Gockowski 2000, ODI 2002, Amariei 2005). However, maintaining these revenue streams requires sustainable management practices, which encounter a host of difficult technical issues, the most important one being the illegality in the forest sector. According to the World Bank/WWF Alliance (2002), it is estimated that the Cameroon Government is losing between 5 and 10 million US$/year in revenue from the felling tax alone due to illegal activities (World Bank 2003).

State of poverty and poverty reduction strategy

While it had one of the strongest economies of Sub-Saharan Africa in the early 1980's, Cameroon is today considered to be off track for meeting most of the Millennium Development Goals such as poverty reduction despite the mass of wealth accruing from the forest. Poverty occurring primarily in rural areas remains widespread, with 40.2% of the population living under the poverty threshold of US$1/day (The MDG Progress Report 2003). Women and children are particularly hard-hit: 52% of the people in poor households are women and half of the members of poor households are under 15 years of age. In order to combat poverty, in 2003, Cameroon adopted a comprehensive poverty reduction strategy in conjunction with the World Bank. The Government of Cameroon's (GoC) Poverty Reduction Strategy Paper (PRSP 2003) recognizes that "poverty is at the centre of environmental problems in Cameroon; the root cause and consequence of environmental degradation" and suggests that improving management capacity in the environmental sector will be needed in order to achieve more sustainable management of natural resources. In order to improve its contribution to rural development and economic growth, the government committed itself in its Forest-Environment Sector Programme (FESP) to a series of environment and fiscal policy and legislative reforms, particularly in the forestry sector. This programme was a blue-print GoC's strategy for poverty reduction outlined in the national poverty reduction strategy and specified in the rural development strategy paper (DSDSR = Document de stratégie de développement du secteur rural). The FESP is aiming at the sustainable management of the natural resources to improve the living conditions of the people and conserve biodiversity. With this approach, it follows the logic of the plan of implementation of the World Summit on Sustainable Development (WSSD, United Nations 2002), which concludes that "sustainable forest management of both natural and planted forests and for timber and non-timber products is essential to achieve sustainable development and is a critical means to eradicate poverty".

Climate change and forests in Cameroon

Climate change projection scenarios

The first National Communication (NC) in 2001 suggests that the GHG emission in the atmosphere in Cameroon is 43 million tonnes equivalent carbon dioxide. The main gazes emitted are CO_2 (55.9%), CH_4 (25.3%) and N_2O (18.8%), with agriculture activities and land use changes accounting for the majority of emissions.

Climate change impacts in Cameroon by the year 2050 are expected to be significant with increases in the mean annual temperature by approximately 1.8°C leading to a total increase of almost 5°C, a net decrease of 559 mm rainfall and a sea level rise of 50 cm (UNEP 2000). The impacts on humans will be certain and in places drastic. Current regional impacts are indicating a drying trend with extreme water resource scarcity in the northern region and rainfall variability in the southern region (Hassan 2006, Molua and Lambi 2007). Drought is projected to increase forest fires by 10-50% (with largest increases in the northern region and savannah zones). Increased rainfall intensity in some areas in southern Cameroon would exacerbate soil erosion problems and pollution of streams.

Cropping, horticulture, livestock and forests will be vulnerable to changes in the incidence of existing pests, parasites and pathogens, and invasion by new varieties for which there are no local biological controls (Dukes and Mooney 1999, Cheal and Coman 2003). The likelihood for such pests, parasites and pathogens to spread southwards increases with climate warming.

Impacts on the forest ecosystem and on humans

The impacts of climate change are likely to affect all forest landscapes (Easterling *et al.* 2004). Indeed, the predicted change in climate variables will place severe pressure on the ability of forests to adapt to these and to survive. With rising temperatures, changes in water availability and expected double levels of carbon dioxide, it is expected that forests will change at two levels: physiology and metabolism; and ecosystem functioning. These changes will impact the availability and quality of both forest goods and services (Meer *et al.* 2001). Wildlife populations that are already stressed by over hunting and other environmental pressures may succumb to extinction with the additional pressure of droughts, floods or increased storm strikes. Increased forest degradation and deforestation will further exacerbate climate change impact on wildlife. The most vulnerable terrestrial wildlife populations have a diet of nectar, fruit or seeds; nest, roost or forage on large old trees; require a closed canopy forest; have special microclimate requirements and/or live in a habitat in which vegetation has a slow recovery rate. Small populations with these traits are at greatest risk, particularly when they exist in small isolated habitat fragments (UNEP 2000). Sea level rise will further increase pressure on the forests due to loss of coastal agricultural lands by salinization, loss of coastal forests (e.g. mangroves and low lying tropical forests) due to inundation and increasing storm events, and migration or loss of wildlife species from altered habitats (FAO 1994, UNEP 2000).

Human settlements will be affected tremendously by forest destruction, mass landslides, blown down trees and tree crops, and water and soil related problems. Those common impacts and effects on the community include: (1) decline in water supplies and in some cases water shortages due to damage caused by top water intakes; (2) flooding of rivers and valleys (this may restrict access within and into some communities); (3) transportation and deposition of debris into villages and towns leading to the blocking of drainage systems; (4) loss of livestock and crops; (5) loss of life and property; and (6) loss and damage of infrastructure leading to the food supply dislocation.

Additionally, already weakened by other deadly diseases such as HIV-AIDS, climate change will constitute an additional burden of disease in Cameroon as in many other tropical developing countries. Climate variability and change cause death and disease through natural disasters, such as heat waves, floods and droughts. In addition, many important diseases are highly sensitive to changing temperatures and precipitation. These include common vector-borne diseases such as malaria and dengue; as well as other major killers such as malnutrition and diarrhea (IPCC 2007b). However, much of this health risk can be avoidable through appropriate health programs and interventions. Concerted action to strengthen key features of health systems, and to promote healthy development choices, can enhance public health as well as reduce vulnerability to future climate change.

Sustainable forest management: mitigation and adaptation

The conservation and sustainable management of forests can enhance ecosystem resilience and therefore improve the ability of ecosystems to provide critical services in the face of increasing climatic pressures. Forests are of great importance in securing good quality and supply of water, protecting against natural disasters, and improving the livelihoods of people living in or near forests. However, these goods and services are typically not valued and traded by the market, which in many instances leads to poor decisions with unsustainable effects on forests and forestry.

Mitigation

The Intergovernmental Panel for Climate Change (IPCC 2007) estimates that about 65% of the total mitigation potential in the forest sector is located in the tropics and about 50% of this total could be achieved by reducing deforestation. In other words, because tropical forests have the greatest potential for carbon uptake and storage, the most cost-effective way of reducing carbon concentrations in the atmosphere is to reduce deforestation of tropical forests and allow for forest cover expansion. Although the action of Cameroon’s Government is still very timid in this regard, three sectors can however be identified where mitigation can play a key role: policies and programs that enhance CO_2 removal through afforestation and reforestation; initiatives that support the use of biomass for energy; and actions to reduce the greenhouse gas emissions from land use change predominantly deforestation and forest degradation.

Adaptation

Forests play key roles in supporting national economic activities and providing livelihood portfolios for many in developing countries. They are at the frontline for climate change adaptation in Africa (Easterling *et al.* 2004). However, there are substantial limits and barriers to this adaptation, including environmental, economic, informational, social, attitudinal and behavioral barriers that are not fully understood. In addition, there are significant knowledge gaps for adaptation as well as impediments to flows of knowledge and information relevant to adaptation decisions (Adger *et al.* 2007). In addition to the limited ability of natural systems to adapt, the ability of Cameroon forest ecosystems to adapt to climate change is severely limited by the overexploitation, illegal practices, effects of urbanization, barriers to migration paths, and fragmentation, all of which have already critically stressed ecosystems independent of climate change itself. Moreover, the creation of financial incentives for reducing emissions from deforestation and forest degradation under the UN Framework Convention for Climate Change still remains very theoretical. The primary obstacle at both the international and national level remains a lack of capital. Current estimates of how much capital would be required to effectively reduce deforestation rates are also unknown. At the national level, land and forest tenure issues present a challenge to the creation of such incentives since the state is the sole proprietor of all forests and forest land in Cameroon. Indigenous and local communities only have user rights.

Therefore, existing standing forests should be managed in a way to ensure they continue to provide goods and services to society into the future. In addition, it is essential to develop forest management strategies for future forests, that is, forests that will be suited to the new climate and to changed biophysical conditions. As the Non-legally Binding Instrument on All Types of Forests highlights, governance is a crucial component of successful sustainable forest management as is law enforcement. Though regulation can be a highly effective means to combat deforestation and promote the use of sustainable forest management, lack of capacity in monitoring and lack of resources for law enforcement are inhibiting factors in many developing countries, including Cameroon.

Conclusion

Forests have tremendous potential to serve as a tool in combating climate change, protecting people and livelihoods, and creating a foundation for more sustainable economic and social development. However, climate change is expected to exacerbate serious environmental, economic and social pressures. Therefore, adaptation would need to be integrated into national development programmes. The implementation of adaptation strategies should follow sector-based responses with a review of the existing environmental legislation and their implications on strategies for poverty reduction and adaptation to climate change.

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