China's Agriculture Drone Revolution

Disruption in the Agriculture Ecosystem

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Acknowledgments

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Center of Excellence for Commercial Drone Adoption
Ipsos Business Consulting, 2019

Introduction

The adoption of drones in China's agricultural sector for crop protection, spraying, monitoring, and risk mitigation is growing at a rapid pace. The number of agriculture drones is estimated to have doubled between 2016 and 2017, reaching 13,000 aircrafts. As of 2018, drones for agriculture is estimated to make up between 12% and 17% of the commercial drone market in China. As the world leading manufacturer of civilian drones, drone technology is readily available in China, and current adoption levels only document the early stages of exponential growth in this market.

China's Agriculture Drone Revolution: ***Disruption in the Agriculture Ecosystem*** by Ipsos Business Consulting published with our partner DJI Agriculture prospects capabilities and applications of agriculture drone technology; the costs and subsidy program for aircrafts, new business services (renting and leasing) of agriculture drones, and the constraints to the eruptive adoption of this technology in China.

It follows our publication ***"Commercial Drone Adoption in Agribusiness – Disruption and Opportunities"***, released in September 2017 by Ipsos Business Consulting. Whereas our earlier work examined the value propositions, manufacturing landscape, levels of adoption and adoption models of drone technologies by leading adopters and countries in Asia, our second publication in this series explores one of the most dynamic and intriguing markets for the development and adoption of commercial drones, with a focus on the current market landscape, impact and implications to stakeholders in China's crop farming sector, and to players in the domestic drone industry.

With real customer case studies provided by DJI Agriculture, this paper illustrates the economic and productivity offerings drones can contribute as a future asset to China's agriculture sector, and provide a roadmap for a new generation of emerging agriculture drone adopters.

Notes:
Civilian drones refer to small unmanned aircrafts operated by civilians, and does not include unmanned aircrafts (drones) used for military and national defense purposes. Civillian drones are segmented into personal hobbyist drones, and commercial drones. The former are typically camera drones purchased and piloted by individual consumers. Commercial drones are drones (often paired with analytics) designed for, and purchased by enterprises for commercial uses; such as professional film and photography, inspection, last mile delivery, agriculture, and light shows for entertainment.

Contents Page

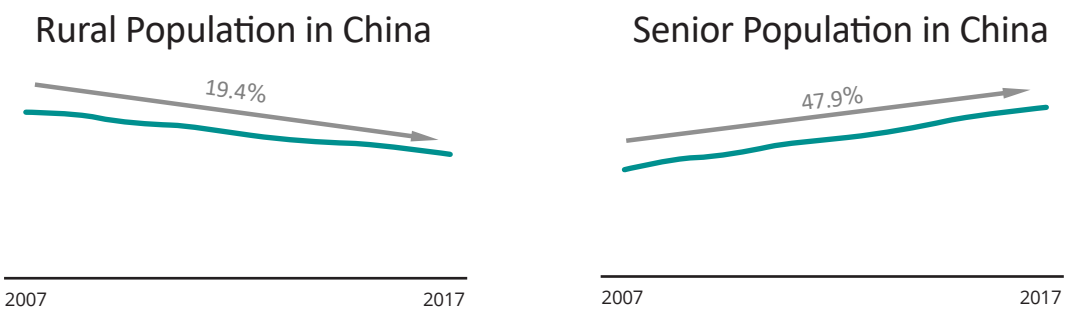
Introduction

Modernising Agriculture in China

Farming in the People's Republic of China (from hereon referred to as China) is critical to global crop production and food supply. Accounting for approximately 8% of the world's total arable land by acreage, China is the top agricultural producing country, feeding about 21% of the global population. In 2016, China's total crop production output was valued at RMB 5,928 billion (approx. USD 895.7 billion).

Achievements at this scale, however, have come at a cost. According to the World Bank and the Food and Agriculture Organisation of the United Nations, the volume of crop protection products China consumes annually is three times more than the United States per hectare of land. The overuse of chemical fertilisers and pesticides has led to soil degradation and water contamination. China's Ministry of Environmental Protection and Ministry of Land and Resources estimated that about 19.4% of China's arable land is contaminated; and if left unresolved, the problem can have long-term impacts on China's agricultural industry.

Urbanisation and ageing population are also posing threats to the world's largest food producer.



Note: Senior population denotes persons aged 65 years and above
Source: National Bureau of Statistics China

China's total population is estimated to have increased by 60 million over the past decade to reach 1.386 billion. Senior population has increased by approximately 42.6 million, and rural population has sharply decreased by nearly 140 million persons. The agriculture sector faces an increasing shortage of manpower owing to rural-urban migration and an ageing population.

With asymmetrical labour supply and demand for crop output to sustain and grow China's agriculture production, the Chinese government and domestic drone manufacturers are leveraging technological tools and automation to address future challenges.

Notes:
[1] *'Combined agriculture' includes agriculture, forestry, animal husbandry, fishery.*
[2] *Figures for 'Agriculture' here does not include forestry, animal husbandry, fishery to reflect the addressable market for crop protection and management by Agriculture Drones.*
[3] *Crop protection products include fertilisers and pesticides*
[4] *Senior population denotes persons aged 65 years and above*

Sources: Food and Agriculture Organisation of the United Nations (FAO); National Statistics Bureau of China, World Bank Group; Organisation for Economic Co-operation and Development (OECD); Ministry of Ecology and Environment of the People's Republic of China; and Ministry of Land and Resources of the People's Republic of China; Ipsos Businesses Consulting Research and Analysis

Manufacturing Domestic Commercial Drones

Chinese drone manufacturers make up the largest supply of civilian drones in the world. It is estimated that Chinese drone manufacturers alone supplied approximately 70% of all civilian drones sold globally in 2017. Thriving local drone manufacturing has led to higher exposure and accessibility at affordable costs for domestic hobbyists and commercial users. Of all commercial drones in operation in China, it is estimated that about 13% to 17% are deployed for agricultural purposes.

Adoption of Agriculture Drones has grown exponentially in China over the past five years. Between 2016 and 2017 the number of agriculture drones in operation has more than doubled, reaching nearly 13,000 aircrafts by 2017. Over the same period, the total treated acreage in China tripled, reaching an estimated 7 million hectares by the end of 2017, placing the estimated treated area to approximately 5%; an increase from 2% estimated in our 2017 paper ***Commercial Drone Adoption in Agribusiness – Disruption and Opportunities.***

Private sector players have been active in developing hardware, platforms, analytics, training, and services to foster drone adoption. The increasingly significant role assumed by agriculture drones in imaging, analytics, and crop-spraying can alleviate labour constraints in the agriculture sector while improving agronomic sustainability and farm yields. In view of the challenges faced by China's agricultural sector, Chinese policymakers have also launched local and nationwide subsidy schemes to encourage agricultural producers to use drones. These initiatives are in line with the government's policy agenda to use advanced technology to modernise agricultural production as outlined in the 13th Five Year Plan.

Sources: The 13th Five-Year Plan for Economic and Social Development of The People's Republic of China (2016-2020), Part IV: Agriculture Modernization. Ipsos Business Consulting interviews, research and analysis.

Subsidy Programs of Agriculture Drones in China

2014

Oct — Henan province

- The country's first drone subsidy program was launched in Henan province in October 2014 by Henan Agricultural Machinery Administration and Henan Finance Department to subsidize purchases of agricultural equipment. Recipients of subsidies include large-scale farm cooperatives and family farms. Drones weighing 5 kg to 9 kg can be subsidised 10% of their purchase prices, those weighing 10 kg to 34 kg can be subsidised 20% of their prices, and those weighing over 35 kg can be subsidised 60% of their prices.

Nov — Zhejiang and Jiangsu provinces

- City-level subsidy programmes were introduced by Ningbo city in Zhejiang province and Yangzhou city in Jiangsu province in Nov 2014 by their respective Agriculture Departments.
- Individual farmers, farm cooperatives, and crop protection service providers in Yangzhou city are eligible for a 50% subsidy for drone purchases. Farm cooperatives in Ningbo city can receive a subsidy of RMB 2,300 for the purchase of a single multi-rotor agriculture drone.

Nov — Jiangxi province

- Jiangxi Finance Department & Agriculture Department introduced a provincial subsidy programmes for agriculture drones in Nov 2016 that offer subsidies to farmers, agricultural machinery cooperatives, and crop protection service providers that can cover up to 50% of the purchase prices of drones.

Dec — Fujian province

- Provincial level subsidy programmes were introduced by the Office of Fujian Provincial Agriculture Department in Dec 2016 to subsidise the purchase of agricultural equipment.

2017

Jul — Changii County

- A county-level subsidy programmes was introduced in July 2017 by the Changji Agricultural Machinery Bureau in Changii County of Xinjiang province.
- A fund of RMB 2 million is available to subsidise purchases of drones by the county's crop protection service providers and agricultural machinery cooperatives.

Sept — First nationwide pilot subsidy scheme

- In September 2017, China's Central Government launched its first nationwide pilot subsidy scheme for drone purchases. It covers Jiangxi province, Zhejiang province, Anhui province, Hunan province, Guangdong province and Chongqing municipality. It was implemented jointly by the General Office of the Ministry of Agriculture of China, the Ministry of Finance and the Civil Aviation Administration of China.
- Farmers and machinery cooperatives, agriculture drone service providers, and crop protection solution providers are eligible to apply for subsidised offered by the programme. The maximum amount of funding annually available for each province/municipality is RMB 10 million. Applicants can be subsidised up to 30% of the prices of drones or a maximum amount of RMB 30,000 per purchase.

Source: Ministry of Agriculture and Rural Affairs of the People's Republic of China ; Ipsos Business Consulting Analysis

Nov — **Guangdong Province**

- In November 2017, Guangdong introduced a provincial subsidy programme with up to RMB 10 million available annually to subsidise up to RMB 14,400 for each 10 to 15 liter payload capacity drones and up to RMB 21,200 for each 15 to 20 liter payload capacity drone purchased. The provincial subsidy programme will last for two years from 2018 to 2020.

Dec — **Anhui Province**

- Anhui introduced a provincial subsidy programme in December 2017 to provide up to RMB 10 million in funding. Up to RMB 16,000 can be subsidized for each drone with a payload capacity of 10 litres and above.

2018

Jan — **Hunan Province**

- Hunan introduced a provincial subsidy programme with up to RMB 10 million in funding for agriculture drones. Subsidy of up to RMB 16,000 is available for drones with a payload capacity of 10 litres and above.

Mar — **Jiangxi Province**

- Jiangxi Agricultural Machinery Administration introduced a provincial subsidy programme with RMB 10 million in funding for agriculture drones. Up to RMB 15,000 is available for 10 to 15 litre payload capacity agriculture drones and RMB 20,000 for 15 to 20 litre payload capacity agriculture drones. The program will last until December 2020.

May — **Chongqing Municipality**

- Chongqing Agricultural Machinery Administration introduced a provincial subsidy programme with funding up to 10% of the allocated amount from the Central Agriculture Machinery Subsidy Program. For drones with a payload capacity of 10 litres and above, up to RMB 16,000 is available for each multirotor drone, and up to RMB 29,000 is available for each single-rotor drone purchased.

Jun — **Zhejiang and Jilin Provinces**

- Zhejiang and Jilin Agricultural Machinery Administration introduced a provincial subsidy programme for purchases of agriculture drones in June 2018. The maximum amount of funding available annually is RMB 10 million for each province. For drones with a payload of 10 litres and above - Jilin province provides up to RMB 15,000 of subsidy per drone, Zhejiang province provides up to RMB 17,000 for multi-rotor drones, and up to RMB 20,000 for multi-rotor drones with GPS. Zhejiang province also provides up to RMB 30,000 for single-rotor drones with payload capacity of 15 litres and above.

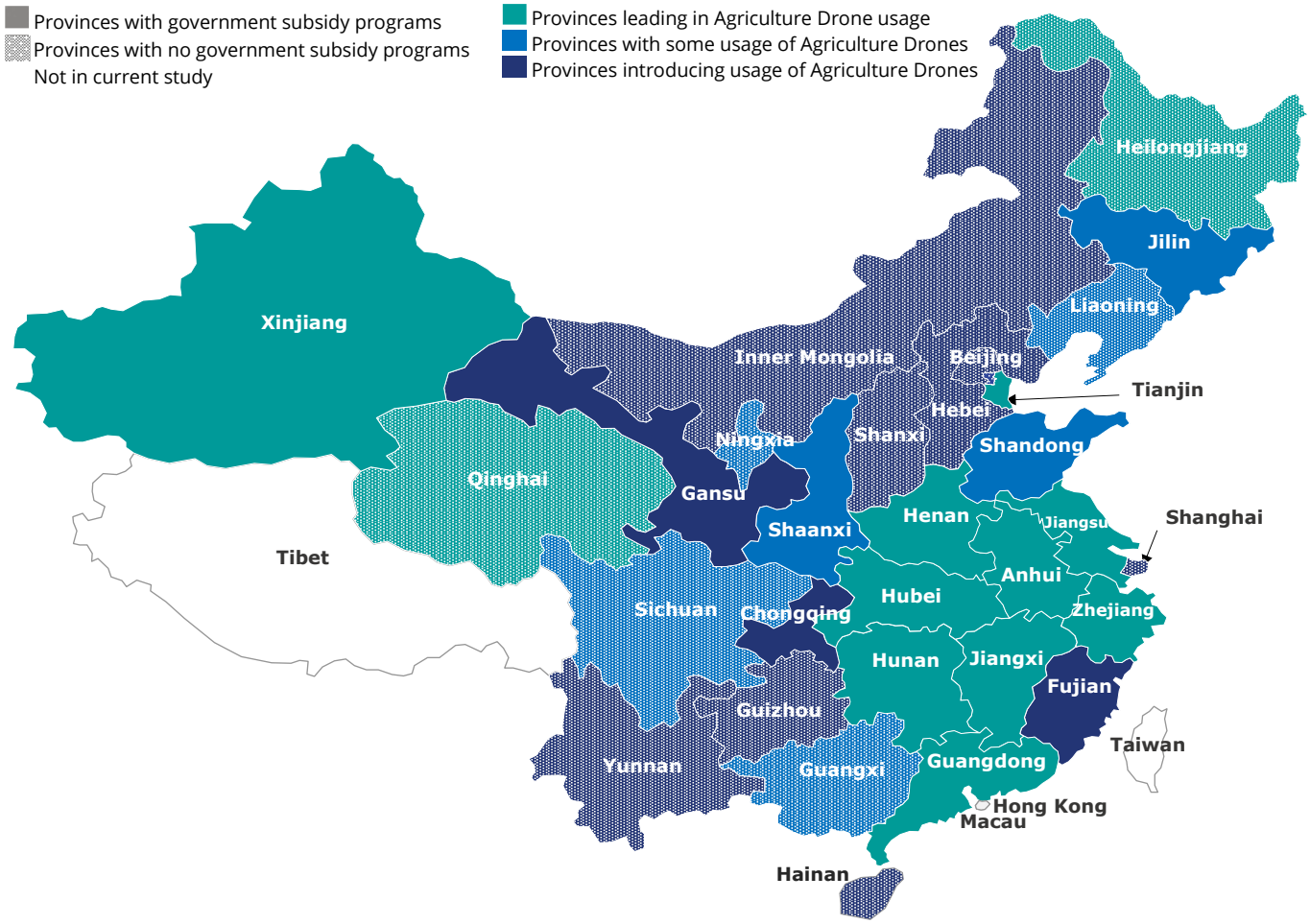
Sep — **Extension of nationwide pilot subsidy scheme**

- Following a successful introduction of the 'Nationwide Pilot Subsidy Scheme', the pilot subsidy scheme has been extended to other provinces to include Jiangsu, Shaanxi, Shandong, Gansu and Hubei Province in September 2018.
- The pilot subsidy scheme in Jiangsu was previously limited to Yangzhou City introduced in 2014. Subsidy will be available for six months in 11 cities across the province (Nanjing, Wuxi, Xuzho, Changzhou, Suzhou, Nantong, Lianyungang, Huaian, Yancheng, Yangzhou, Zhenjiang city) with the trial up for evaluation in February 2019. The programme provides a subsidy of up to RMB 14,000 to each agriculture drone with a payload capacity of more than 10 litres.
- RMB 10 million is available for Shangdong's provincial subsidy programme for agriculture drones. A maximum of RMB 10,000 and 16,000 can be subsidised for each multi-rotor drones with a payload capacity of 10 litres to 15 litres, and above 15 litres respectively. Up to RMB 30,000 of subsidy is available for each single-rotor drone with a payload capacity of 30 liters and above. The programme will last until 2020.
- For Shaanxi, Gansu and Hubei, the maximum amount of funding available annually is RMB 10 million, subsidizing up to a maximum RMB 30,000 for each drone. The provincial subsidy program will last for two years from 2018 to 2020.

Source: Ministry of Agriculture and Rural Affairs of the People's Republic of China ; Ipsos Business Consulting Analysis

As of 2018, subsidies available for agriculture drones are mainly intended for provinces in the South-Eastern region of China, such as Henan province, Chongqing municipality, Hunan province and Guangdong province. Agriculture provinces such as Heilongjiang, Sichuan and Hebei have yet to offer government drone subsidies. However, agriculture drones are more popular in these regions, driving growth in adoption, despite the absence of subsidies.

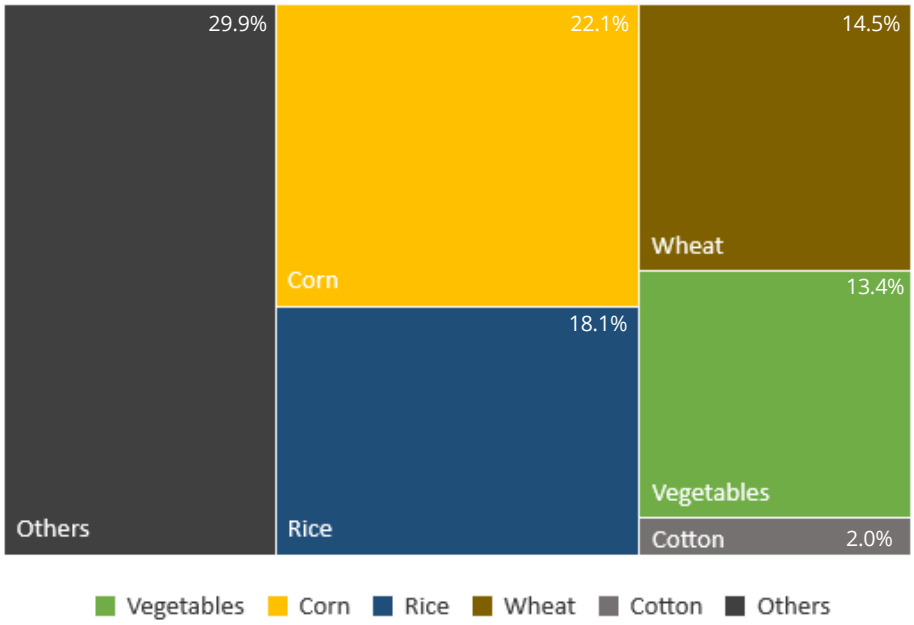
Subsidies and Adoption of Agriculture Drones between Provinces



Crop Land Use in China

Rice, corn, wheat, vegetables, and cotton are the top five crop types in terms of land use in China, accounting for approximately 86%of total output tonnage in 2016. Provinces leading in Agriculture Drone adoption in China include Xinjiang, Heilongjiang, Anhui, Hubei, Hunan, Jiangsu and Jiangxi for mass production and specialty crops, such as rice, wheat, corn, fruits, beans, and tea.

Land Use by Crop Type in China



"Note: Latest statistics from 2016
Source: National Bureau of Statistics of China

In particular, Heilongjiang, Anhui and Xinjiang are considered to be forerunners in adopting agriculture drones. For example, Heilongjiang and Anhui use drones to help grow staple crops, such as rice, soybeans, maize, wheat, and potatoes. As the top cotton-producing province, drones are used in Xinjiang to help monitor and manage cotton, grains such as wheat and corn, and specialty crops such as hop, sugar beet, tomatoes, mushrooms, and lavender. Other provinces that use agriculture drones on a larger scale include Zhejiang (tea), Henan (tea, grain, cotton and oil), Hubei and Hunan (rice), and Jiangsu (rice and wheat).

Prior to the Extension of Nationwide Pilot Subsidy Scheme in September 2018, Shanxi, Shandong and Gansu had already deployed drones for other crop types, such as sunflowers, soybeans, jujubes, apricots and peanuts.

Farming has traditionally been a labour-intensive activity. Seeding, pollination, crop-spraying and harvesting have to be performed manually. Modern farming technologies such as drones can automate these processes, reduce costs and increase output through administering both liquid and granular aides at different stages of the crop's growth cycle. Farmers are adopting agriculture drones for crop management and crop production for staple crops and specialty crops in China. The following case studies from China's leading drone manufacturer DJI illustrate these improvements.

Case Study 1

Pollination for Aksu Pears in Xinjiang

Xinjiang	
Total Area	1,664,897 km^2
Terrain	Mostly high mountains and large basins
Average Annual Temperature	Approximately 7°C - 13°C
Average Annual Precipitation	Approximately 165mm - 510 mm
Key crops	Cotton, wheat and fruits
Drone Subsidy Programs	Limited to Changii County as of 2017

Kaletale town, Xinjiang Uygur Autonomous Region is famous for the wide variety of fruits it produces, such as Aksu pears, which are sold locally and exported to overseas markets.

Tieman Crop Care uses drones to deliver and apply boron and zinc fertilisers to blossoming Aksu pear trees spread across 1,000 mu (or 66.8 hectares) of land to facilitate pollen growth, enrich the crops with nutrients, and improve yield.

Prior to using drones, a team of five had to fertilise the crops with a stretcher-mounted sprayer. It used to take the team a whole day to fertilise all pear trees spread across a piece of 100 mu (or 6.7 hectares) farmland. Reaching 6 to 7 metres tall, climbing up and down to ensure the foliages and blossoms are sprayed was a labourious task. After using the assistance of drones, two people can now fly these aircrafts to spray fertilisers on treetops over 9 metres tall across 200 mu (or 13.3 hectares) before sunset, saving the company a considerable amount of time and manpower.

Source: National Bureau of Statistics of the People's Republic of China, DJI, Ipsos Business Consulting Reseach and Analysis.

Case Study 2

Crop Protection Application on Irregular Terrain for Pepper Trees

Chongqing	
Total Area	82,403 km^2
Terrain	Uneven terrain, e.g. mountains
Average Annual Temperature	Approximately 16 - 18°C
Average Annual Precipitation	Approximately 1,000 - 1,400 mm
Key crops	Rice, corn, fruits
Drone Subsidy Programs	nationwide pilot subsidy program as of 2017

Sichuan pepper is one of the essential ingredients in Chinese five-spice, and are famous for their signature fragrance and numbing bite in Chinese cuisine and in traditional Chinese medicine. China is a leading producer of chilli peppers and Sichuan pepper, accounting for 46% of the world's annual production with over 20 million mu (1.3 million hectares) of plantations producing 28 million tons in 2016.

Pepper trees thrive in warm, humid climates but can also endure diverse conditions that may lack regular irrigation and direct sunlight. Most Sichuan pepper tree plantations are found on irregular landscapes such as terrains, terraced fields and uncultivated land. Sichuan Pepper trees grow to 2 to 7 meters tall with clusters of peppers emerging from the trees' dense intertwining shrubs

Small pests are the biggest threat to Sichuan pepper trees, especially spider mites. Spider mites thrive in April and May when Sichuan pepper trees blossom. They feed on leaves, flower buds, young fruits and tender shoots, causing flowers and fruits to drop. Spider mites produce about eight to nine generations a year, which can perpetually damage crops if left unmanaged.

Traditionally, pest control and prevention for Sichuan pepper trees are an arduous task, requiring labourers to navigate through thick cultivation and irregular terrain with backpack sprayers applying pesticide at a rate of 6 to 9 mu (or 0.4 to 0.6 hectares) per day.

Jiangnong, a local plant protection service provider, uses DJI Agras MG-1 drones to spray locally produced pesticides on pepper plantations spread across irregular and sloped terrains measuring 50 to 70 mu (about 3.3 to 4.7 hectares) each day. This translates into 7 to 8 times improvement in efficiency compared with manual spraying.

Source: National Bureau of Statistics of the People's Republic of China, DJI, Ipsos Business Consulting Reseach and Analysis.

Case Study 3

Defoliant Spraying for Cotton Harvest

Xinjiang	
Total Area	1,664,897 km^2
Terrain	Mostly high mountains and large basins
Average Annual Temperature	Approximately 7°C - 13°C
Average Annual Precipitation	Approximately 165mm - 510 mm
Key crops	Cotton, wheat and fruits
Drone Subsidy Programs	Limited to Changii County as of 2017

China is the world's second-largest cotton producer, contributing nearly 20% of global cotton production. 24 out of 34 provinces in China produce cotton, with Xinjiang province alone contributing 74.4% of the country's total cotton production in 2017.

To increase efficiency in cotton harvesting, it is vital to apply defoliant on the crops to remove the leaves surrounding the cotton bolls. This important step allows for quicker drying, avoids staining and rotting of bolls from foliage, and encourages green bolls to open. Exposing the cotton bolls improves harvesting efficacy from mechanized cotton pickers or cotton strippers.

Cotton is typically grown in vast fields where plants mature into a crowded bloom. Defoliant is commonly sprayed by tractors to efficiently cover a large acreage, but tractors often cause flattening of cotton plants before harvest, causing a loss in 20% of cotton produced in the field. According to Yin Bin, a cotton grower working in Xinjiang Province, it took a team of three to finish spraying their 600 mu (or 40 hectares) field with tractors over a few days.

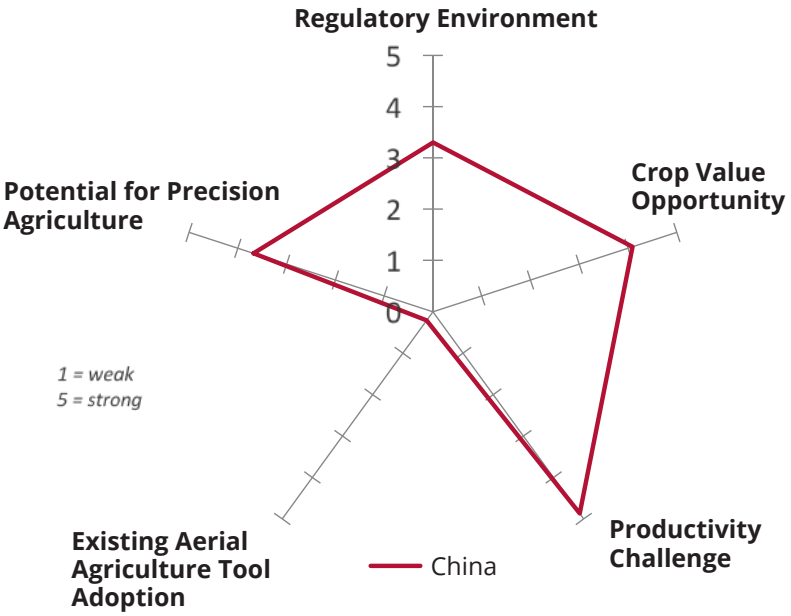
Using DJI MG-1S drones from Haisen UAV Plant Protection, the team was able to finish spraying the 600 mu (or 40 hectares) field in a single day without damaging any crops for harvest. This solution saves a considerable amount of time and costs for farmers, helping them optimise cotton yields for the harvest season.

Drivers for Agriculture Drone Adoption in China

As agriculture drones have become more affordable, their adoption has gained momentum, and users willingness to adopt drones have been supported by government subsidy programmes that encourage agricultural aircraft purchases. According to China's Department of Agriculture (DOA), the number of agriculture drones registered for operation has been increasing on an upward trajectory, rising from 2,324 in December 2015 to an estimated 13,000 in 2017. It is projected by DJI that the number of agriculture drones deployed by China's farming sector will reach approximately 40,000 by 2020.

Based on our **Ipsos Business Consulting Drone Adoption Attractiveness Index** for the Agriculture sector, there remains a high potential for agriculture drone adoption in China. The market is particularly attractive for commercial drones to address productivity challenges and economic incentives derived from better yields, reduced production inputs, and labour alleviation. Similar to other markets for commercial drones, regulatory development will set the pace for drone adoption in the Chinese agriculture sector.

Attractiveness Index for Agriculture Drone Adoption



*Source: Ipsos Business Consulting, 2017, "**Commercial Drone Adoption in Agribusiness – Disruption and Opportunities**"*

This opportunity is also driven by several factors in China's agriculture sector to enhance and transform current crop management practices.

The introduction of this technology could provide potential benefits to farm operators by mitigating risks of health hazards from airborne chemicals, reduce their operating costs, and increase their yield revenues. It can also help the country address some of the challenges to the sustainable development of its agriculture sector. This is enabled by the ability of the technology to provide alleviation to the country's ageing agriculture population as well as to offer support to Chinese farmers operating in small, fragmented plots and challenging terrains.

Reducing risks of health hazards

China is home to over 200 types of farm crops, which are threatened by more than 2,000 types of insect pests and plant diseases. According to the MOA, the country's agriculture sector on average suffers from an annual loss of 24 million tons of crops in 2016 due to pests and diseases.

The use of pesticides and herbicides help minimize crop losses, and secure crop yields. Although China's agricultural sector has been using modern farming equipment, most small and medium-sized farms operating on fragmented plots still spray crops manually, covering farm plots on foot while carrying a spray tank to administer crop chemicals with handheld applicators, Most small and medium farms in China still practise manual spraying, a labourious and time-consuming exercise, particularly for an ageing agrarian population.

Manual spraying exposes the sprayer to health risks due to close proximity and contact with airborne chemicals, which are key health and safety hazards associated with China's agriculture sector. According to a study conducted by Southeast University, approximately 53,300 to 123,000 cases of pesticide poisoning are reported every year in China. Deploying agriculture drones can help maintain a safe distance between farmers and airborne chemicals and thereby reduce the risks of exposure and health hazards.

Resource alleviation for China's aging farmers

China's agricultural industry is challenged by an ageing workforce. About 33.6% of the country's farming population are aged 55 or above. A low replacement rate due to a shrinking young population entering the agriculture sector exacerbates the challenge, affecting the sustainability of farming businesses. The use of machinery and technology in agriculture, such as agriculture drones, is hailed by the Chinese government as a way to alleviate the labour shortage that afflicts the agricultural sector.

Improve cost efficiency and increase yield revenues

Drones can help China's farm operators improve efficiency on the costs of labour, herbicides, pesticides, and fertilizers – key components of overhead costs. It is estimated that manual spraying can cover 1 to 2 mu (0.06 to 0.13 hectares) of land per hour. In comparison, agriculture drones can spray approximately 40 to 200 mu (2.67 to 13.33 hectares) within the same period of time. Drone manufacturers also estimate a saving of up to 60% of liquid crop protection products that would otherwise been over-applied through manual spraying methods.

Highly automated and easy to operate, agriculture drones are designed to perform crop-spraying tasks with accuracy, consistency and efficiency. Some are fitted with laser and/or ultrasonic echoing sensors (such as "lidar", for "light detection and ranging") that can help adjust the drone's flight altitude to adapt with changes in topography and crop variety. These enhanced capabilities are necessary for the delivery of high-precision field and crop management services. The technology can also help generate more revenue by minimizing crop losses, increasing crop yields, and improving farm sustainability.

Agility on fragmented plots and challenging terrain

Most farming in China is often practised on small, fragmented plots. Average farm size in China measures at approximately 0.6 hectares (by comparison, the average farm size in the US measures at 170 hectares). In South-Eastern parts of China, farmers in Yunnan and Guangdong provinces have been growing a wide variety of crops manually on mountain slopes, terraces and many different forms of terrain that can be affected by adverse climate conditions or hampered by limited accessibility. The terrain topography, irregular, and smaller plot size often present practical challenges to the introduction of ground-based agriculture machinery. Agriculture drone technology provides farmers with a viable and cost effective option especially through the use of drone-sharing services, to elevate operational efficiency utilising mobility through space above the terrain.

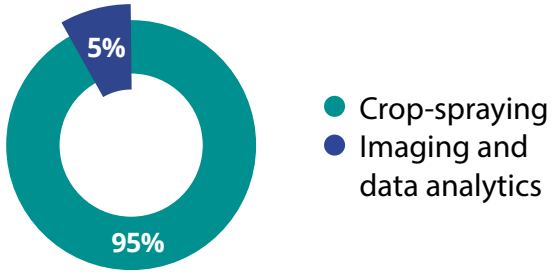
"Sources: "Pesticide poisoning and neurobehavioral function among farm workers in Jiangsu, People's Republic of China." Injury Prevention Research Institute, School of Public Health, Southeast University, Zhang, Wu, Yao, Yang, Cui, Tu, Stallones, Xiang. 2016.

Applications of China's Agriculture Drones

Agriculture Drone applications serve two primary functions: imaging and analytics, and crop-spraying. Drones can be designed or retrofitted with equipment for photographic imaging and hyperspectral data analytics, GPS-guided automated flight, and variable rates of spraying (for purposes of seeding and crop-spraying). These capabilities can help relieve productivity challenges typically encountered by manual labour and operators of traditional ground-based farming equipment.

Currently, farmers in China mainly deploy agriculture drones for crop protection purposes. Agriculture drones are used as tools to help reduce efforts carried out by manual labour by administering crop protection products over fragmented farms or rugged areas quickly and efficiently, conserving time, effort, and insecticides, herbicides, and pesticides. Until recently, agriculture drones were not frequently used for imaging and data analytics in China. Most farms are fragmented plots, family owned, and practice manual farming techniques to maintain crop yield. Aerial surveying and crop analytics were typically reserved for large field operators or commercial farms who have the scale, capital, and crop homogeneity to seek agronomic information for proactive farm management. The emergence of drone service providers and dedicated drone platforms for sharing services have improved the affordability and accessibility of agriculture drone technology, especially for small and medium-sized farm operators. The proliferation of agriculture drones usage also promote demand for farm surveying and imaging services to enable farm operators and collectives to diagnose and complement existing crop protection efforts.

Usage of Agriculture Drones in China



Source: Ipsos Business Consulting; survey of news articles reporting on drone use in China

Agriculture drone companies primarily providing imaging drones in China include companies such as senseFly and Beijing VIGA UAV. Notable drone companies supplying crop protection drones in China include several local brands such as XAG (formerly known as XAircraft), DJI, Gaoke Xinnong (GKXN), Guangzhou TXA Aviation, Beidahuang Agriculture Aviation, AnYang Quanfeng Aviation, Xinjiang Tianshayuren, Shenzhen Hi Tech New Agriculture, and Wuxi Hanhe Aviation.

Agriculture Drones Pilot Training and Certification

The increasing adoption of agriculture drones underscores the need for more certified civilian drone pilots. Pilots operating drones weighing over 7kg must obtain a drone piloting license from the Aircraft Owners and Pilots Association of China (AOPA-China), which is under the supervision of the Civil Aviation Administration of China (CAAC). Pilots of agriculture drones also need to meet additional requirements under Commercial Drone regulation Class V - 'Crop Protection Class' for agriculture drone operators.

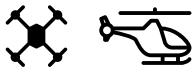
Momentum in the number of training centres and drone pilot certifications provide an indication of the rate of adoption for commercial and agriculture drone technology. In 2014, there were 18 training centres and 244 drone pilot certificates issued. This grew exponentially to 199 training centres and 24,407 drone pilot certificates by the end of 2017 according to AOPA-China. Approximately 40,000 drone piloting licenses* have been issued between XAG's XAG Academy and DJI's UTCs training centre programmes alone. DJI's Unmanned Aerial Systems Training Centre（慧飞无人机应用技术培训中）(UTC) plays an active role in training pilots for operating agriculture drones through their established branches in key agriculture provinces, ranging from Heilongjiang to Anhui. As of November 2018, UTC trained over 25,000 graduates across 150 centres globally licensed pilots for operating agricultural drones in China. Licensed operators are able to fly different types of agriculture drones for crop monitoring, inspection, and application.

*Note: Drone certification and drone piloting certificates from AOPA-China, XAG, and UTC, are for all drone aircraft types, and are not limited to agriculture drones. XAG and UTC offer agriculture specific training to their piloting programs.

Price of Agriculture Drones and Crop-Spraying Services

Agriculture drones are generally classified into two types: Crop-spraying drones, and multispectral imaging drones. In China, multirotor agriculture drones can be deployed for both crop-spraying and imaging.

Agriculture Drones Manufactured in China

		Crop-spraying drones 		Imaging Surveying Drones 
		Unit price of locally manufactured drones		*Unit price of locally manufactured drones*
Types of aircrafts	• **multirotor drones** • **helicopter drones**	*RMB 13,000 to RMB 122,000* *RMB 168,000 to RMB 290,000*	• **multirotor drones** • **fixed-wing drones**	*RMB 10,000 to RMB 39,999* *RMB 61,800 to RMB 380,000*
Benefits		• save up to 90% of water used for irrigation • save between 20% to 60% of Crop-spraying chemicals		• Costs less than aircraft and satellite imaging to cover fields under 300 mu (20 hectares) • less aerial obstruction helps capture images with higher resolution

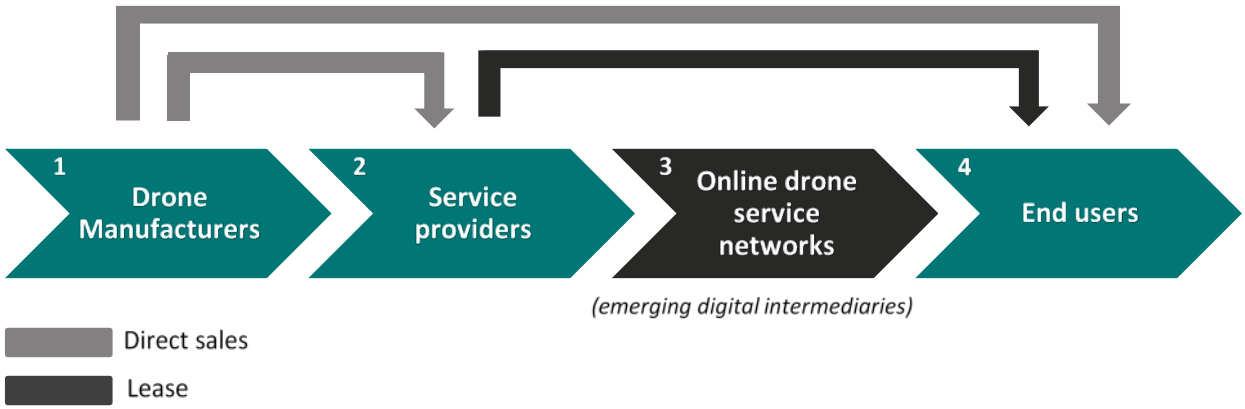
Prices of Crop-Spraying Service

PRODUCT CATEGORY	DESCRIPTION	PRICE PER 1 MU (0.067 HA)
CROP TYPE	tall-stalk crops (高秆作物)	RMB 18 to RMB 30
	short-stalk crops (低秆作物)	RMB 10 to RMB 12
	field crops (大田作物), such as rice, wheat, and maize	RMB 8 to RMB 15
	orchards (果树)	RMB 25 to RMB 40

*Note: Prices quoted are samples obtained up to January 2019, and are for general reference only. Service fees may also vary, depending on the area and topography of the terrain. Crop-spraying services are typically cheaper for large areas and flat farmlands.

Evolving Business Models in China's Agriculture Drone Industry

Value Chain of China's Agriculture Drone Industry



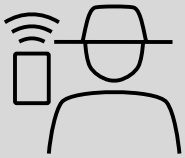
Most agriculture drones operating in China are manufactured domestically. They are comparatively more affordable than international brands such as "Parrot" and "Yamaha". Operators of large-scale commercial farms prefer to have their own fleets by placing orders directly with drone manufacturers and maintain their own in-house drone pilot teams. Local drone manufacturers have also expanded their services to provide leasing, imaging and crop-spraying services to farm owners. A few large service providers and manufacturers have already established offices in different regions across China to better serve their clients.

Online platforms, such as Farmfriend (农田管家) launched in 2016, for product and agronomic knowledge sharing, have further fuelled the growth of drone products and services targeting smaller farm operators. These platforms make the knowledge of using agriculture drones in real-world applications more accessible to new users and facilitate communications between farm operators and service operators. They also help farmers compare and select service providers based on location, price, availability and suitability of service, budget considerations, and other agronomic requirements.

Source: Ipsos Business Consulting Reseach and Analysis.

Accessing Agriculture Drones in China

There are three common models for end-users in China to gain access to and operate agriculture drones: the farm owner-operator model, the leasing-service provider model, and the platform-operator model.

Types of operation models in China	Present Prevalence	Future Trend
 Farm Owner-Operator Model	 Uncommon	 Present Short-term Long-term
 Leasing Service Provider Model	 Common	 Present Short-term Long-term
 Platform Operator Model	 Uncommon	 Present Short-term Long-term

Farm owner-operator model: Owners of large-scale corporate farms (种粮大户) prefer to purchase agriculture drones directly from manufacturers and develop in-house fleets as well as service teams for their own farms. Some of the corporate owners of these farms may also lease the drones piloted by their own in-house drone teams as a service.

Leasing-service-provider model: Agriculture service cooperatives (植保服务专业合作社) and commercial crop-spraying service companies (植保小队) provide one-stop services, ranging from agronomic consultations to crop-spraying. They also offer farmers pesticides and fertilizers best suited to the operation of their drones. These service providers either lease or purchase their drones directly from manufacturers.

Platform-operator model: This service model evolved with the emergence of digital intermediaries between service providers and farmers. These digital intermediaries create online platforms for farmers to search and select service providers based on their needs and requirements. Service providers who register with these online platforms are able to offer their services and connect with target customers.

Challenges to China's Agriculture Drone Industry

As the agriculture drone industry continues to develop, stakeholders in this segment must take steps to address looming barriers and challenges to ensure the budding momentum takes root to expand this market in China. Challenges and barriers to the pact of adoption include hardware development, affordability and accessibility of drone services, technological acceptance by farm owners, supply of drone pilot operators, and VLOS and night-time operations.

Current aircraft flight time and payload capacity

Agriculture drones available in China are mainly used for crop-spraying they are engineered to carry a heavy payload to mobilise crop protection chemicals. Most domestically produced agriculture drones are powered by batteries instead of gasoline. The comparatively shorter capacity and run-time of battery packs limit operational flight time from 10 to 25 minutes, and maximum payload from 6 to 35 kg. Currently, developments are underway to extend the battery life used by agriculture drones. For instance China Aerospace Science and Technology Corporation (CASC), which is developing drones powered by photovoltaic cells with longer battery life to help extend flight time and payload capacity. According to the China Academy of Aerospace Aerodynamics, agriculture drones will soon be able to handle payloads up to 50 kg.

Affordability of drones and crop management services

According to the National Bureau of Statistics of China, 95.8% of the country's arable land is cultivated by private farmers with an average annual income of RMB 33,612 in 2016 – substantially less than the national average annual income of RMB 67,569. Most of these farms are family operated, practising subsistence farming on small, fragmented plots of land, with limited financial resources to invest in new technology or purchase machinery. Promulgation of China's 13th Five Year Plan (2016-2020) promotes adoption of technology and machinery in the agriculture sector. This was followed by the launch of subsidy programs at national, provincial and city levels to encourage and facilitate the adoption of agriculture drones by China's farmers and farm operators in the coming years.

Training for Farm Owners

Agriculture drones represent a new, disruptive technology that is still unfamiliar to most of China's small and medium-sized farmers, who might lack basic know-how and experience to utilise in day-to-day operations. It is important for stakeholders of the industry (such as manufacturers, wholesalers, leasing companies, and operators of online platforms) to provide resources to facilitate the accessibility of this technology, and to familiarise end users on the benefits and basic operation of agriculture drones. The industry's momentum in addressing this challenge will influence the readiness of China's agriculture sector to revolutionise itself with drone technologies.

Supply and Training of Drone Pilots

The speed of drone adoption in the market has not been matched by the rate of licensing for pilots to operate aircrafts. The result is a shortage of licensed pilots of drones and training institutes to meet China's eager demand over the past 5 years. Further, the training required for agriculture operations differ from piloting drones for imaging and inspection in other industry sectors. Drone operation for crop protection requires an understanding of the agronomics behind captured analytics to dispense appropriate crop protection products for effective crop management on the farm. Increasing the number of training centres with specific training on drone spraying and farm management agronomics will encourage the pace of drone adoption in the agriculture industry.

Regulatory Restrictions to VLOS and Day-time Operations

Perhaps more significant than other commercial industry applications, limiting drone flights to within VLOS (Visual Line of Sight) and Day-Time Operations in agriculture limits the effectiveness of crop protection for diseases and pests that needs treatment during the night. Due to the biology of some crop diseases and pests activity, some herbicide and pesticides are most suited for night-time applications. It is common for farmers to apply herbicide and pesticides at night where there are better spray drift control and humidity for effective results, or when pests emerge are most active, migrating and feeding on crops, causing damage to both the crop and the plants. Permitting (Beyond Visual Line of Sight) BVLOS and night-time operations for drones in agriculture will unfasten the full potency of this technology for crop management in China.

Industry Perspectives: DJI Agriculture

As part of our assessment, we have met with drone associations, institutions, manufacturers, service providers, value chain stakeholders and industry experts. We have also participated in international conferences on drone technologies and agriculture innovations. We had the opportunity to catch up with Sun Jiadong, Head of DJI Agriculture, and his team this year. As the world's largest civilian drone manufacturer, we explored the team's views on current market dynamics, industry developments, and what the future holds for DJI Agriculture as it continues to advance the Agras drone product line.

Sun Jiadong
Head of DJI Agriculture

IBC: For those who are unfamiliar with DJI's enterprise solution, can you tell us about the services and products of DJI Agriculture? What can your aircrafts do? What were the difficulties over the course of developing this product line?

DJI Agriculture: In 2009, a group of engineers at DJI have been commissioned to research and develop agriculture spraying technology to be paired with drone solutions. Working with scientific research institutes and universities in the country, DJI's objective is to improve productivity through precise and efficient crop protection through drone technologies.

Developing a drone aircraft specifically for agriculture introduced new challenges for the engineering team because of different functional requirements compared to DJI's Phantom, Mavic, and Spark aircraft lines. Transforming drones into a modern agricultural equipment required the aircraft to cater to different weather conditions, terrain, crops, adapting the drone for high usage frequency, higher payload, and to withstand a strong corrosive environment from crop protection chemicals.

DJI Agriculture was formally established in 2015 to expand drone delivered solutions for agriculture. Since 2015, DJI has developed a few iterations of the Agras platform, resulting in a smarter aircraft with a more stable and reliable system. DJI's first agriculture drone, Agras MG-1 was released on November 2015 equipped with a battery and 10-litre payload. This was followed by the launch of Agras MG-1S in November 2016 with the added feature of Radar Terrain Follow Modules, RTK system, Obstacle Avoidance Radar Modules, and Intelligent Operation Planning Systems to make crop spraying a faster and easier task.

IBC: In our Ipsos publication, we examined China's agriculture drone industry and adoption in recent years from a business model and competitive landscape perspective. Could you share with us your front-line experiences in introducing agriculture drones to the market since 2009?

DJI Agriculture: Agriculture drones are mainly adopted by industrial farms, professional plant protection teams, and independent users in China. DJI Agriculture drones are used in all provinces in China except Beijing, Hong Kong, and Macao. Farmers in the Northern and Western agricultural provinces such as those in Heilongjiang, Liaoning and Xinjiang were early adopters. They initially used them for rice and cotton fields, and have now extended to other types of crops.

Customers in the agriculture market are quite price sensitive, they expect the cost to justify economic benefits. DJI's Agriculture drones improve crop-spraying efficiency by up to 40 times to 60 times faster than manual spraying, reducing consumption of crop protection chemicals and improve farm productivity. The government subsidy for agriculture drones has also relieved some economic barriers for farmers to adopt this technology The Agras drones are approximately half the price of other agriculture spraying machines presenting a lucrative opportunity for service providers and farm cooperatives to earn more money.

The number of farms using drones for crop protection spraying in China is actually still quite low. Our mission is to penetrate this technology into the market quickly, increase our contribution and support the agriculture market.

DJI drones already have autonomous features, such as obstacle avoidance, terrain detection and mission planning. Together with our flight planning and management app, operators can already set a specific mission and enable the drone to fly automatically. DJI is also developing digital agriculture to bring more precision solutions to crop-spraying and food production through drone solutions.

IBC: How do you see China's agriculture drone industry and drone users change in the coming years? What are the specific areas that have yet to be developed in the industry? What is DJI's role in these developments?

DJI Agriculture: There are almost 200 different kinds of agriculture drones currently in the market with an estimated 150 to 400 different agriculture drone manufacturers, but there is still room in the industry to improve aircraft quality, capabilities, and establish more after-market services for drone customers. After a few more years of growth, we expect the number of agriculture drone brands to reduce compared to 2017.

What would be helpful for the agriculture drone and enterprise drone industry is to provide more scientifically backed and standardised regulations for flight operations. It would be important for regulators for drone companies such as DJI to work towards a common goal for safe skies that are open to innovation; striking a balance for businesses to take advantage of drone technology in a safe and responsible manner. In our opinion, this would stimulate more market development and benefit for the agriculture sector by involving more organizations and intuitions.

Wider development of specialised drone spraying service teams will help faster adoption of agriculture drones. It is difficult to measure the number of service providers because they can be a one-person team, a collective team or a few agriculture drone owners, or a professional spraying team. Illustrated by Ipsos Business Consulting, there are a few business models that can be realized with drone technology in agriculture, with increasing participation in shared resource models, all servicing different farm types, land size, and needs of farmers.

From our UAV Training Center in China, we already see entrepreneurships and start-up service providers using this technology to provide service to local farmers, who may not want to acquire the technology but appreciate the benefits of drone technologies. There are over 10,000 pilots using DJI drones with an opportunity to earn more from spraying services. During a peak season for agriculture spraying, some pilots can earn over USD 1,500 per month, and break even in 6 to 8 months. This level of earning is only for peak season, and only around 20% of pilots can achieve this. If they expand their services with drones they can earn even more during peak seasons.

DJI aims to help commercialise more agriculture drone spraying service so up to 50% of pilots can earn more than USD 1,500 per month during peak seasons. The most important next step for our industry is training programs for agriculture drone pilots to learn how to optimise their flights, on spraying, and maintenance. Better pilot training will help the industry grow further in the future.

IBC: Moving into the next stages of product evolution, what will be DJI Agriculture's mission and developments for the agriculture drone industry?

DJI Agriculture: Whether it's our consumer drones or enterprise platforms, our goal remains the same which is to develop easy to use, safe and reliable technology that can be made accessible to more people around the world, for work or play.

For enterprise product specifically, it's also about talking and listening to our partners, customers and understanding the shifting needs of the industry for us to come up with the next generation of amazing aerial technology. This is also very true for our work in the agriculture field.

We recently launched the Agras MG-1P in Thailand and the initial feedback has been very positive. In December 2018, we also launched the DJI T16 agriculture drone with a payload of 16 litres, a 20 minutes quick-charge battery, and a spray width spanning 6.5 metres during operation. In addition to DJI's obstacle avoidance sensory technology, the T16 includes a First-person view (FPV) camera, dual spotlights, and an all-new integrated Digital Beamforming (DBF) Imaging Radar which supports 3D point cloud imaging that effectively senses the environment to circumvent obstacles, and also enables operations at day time, night time, and low visibility conditions. There is a lot of potential for drone technology in Southeast Asia, especially in countries where agriculture plays a vital role in the economy.

We believe once people learn about drone technology and know how to use it, they will find new and creative ways to adapt it into the enterprise operation and workflow.

Future Outlook

China is a remarkable market for agriculture drone adoption; a leading food-producing nation accounting for 21% of global food production and responsible for manufacturing 70% of the world's supply of civilian drones. Yet, its market is juxtaposed with only 2% in agriculture drone adoption.

Between 2016 and 2017, the number of agriculture drones in China is estimated to have doubled to approximately 13,000. Our partner DJI expects this figure to reach 40,000 by 2020. Looking ahead, we expect adoption in China to exceed this pace beyond 2020 from untapped demand, but the industry will need to address key adoption barriers to unlock the full market potential offered by the ripe combination of government subsidies, technological accessibility, mature production capability, and integrated drone service platforms.

Technology for basic crop protection drone manufacturing is no longer in its infancy. Developments in flight control, payload, surveying and crop-spraying set the stage for wider commercial drone applications, solidifying market readiness for precision agriculture and technology-assisted farm management practices. Continued advancement in drone technologies, such as fault tolerance control, BVLOS, night-time operations, higher automation, and integrated diagnostic and spray functions, against a backdrop of regulatory receptiveness, will reinforce the status of agriculture drones as a versatile staple tool for the future of China's farming sector.

We anticipate China's prominent drone manufacturers and major crop science organisations to lead the unification process of agriculture drone standards. Crop science organisations will move towards standardising formulations and product mixes to fit drone delivered solutions. Growing market share of leading drone manufacturers in China will proliferate wide usage of common agriculture drone models in the domestic market.

These drone manufacturers will also propagate standardised spraying systems to effectively deliver common crop protection products formulated for drones by major crop science organisations. Efforts from both groups will drive the convergence of drone technologies that would impact spraying and crop protection performance; ranging from system hardware such as flight mechanics on spray drift coverage, variable flow controls and electrostatic nozzles, to field intelligence, such as standardised collection of images and data points for collation on digital farming platforms.

With abundant room for market growth, we expect the leading drone manufacturers to expand, streamline, and improve their products to be compatible with leading crop science companies. Those who develop targeted distribution channel and go-to-market strategies will be able to establish a stronghold in the market through first-mover advantage. Smaller drone manufacturers will increasingly compete with more economical or specialised products in China's market space.

Broader access to drone pilot certification and training will also strengthen revenue opportunities in ancillary services, such as drone leasing for surveying and inspection, crop-spraying, and precision farm analytics, specifically addressing Chinese and Asiatic crops. The additional financial incentives will encourage farm operators and collectives to pursue omnichannel farm management practices in the future.

The emergence of commercial drone technologies presents a prime opportunity for stakeholders in China's agriculture sector to modernise and reshape the future of domestic and smallholder farm management. China's drone manufacturing supply is well-positioned to cater to the imminent expansion in domestic demand. Activating faster growth in the market will hinge upon public and private sector collaboration to overcome localised barriers to adoption. The realisation of agriculture drone applications in China will lay precedence for drone technology adoption in the region, underlining China's leading position in commercial drone manufacturing and global food production.

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