Agricultural UAVs - A Case Study on Their Implementation in the

US Market

[Source: MIT Technology Review]

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Abstract / Executive Summary

The use of UAVs in agriculture represents a new market ready for explosive domestic growth, and could even be a game changer. Like the PC industry, many military funded technologies have been combined in products that are now just sold as a niche novelty for hobbyists. The agricultural UAV industry is near the point where the market can shift from this hobbyist, small-scale into an agricultural necessity, much like the PC industry shifted when IBM and its PC came onto the scene. Many small companies (and divisions of larger ones) are working on the use of drones in agriculture, but face unique regulatory challenges. This paper explores this budding agricultural UAV market, compares existing agricultural solutions, examines the technologies behind this new market, the regulations constraining this technology, and includes an evaluation of the field's economic and technological likely future.

Introduction

Drones are swiftly moving from military to commercial use. Agricultural drones could eventually become a technical imperative for land management, agribusiness, and ecosystem stewardship. Up until recently, farmers have relied on traveling their fields or supervising them via manned aerial flights in order to gather data and valuable information about their crops. Using the data gathered from drones, farmers can apply chemicals, fertilizer, or water where needed, plot their fields, oversee crop conditions, inspect for disease, and monitor livestock.

Companies in Oregon such as SkyRis Imaging, Skyward, ATI, and HoneyComb serve unmanned drone applications in agriculture, but face many issues before drone use in agriculture becomes mainstream. Drones are used in agriculture in other countries such as Japan and Australia, but face issues with social adoption and regulatory approvals domestically.

In this paper we explore the history of UAVs, compare and contrast traditional agricultural methods with precision agriculture technologies and methods, and investigate the potential market and economic impact of precision agriculture in the United States.

Problem Definition

Affordable and easy to fly Unmanned Aerial Systems or 'Drones' have arrived. Now hardware prices are falling, and the feature sets of the semi-autonomous machines are growing exponentially.

In 2012 the US Congress passed a law that set a deadline of September 2015 for the FAA to integrate commercial drones within the domestic airspace. The problem is that according to the US government's own internal audit, the Federal Aviation Administration is "significantly behind schedule" [27].

Because commercial agricultural drones hold promise for farmers this means delays across the board for both the pace of innovation, and the rate of technology adoption by the sector. The FAA's measured approach to a potentially disruptive and difficult to manage technology could avoid accidents and bad publicity or it could give the upper-hand to non-American companies.

How soon will this early stage technology find adoption within the Agricultural sector? What might the future hold for AG drone manufacturing companies hoping to define this nascent market? Which other technology-adoption case studies might guide a technology forecast for Unmanned Aerial Systems in the agricultural sector?

Methodology

The research methodology included a survey of available literature, a survey of recent news items, an industrial survey of companies in this space, a regulatory survey of applicable agency publications, interviews, and field research.

Much of the applicable literature was found in periodicals or on the web. The industrial survey involved reading material published by companies in the field and occasionally via direct contact with the firms. Transport Canada, the FAA, and other government agencies publish their guidelines and requests for comment which were read.

Interviews were conducted with individuals like the editor of DroneLife and the founder of ATI (a local agricultural drone vendor). Field research included touring a local manufacturer's facility as well as attending local operator meet ups.

The research can be considered somewhat qualitative rather than quantitative as statistical data sets were not yet available, and a full quantitative analysis is outside the scope of this document.

Data Analysis & Results

UAV Systems:

An Unmanned Aerial Vehicle (UAV), widely known as a drone, is a no pilot aerial vehicle on board or a remotely piloted aircraft (RPA). Unmanned aircrafts are generally categorized into two types: Autonomous aircraft or remotely piloted aircraft at a ground control station.

The majority of typical unmanned aircraft systems comprise of the following components: unmanned aircraft, sensors (visual, multispectral, stereoscopic, thermal, lidar, hyperspectral), a command system, ground kit, control link, Ground Control Station (GCS), video management or terminal (via software), data analyser and other equipment such as infrared camera or an artificial intelligence system for detecting the weather conditions beside ground support apparatus [25].

History

Drones in one form or another have existed for a long time. From before WWI to 2015 humans have developed drones for use across various applications. One of the first recorded usages of drones was by the Austrians on August 22, 1849. They sent about 200 pilotless balloons equipped with bombs over Venice. One of the first pilotless aircraft were built during WWI. Leading the way, using A. M. Low's radio control techniques, was the "*Ruston Proctor Aerial Target"* of 1916. In 1917, Elmer Sperry, with radio engineer Peter Hewitt, began construction of the radio-controlled "flying bomb." The Automatic Airplane was able to fly 50 miles carrying a 300-pound bomb after being launched by catapult. The biggest boon to UAVs happened shortly after WWII. When the US Air Force accessed the huge number of lost aircraft (>40,000) and lost crew members from WWII, they began to focus on aircraft solutions that would not lose lives. The US then worked to develop a new drone with an air-air subject named Lightening Bug, which was used in Vietnam and South Asia in the mid to late 1960s.

Rapid advances in technology and digitization have further developed and accelerated the use of unmanned aircraft. In the late ‘80’s and early ‘90’s, the United States renewed its commitment to develop unmanned aerial systems after perceiving the unique advantages possible. In the early 1990s, partially in response to an aging population of farmers and a shortage of young farmer successors, YAMAHA established a new generation of UAVs for civilian use. [33]

UAV Categories:

Based on the Joint Doctrine Note definition in May 2010, “ballistic or semi-ballistic vehicles, cruise missiles, artillery projectiles, torpedoes, mines, satellites, and unattended sensors (with no form of propulsion) are not unmanned vehicles” [23]. The most significant parameter of success in UAVs rather than Satellites is the low-altitude view (from a few meters above the plants to around 120 meters) which gives a perspective that farmers have rarely had before. However, drones are divided into a few general categories. Usually drones are commercialized under four different categories [38]- fixed wing aircraft, helicopter, balloons or airships,

The most recent generation of quadrocopter (rotorcraft) micro UAS with vertical take-off and landing (VTOL),in fact, this ability have been shown as a useful instrument in local agricultural application.

A. Dragonfly X8 quadrocopter **B**. fixed wing aircraft **C**. helicopter

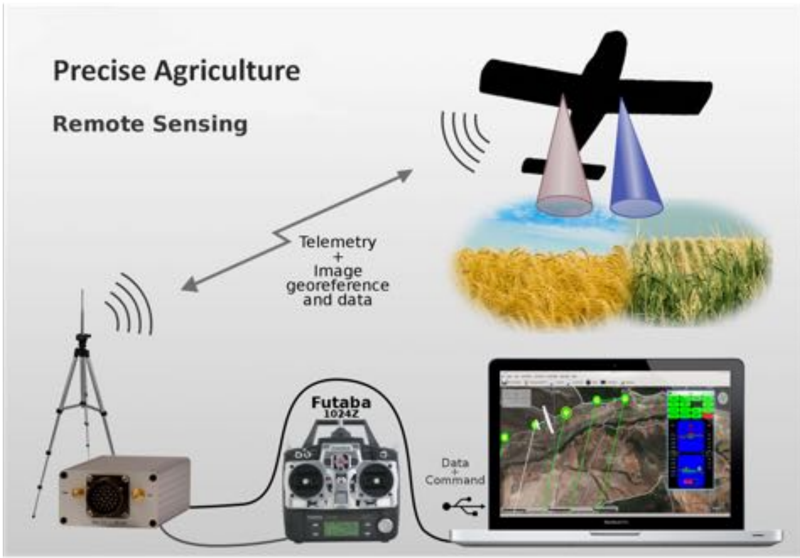
UAVs Applications:

The value of using UASs in scientific applications has been thoroughly demonstrated in recent years. UAVs are used in a widespread range of fields such as aerial surveys, meteorological sampling, data collection, autonomous target identification, reconnaissance missions, Agriculture, homeland security, forest fire monitoring, quick response measurements for disaster preparedness, volcanic gas sampling, humanitarian needs assessments, biological/chemo sensing tasks, and monitoring of gas pipelines [43].

Operations:

If one segment of a farmer's field is damp, and another segment is too dry, what should the farmer do to find the problem except to walk his fields? Seeing the crops from the air can reveal patterns that may expose problems related to irrigation or soil variation issues, also pest and fungal infestations that may not yet be apparent at eye level. Drones are becoming popular on America's farms. Despite all the restrictions imposed by the FAA, the demand for drones' data is increasing and this market is getting more popular every day. One of the challenges relates to how an agricultural drone works.

After a UAV take-off, a flight controller sends an automated stabilization signal from the controller to the UAV. This provides the farmer the time needed to program subsequent actions. The desired route is chosen and the instructions are transferred. All collected digital data can be later accessed and analyzed via computer.



Traditional Agriculture

Traditional agriculture exists as a means to produce reliable, abundant food over time in a specific region. Throughout human history our species has survived mostly due to their ability to hunt and gather food, but it wasn't until the advent of agriculture that our ancestors, through farming, starting producing their own food and agricultural goods. According to available data, in 1790, 90 percent of Americans were farmers [9]. Depending on the region however, this success has come with a costly price tag, often associated with environmental and social impacts. Traditional agricultural techniques are for the most part nowadays practiced on small family farms, for subsistence and to provide for local communities and in developing countries where the lack of industrial technology offers no alternative. Like most technologies, small-scale agriculture has evolved in response to changing environmental, social and economic conditions over time [13]. Recent trends show that the rate of change has rapidly increased, due to multiple factors such as technological innovation, climate change, and the economic development of specific regions.

Traditional Farming Methods:

Several traditional farming methods exist and are region specific, based on environmental conditions, population density, soil quality, water supplies, and the overall economic and technological development of a region. Manual labor is the primary resource for traditional agriculture in developing and less prosperous regions, while developed countries utilize more industrial based methods to support agriculture. Tremendous progress has been made in developed countries where advances in science and technology have transcended the farming industry. In poor countries, several traditional methods no longer practiced in developed countries still exist and can be categorized as follows: hand tillage, mixed cropping, slash-and-burn agriculture and subsistence farming.

In contrast, industrial farming that relies on machinery and advanced tools has been adopted around the developed world. This industrialization allows these countries to cope with a growing human population. Leveraging on recent technological innovation, several techniques have been used to enhance productivity and manage costs in large-scale farming deployment. The global agency FAO, the Food and Agriculture Organization of the United Nations, established a clear correlation between economic growth, advances in agriculture, and the poverty index in one of its annual report titled “Food and Agriculture in National and International Settings”. A summary of the findings is illustrated by the graph below [11]:

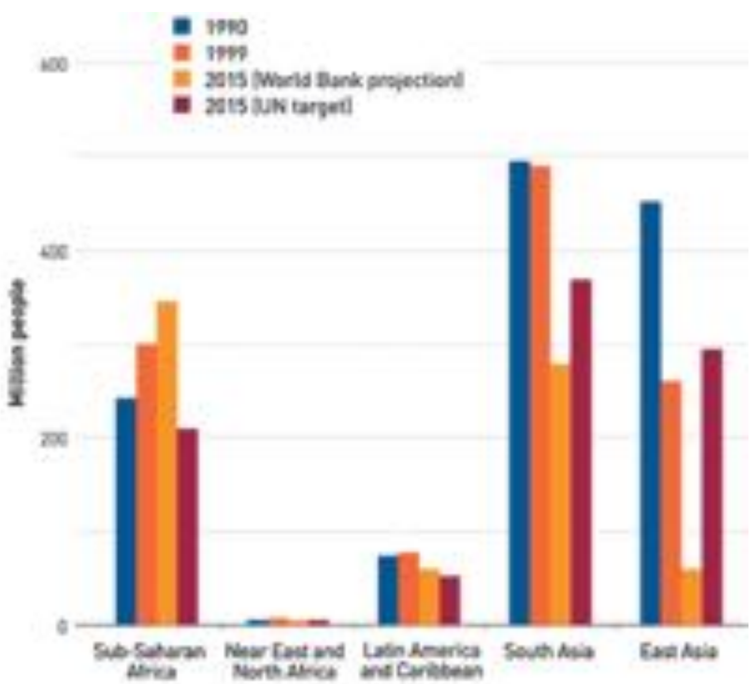


Fig1: Progress in poverty alleviation.

This graph highlights that the poorest regions are also the ones that rely most heavily on traditional agriculture where the integration of technological advancement is lacking, in this case the African Sub-Saharan regions. From this analysis it appears that technology management is a vector of economic development as seen with the example of East Asian regions where the transfer of technologies has helped improve the poverty index significantly.

Limitations and Challenges:

Although human settlements rely heavily on agriculture and its abundant food production, the ecological, social and environmental impacts of unsustainable farming can no longer be ignored. As the purchasing power of middle-class populations in developing countries who are demanding better quality products increases, global food demand is forecast to grow rapidly. Due to environmental impact and soil depletion, coping with that trend has become especially challenging now as agricultural resources, along with water availability tighten [20]. If the last century has been recognized for technological innovation, advances in science and related fields, it has become clear that along with progress in technology we have inherited emerging issues and challenges for sustainable development. Arguably, one of the main challenges facing humanity is how to cope with a growing human population and adapt in a time of increasing scarcity of natural resources, food production and energy[39]. As a result of the forecast for rapid population growth, world food demand will surge exponentially in some parts of the planet. To make matters worse, the scarcity of resources such as water and land that are critical to agriculture and rural development is threatening our ability to sustainably meet future needs for food and energy[11].

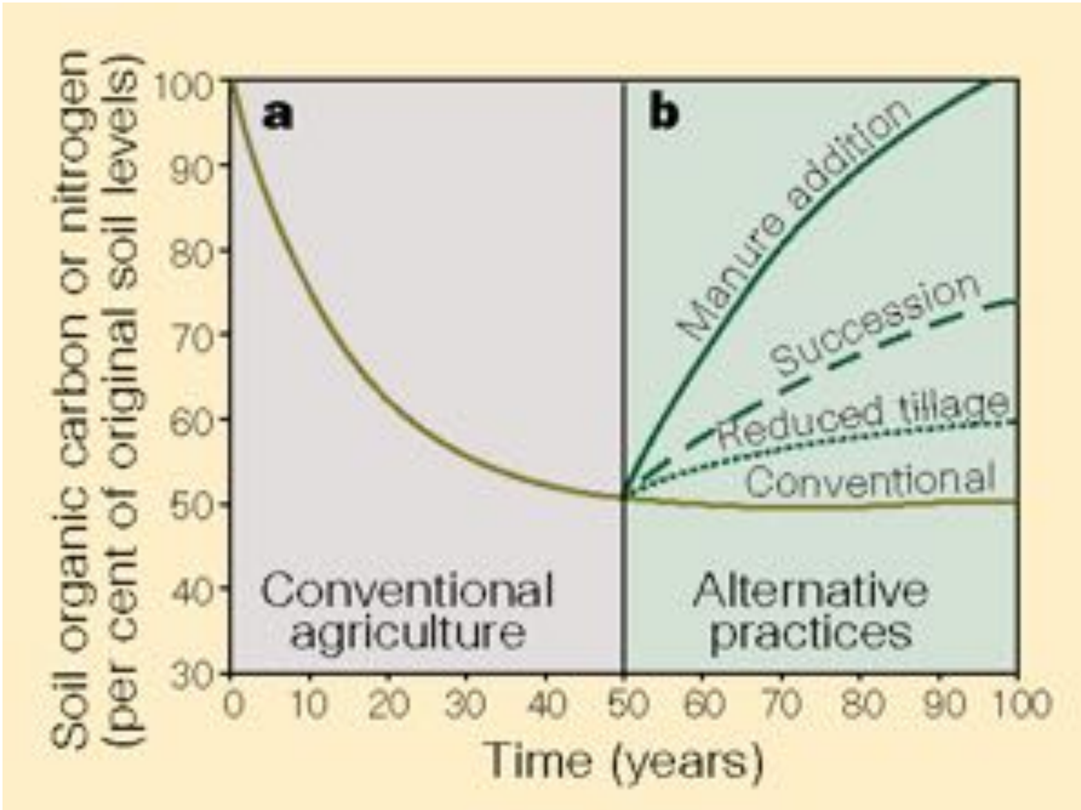


Fig2: Typical effects of different agricultural practices on the total organic carbon or nitrogen content of soil.

(a), Over about 50 years, conventional agricultural fields that are tilled and then fertilized with mineral nitrogen, phosphorus and potassium (NPK) fertilizer lose 50-65% of pre-agricultural amounts of soil carbon and nitrogen. (b), The effects of different practices on recovery of soil fertility after 50 years of tilling. Practices that reduce the amount of tillage of soils can lead to accumulation of about 20% of the lost carbon or nitrogen. Succession here refers to the process by which abandoned fields are gradually invaded by successive populations of native vegetation and animals, eventually reaching a stable 'climax' community structure. We have found that it takes about 200 years of natural succession for fields to recover pre-agricultural carbon and nitrogen levels (J. Knops and

D. Tilman, manuscript in preparation). The addition of manure can double soil carbon or nitrogen levels in about 40 years [37].

The graph above (Fig2) is a perfect illustration of the impact of traditional agriculture on soil depletion. Several negative environmental impacts are attributed to traditional agriculture: soil depletion, habitat loss, climate change, production waste, and scarcity of resources (water, minerals, etc).

A recent research project conducted at the University of Oxford's Smith School of Enterprise and the Environment focused on agricultural impacts of climate change. It reveals that land degradation and water scarcity are among the most severe damages induced by the effects of traditional agriculture. The finding illustrated by the graph below also estimates the financial cost in a range of $4.4 to $8 trillion potentially each year [21].

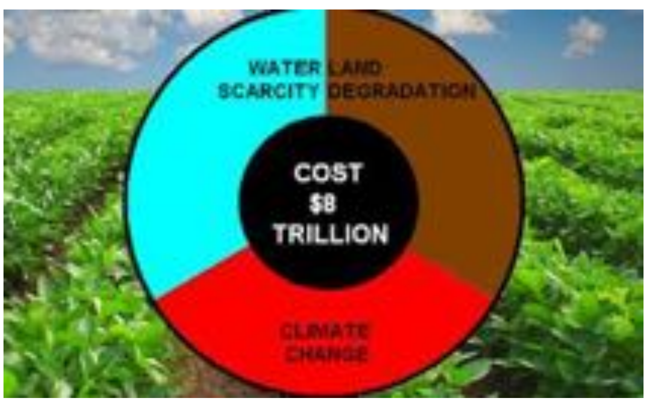


Fig3: Agricultural Costs of Climate Change, Land Degradation and Water Scarcity (**© 2013, Richard Matthews. All rights reserved.)**

Are UAVs the Future of Modern Agriculture?:

Facing a global economic crisis coupled with food security challenges, once again science and innovation are called upon to help. For decades, science and technology have been key enablers behind agricultural growth and successful integration of large-scale farming .It is thus no surprise if several industry leaders are involved in tackling the challenges of sustainably[6]. IBM, the computing and services giant, is among one of the companies shaping the future of modern agriculture. Adopting the green revolution concept and its conservation-oriented practices, data analytics are used to enhance agriculture at a global-scale. Several optimization models are built upon new services, computerized tools and emerging technologies such as agricultural drones, thermal infrared imagery and real time monitoring[21].

Emerging Technologies & Precision Agriculture

IBM and other companies are capitalizing on a trend towards data-driven agriculture over traditional agriculture. Precision agriculture, as it is called, involves the collection of data to monitor weather, soil and air quality, crop maturity and to use predictive analytics to collect samples, improve yields, and fight disease with precise application of nutrients and pesticides. UAVs support precision agriculture by giving farmers the tools to collect real time data. UAVs can cheaply and effectively fly into remote areas to monitor, photograph, and map land that traditionally was unapproachable.

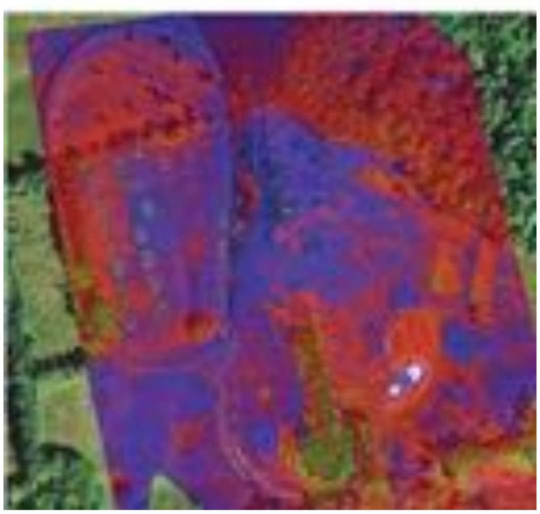
As the population of the earth grows, the need for more targeted, more effective agriculture becomes paramount. Precision agriculture and the markets surrounding it will become essential to providing the food necessary to sustain the world's population.

Large scale agriculture applications of precision agriculture include agribotics, depositing accurate amounts of water, fertilizer, and pesticides, and the early detection of disease or stress on crops, especially those difficult to reach via traditional methods (driving vehicles on land, biplanes, etc).

Small scale agriculture benefits from precision agriculture because small, cost-effective drones can be used to monitor crops, take pictures, map landscapes, and reach land difficult for humans to reach at low capital costs. Winemakers, as reviewed in the MIT Technology Review, are using drones as simple aerial cameras to see patterns across their land. They hope these rather affordable (<1k USD) UAVs will allow them to understand and map their land more effectively [2].

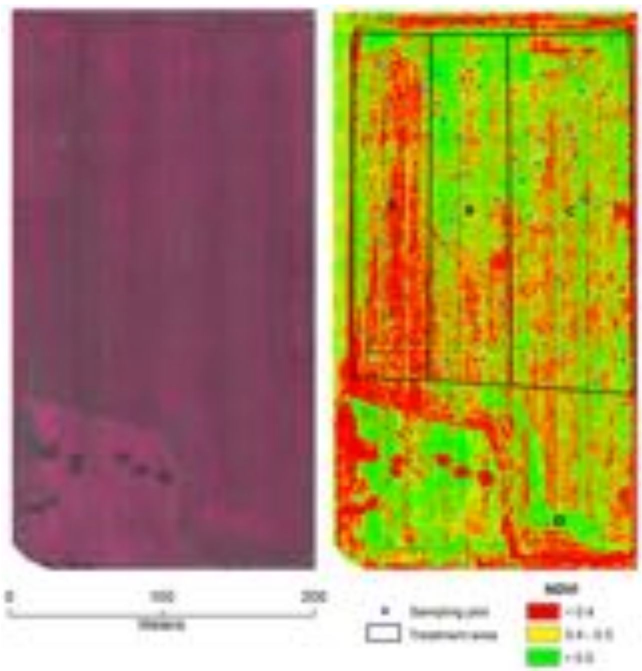
Several case studies in Canada and Australia investigated the use of sensors and imagery collected via UAVs, and evaluate their usefulness. A report by SkyView Solutions Ltd explored the use of NIR imagery, GPS, and set flight paths. It determined that Red-Green-Blue and

Near-Infrared imagery can be reliably obtained using a small UAV, and that it is possible to image process this data to get usable, understandable results. The report stated that more research and regulation were necessary to fully integrate this technology into Australia's infrastructure. [17] Low altitude remote sensing (LARS) was explored in a case study in Ontario, Canada. It found that several obstacles remain to fully utilize LARS technology in UAVs and agriculture. Costs, training, the interference of weather/clouds on the sensors all contribute to making LARS feasible by use of consultants or private research teams.



Top: A drone from PrecisionHawk is equipped with multiple sensors to image fields.

Bottom: This image depicts vegetation in near--infrared light to show chlorophyll levels. [2]



LARS images during the Ontario study

The results suggest that it is feasible to gather good data and images from LARS. However, due to cost and logistics the use of LARS in precision agriculture is still in its infancy.

There are many emerging companies in precision agriculture working towards the use of UAVs and sensors in agriculture domestically. Stevia Corp in California is conducting a large study using UAVs to interrupt Stevia's photoperiod during growth using illumination. This could allow for growth around the clock, thus improving yields.

Agricultural UAVs - Key Players Domestically

Companies with specialities in precision agriculture are emerging onto the domestic market. Locally, HoneyComb Corporation has pioneered the AgDrone System, a UAV system that can be rented out to local farmers or anyone who is interested in imaging land.

Yamaha in Japan contracts out UAV systems to local farmers. Is contracting out UAV work the future of precision agriculture? Will that be the way this technology is integrated?

Not all technologies utilized in precision agriculture are UAV based. A vector probe can measure moisture and temperature along a route in the soil. AquaSpy, a company in the United

States, makes these soil moisture monitoring sensors that allow farmers to understand and map how well irrigated the crops are across their fields.

Although the market and technology seem poised to accept the use of agricultural UAVs, regulatory restrictions have thus-far prevented this technology from creating a market domestically.

Regulatory Environment

For two consecutive nights last month, at least 5 unauthorized drones were observed flying over key landmarks in Paris [19]. The FAA has long been considered risk-averse, and in the present environment of terrorism-awareness and cyber-espionage it should be unsurprising that the FAA is dragging its feet authorizing Unmanned Aerial System flights (UAS) for commercial purposes.

Should rural agricultural drones be regulated differently?

Aviation agencies have long been concerned about birds colliding with airplanes [8]. A problem with UAVs is that they are a lot like birds only without any ability to "Sense and Avoid"[17]. A drone can lose contact with its pilot, and many manufacturers have no lost link protocol. Drones can be hacked, and hi-jacked which is of real concern for Homeland Security.

Despite these concerns - many countries have forged ahead with authorizing UAVs. After Japan which has had agricultural UAVs in service since the 90s, Transport Canada is considered a leader for sensible pragmatic rule-making. Issuing 'Special Flight Operations Certificates', allows Transport Canada to certify and regulate the operators. Simple rules inspired by the Canadian example, like weight, altitude, line-of-sight, and daylight restrictions are evident in the FAA's latest NPRM (Notice of Potential RuleMaking) issued in February.

Even these pragmatic rules have a big impact on the economic viability of a UAS. In one of the relevant case studies from Canada, it is noted that by restricting the operating height, a much larger number of images need be collected for each field. A 40-acre field may require over 400 images which must be mosaic-ed together effectively.

In Canada the SFOC (Special Flight Operations Certificate) may require a team for each flight. One spotter and one pilot, and this increases labor cost [42].

According to the AUVSI - the industry's leading trade group, Japan has ~10k drones deployed doing 90% of pesticide application. This is perhaps why some industry analysts predict 80% of American UAS sales will be for agricultural use soon. [29]

However some experts doubt these numbers, because comparatively huge farms in the US may continue to benefit from large capacity applicator aircraft, compared to Japan with its small farms averaging 5 acres [33].

Japan with its earthquakes and natural disasters can be considered ahead of the curve for agricultural drones. In fact the same technology developed originally at the behest of the Ministry of Agriculture was later used to monitor the erupting volcano Mt. Usu in April of 2000, and to monitor radiation events [33].

The next country to regulate UAVs effectively was Australia - which has been testing Japanese agricultural UAVs for some time, and has a practical regulatory framework. Uruguay and Brazil have also authorized these systems and are experiencing growing rates of adoption.

But what about the USA? Following the much publicized military silent stalk and kills by Drones at war, many US states and municipalities have enacted rules of their own at the more local level. Some farm-belt states have passed 'AG-Gag' laws to protect the confidentiality of animal-husbandry abuses, and experimental fields. [29] There now exists a regulatory soup wherein a trespass on private farm property has become hard to define. [10]

Demand for this technology does exists. If farmers could use UAVs to capture just 1% more efficient operations or just 1% more yields, "you're talking about billions of dollars." [30]

American farmers know this and are using UAVs to locate missing cattle with thermal cameras, survey drainage issues, and in one example survey damage to plastic irrigation pipes caused by black bears. [30] "I think it's fair to say the technology is far beyond the law, and we're trying to play catch-up here." [32]

Even though the FAA has issued a few cease-and-desist orders [30], thousands of farmers are comfortable bending the drone rules because the FAA has bigger fish to fry.

Current events could quickly change the regulatory climate. When a UAV nearly collided with an Airbus A320 in July this drew some attention in Europe where the number of UAS operators has increased by 350% in one year [1]. Commissioners in Europe are concerned that the very low price of these systems creates an excessively low barrier of entry into the (Remotely Piloted Air Systems) space. [1]

Let's consider some of the risk factors. There can be loss of vehicle control for many reasons. One risk is that unlike manned aviation where the government provides Air Traffic Control and observation, UAS systems rely on third-party communication systems. The payloads under consideration (fertilizer, pesticides, and mechanical arms) could pose new risks [17]. One study describes the needs for 'Crashports' and self-destruct protocols for these craft.

One sensible way to address the FAA's and Homeland Security's worries regarding UASs would be to develop counter-measures. Airports have them for birds. Some municipalities have offered a bounty for any downed drone, but we need something more practical. Given the regulatory exemption for law enforcement drones, what is needed is a technological solution to safely knock these UAVs out of the sky when they misbehave. As these flights are all unmanned - destruction of the craft should be of no concern when human lives are at risk.

What good is regulation without a capacity for enforcement? Perhaps this is the real reason the FAA has been dragging its feet.

SWOT Analysis

In light of the global food security crisis, technology is sought to provide the answer, particularly precision agriculture and its innovative cutting-edge tools and services. Agricultural drones are essential to the successful implementation of Precision Agriculture as they are used to gather big data volumes from the field. Although the technological argument for agricultural UAVs has reached consensus, a financial and market analysis conducted on a case by case basis including regional variations is still needed to evaluate opportunities and challenges facing the integration of agricultural drones at an industrial scale.

<u>Strengths</u>

· Technology

Without doubt the technological innovation of Agricultural drones is the biggest strength in this emerging market. Unsurprisingly, the reputable MIT Technology Review listed “Agricultural Drones” first in their list for 2014 Breakthrough Technologies [2].

· Flexibility

Another great advantage of using agricultural drones is their usage flexibility. They can fly over difficult areas, using GPS coordinates in auto-pilot to cover fields and provide mapping tools. In addition their weight allows for relatively longer flight hours with the recent breakthroughs in lithium battery technology. Agricultural UAVs can also be specifically tailored to an individuals' needs. Systems can be as elaborate as a $40,000 quadcopter with multiple sensors and batteries, to a simple small vehicle with a camera attached. This flexibility will allow this technology to hit the market where it is needed for both small and large applications.

- Advanced Imaging

Because of their ability to fly at very low altitude, agricultural UAVs produce superior imagery through data collection critical for analytics. Color contrast technology allows seeing crop health in great details.

Weaknesses

- weather conditions and data acquisition

Despite advanced technologies such as LARS (low altitude remote sensing), the quality of data collected is still very dependent on weather and environmental conditions.

- reliance on limited battery sources

Relying for the most part on battery technologies, the limitations associated are in term of flight time, weight and extra features.

- software integration for data processing

Another big challenge with the use of agricultural drones is the ability to convert these images into useful data for the farmer and to subsequently enhance the performance of the crop.

Opportunities

- smart analytics

As big volumes of data are being collected, the challenge of making them useful through analytical and computing algorithms will transcend and expand across several industries.

- mapping and data processing

As an improvement from satellite imaging, the better imaging resolution at low altitude provided by agricultural drones could be leveraged to build cheaper and more accurate and customized mapping tools.

- real-time monitoring

The advances in sensor, communication and networking technologies makes it possible to gather data at remote locations, and transfer them almost seamlessly to a processing center.

Threats

- security concerns

A recent incident involving a drone crashing on the premises of the most guarded house in the USA, the White House, has revived the conversation surrounding the safety problem of drones in general.

- public adoption

It's paramount to well define the boundaries of commercial drone use as several cases of public disturbance and privacy invasion have been reported here and abroad, in California and recently in Paris, France.

- regulatory rigidness

Arguably one of the biggest impediments again the wide integration of agricultural drones is the lack of regulatory policy to clearly define the rules of engagement in the industry. One of the threats against the successful integration of agricultural drones is the potential rigidness of regulations in response to general public misperception about drones.

In summary, the benefits of using agricultural UAVs for crop surveillance have been well established as they help enhance farm crop yields. Additionally, the cost savings versus walking the fields or airplane fly-over filming can be significant [34].

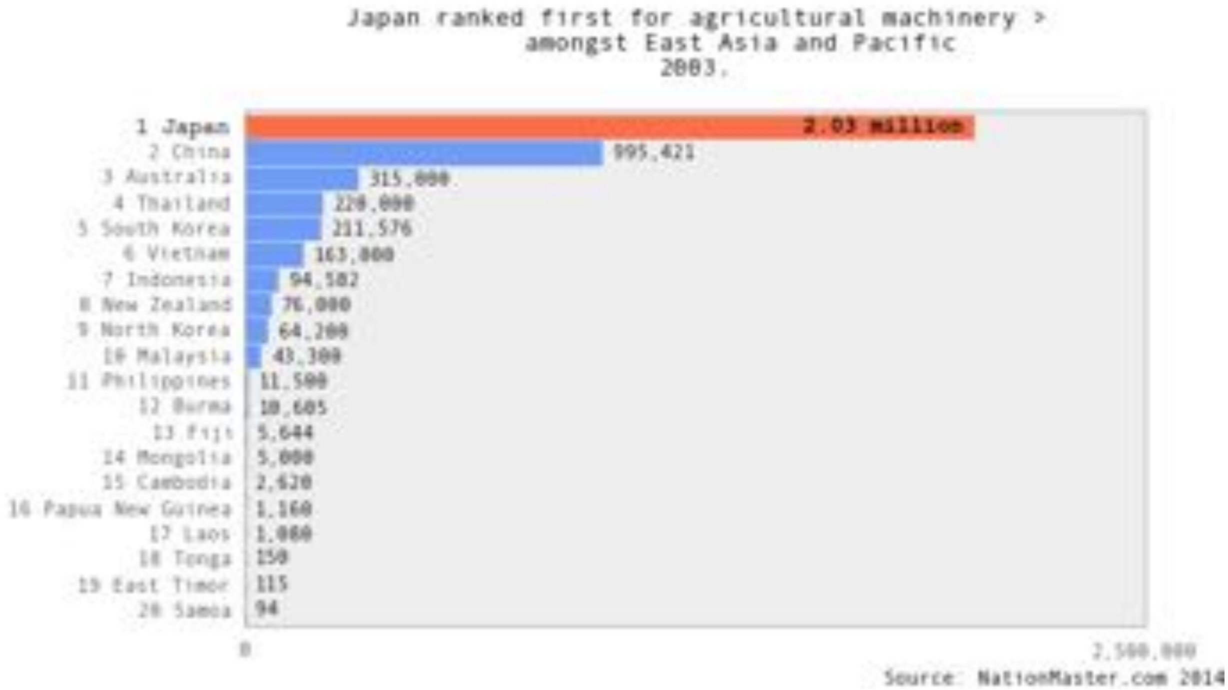
Evaluation Model

New technologies can improve a farmer's income when they reduce the marginal cost of producing one unit of output. Since output prices will for a time be driven by the prevalent (old) technology, profits will increase for those who adopt the new one, with early adopters benefiting the most. Eventually all or many farmers may adopt the new technology, causing increases in output and a possible reduction in output prices. However, farming in an open economy means competing on a global scale, with output prices determined by the most productive farms. Poor farmers are not usually among the early adopters; they lack the necessary access to information, capital, skilled labor, roads, and other such factors. We will compare the impact of regulation around such a practical system like a drone on the annual harvest income and compare to the other countries without.

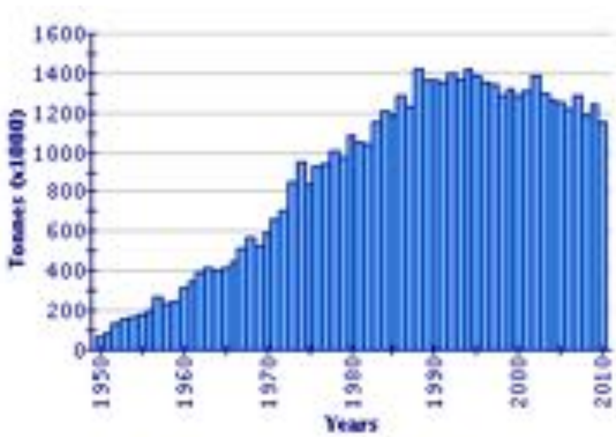
In the regulatory section Japan is identified as a pioneer of precision agriculture and Canada as the torch-bearer for future regulatory efforts. If we look at the statistics from 2003 we see Japan, almost double the other countries in East Asia, using new technology and subsequently producing more harvest.

Japan:

55% of Japan's farmland is rice paddies. In 2014 unmanned helicopters sprayed 40% of Japan's rice crop. UAVs perform 85% of aerial crop spraying in Japan.

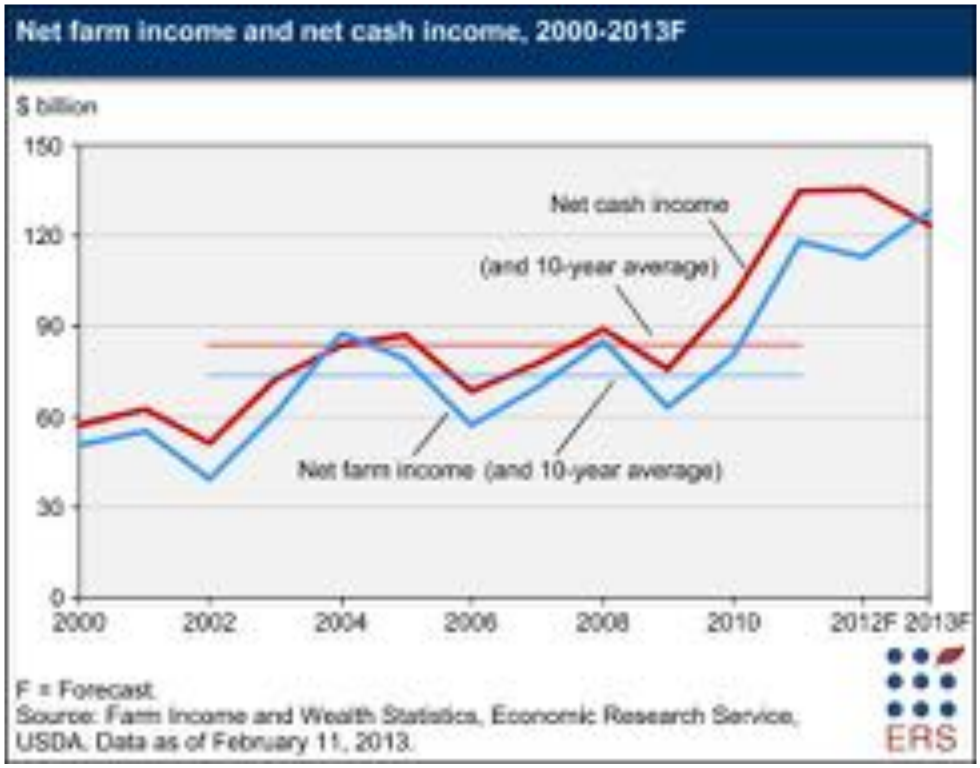


Canada was using 732,600 tons which is less than China.



America:

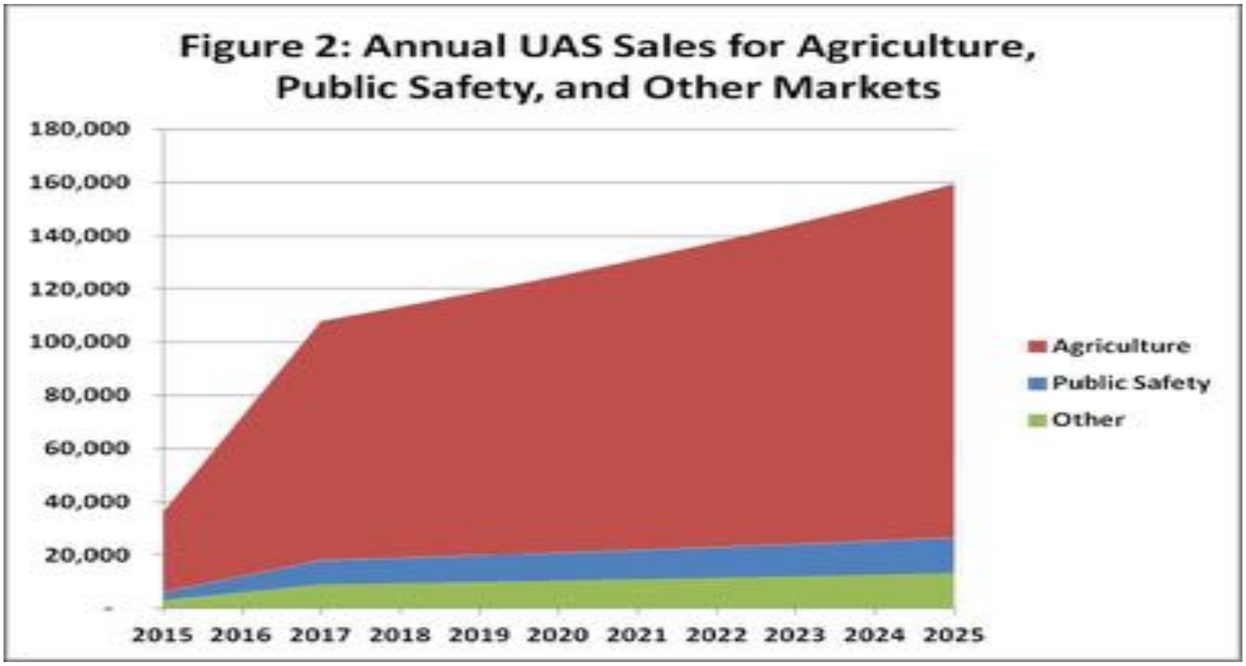
The US, based on statistics which were gathered by ERS (European Respiratory Society) had a chance to enter the European agricultural market in 2012 [43].



Based on statistics if the US decreases the cost of agricultural production (labor cost, pesticide cost, etc.) they save more than 10%. This represents an income increase of approximately 15

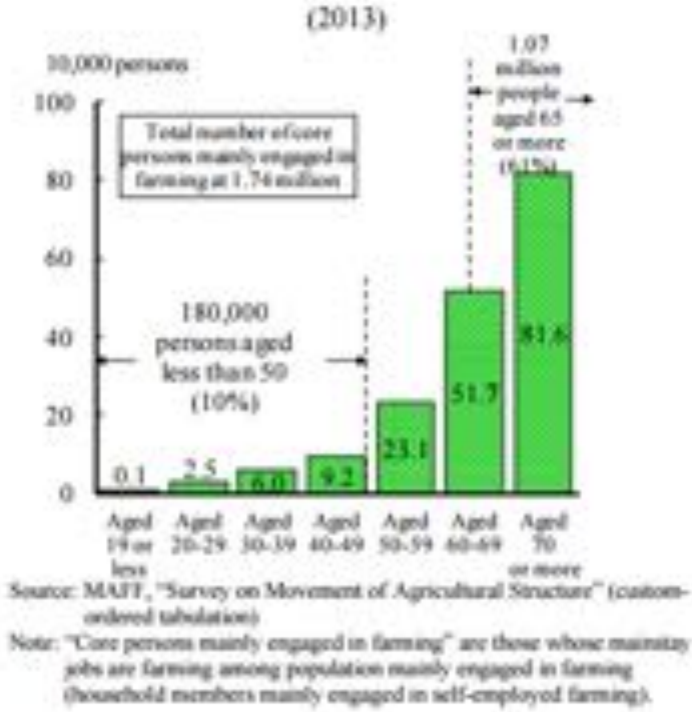
Billion dollars per year. In addition, according to the AUVSI study, the US loses $10 Billion for every year drone production sales are delayed [4].

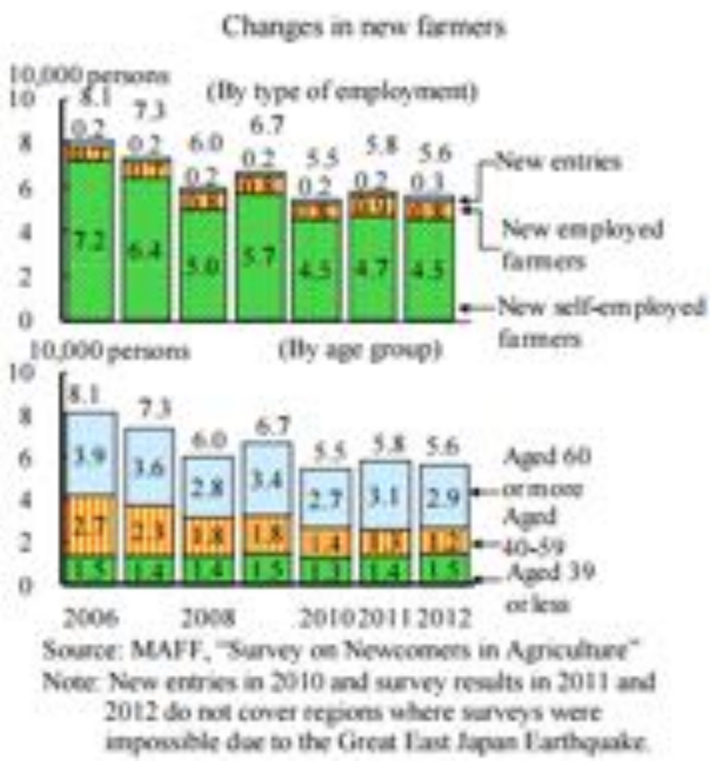
The AUVSI predicts that, with proper regulatory approvals, the growth of UAVs in the USA will expand in the next few years (see below graph), with agricultural drones dominating that sector.



As previously mentioned, one of the main reasons to globally increase UAV use is the growing population of elderly farmers. By using UAVs, farmers will have an easier time applying pesticides to their fields. The following figures compare the numbers of elderly farmers in the USA and Japan.

Japan:





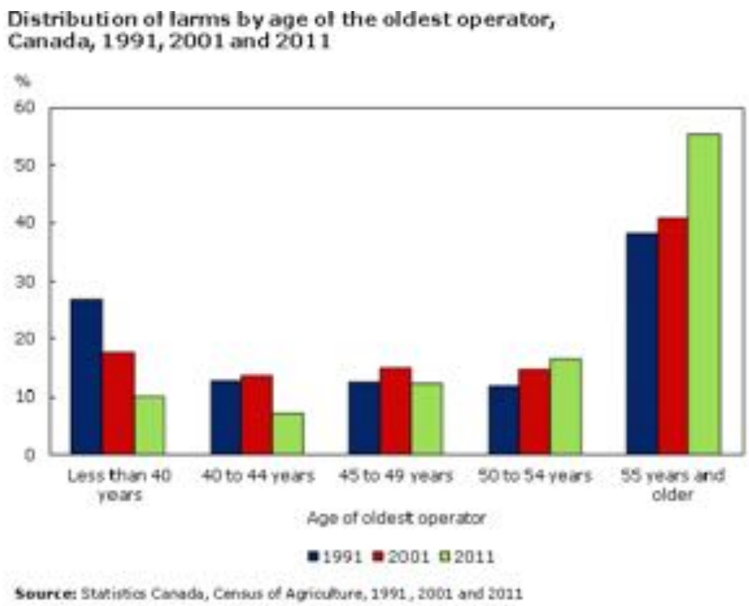
In 2013, 61% of Japan's farmers (1.07 million people) were 65 years or older. Farmers younger than 50 account for only 10% of Japan's farming population.

The number of new farmers in 2012 totaled 56,000 (down 3% from the previous year). By type of employment, new entries numbered 3,000 (up 43% from the previous year) under the effects of new farmer promotion measures including the farming grant for young farmers. By age group, new farmers aged 39 or less accounted for 15,000 (up 6% from the previous year) [22].

Canada

The aging Canadian farming population is getting much older as a statistical group as well.

In 2011 farmers (“farm operators”) 55 years and older made up 48.3% of total farmers, an increase from 40.7% in 2006 and 32.1% in 1991. Farmers in the age group of under 35 are only 8.2% of total farmers in 2011, compared to 9.1% in 2006 and 32.1% in 1991. [5]



USA

	2007	2002	% Change
All Farm Operators	3,281,534	3,053,801	+7
Under 45 Years	732,322	851,091	-14
45 to 64 Years	1,725,777	1,527,742	+13
65 Years and Older	823,435	674,968	+22
All Principal Farm Operators	2,204,792	2,128,982	+4
Under 45 Years	387,431	489,365	-21
45 to 64 Years	1,161,707	1,081,787	+7
65 Years and Older	655,654	557,830	+18

As mentioned before, the most significant role of UAVs is making it easier to pesticide spray and maintain the agricultural field. The population of farmers in the United States is getting older as well. From 2002 to 2007 the number of farms in the U.S. that are 65 years and older increased by 22%, while the number of those under 45 years of age decreased by 14% [41].

In addition to all the aforementioned points, Autonomous UAVs have the potential to revolutionize aerobiological sampling above crop fields. In view of the global focus on developing safe flight regulations, the increasing availability of the technology, and the projections for the global drone markets, the prospects are high for the proliferation of drone use in the US in the foreseeable future. It is true that some of the uses for drones may not be controversial, and thus it would be wrong to demonize the technology itself. However, as we look forward to a world that will inevitably include drones, it will be important to continue to reflect on the original question: will the proliferation of domestic drone use in the US raise new concerns for privacy? There are many arguments to suggest that they will.

Lessons Learned

This study of agricultural UAVs has highlighted how essential regulations are to successful technology adoption and innovation. Without a simple, specific regulatory structure, new technologies struggle in the market. Hopefully with the addition of the FAA's recent proposed regulations, the US market can successfully integrate UAVs into a commercial agricultural setting.

Agricultural UAVs can support sustainable farming. With the ability to map, characterize, predict and release various resources such as water, fertilizer, pesticides, etc, farmers will be better able to manage their crops with the resources needed to sustain them.

Agricultural Technology Management is a vector of human development and economic growth. The successful implementation of technology used in agriculture will help support a growing human population and its increasing demand for food. It will also help alleviate the scarcity of resources and improve crop yields worldwide.

Large companies such as IBM are employing their predictive analytic resources to the field of precision agriculture with the goal of nourishing future generations.

Conclusion

Much like the early hobbyist PC industry which shifted upon the arrival of IBM and its market defining leadership, a similar opportunity exists for Boeing, Lockheed Martin, Yamaha or a similarly established manufacturer to commercialize their preexisting drone technology for US agriculture. Based on analyses of countries that have successfully implemented UAVs in agricultural applications, the United States agricultural UAV market is poised to grow substantially once FAA regulations are in place.

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