Title: Autonomous Farming with UAVs

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ABSTRACT
As the global need for food grows, agriculture is adapting autonomous farming techniques to scale in response. One of the most useful tools are UAVs (Unmanned Autonomous Vehicles), which are providing invaluable information and assistance to farmers. In some countries, UAVs are being rapidly embraced, while in others this progress is much slower. For a number of reasons, the United States has not broadly adopted this technology in assisting agricultural practices. In this article, we focus on the challenges companies and farmers are facing in making use of UAVs and what might be done to push this technology into widespread use.

SECTION I

Introduction

To meet the massive demand of the world's growing population, agriculture has revolutionized with automation, robotics, information services, and intelligence. Over time, smart and autonomous farming is reaching into each and every nook of the world, as its prospects are immense. Another reason why autonomous farming is growing is because, across the world, farmers face many obstacles with traditional farming, like soil degradation, lack of space, pollution, water shortages, etc. In addition, a lack of people willing to work on the farm is growing everywhere. Technology is helping to meet this demand by making work in agriculture more efficient.

UAVs (Unmanned Autonomous Vehicles), popularly known as drones, can provide invaluable information and assistance to farmers. They seem to significantly reduce the working hours in the field and to help farmers grow crops with less manpower, resulting in increased stability and productivity, and thus to farmers' profitability. UAVs can quickly and cost-effectively identify problem areas with imagery and infrared analysis to help farmers diagnose issues early on. Advantages of automation farming include customer benefit from better cared for plants and labor efficiency from needing to do less work by acting on better data. Using UAVs, farmers can better monitor their crops to know when they need more water, pesticides, or nutrients. Spraying of crops can be done quickly by the farmer aerially, without having to have a plane on hand. It can better enable precision farming through image analysis, such as applying pesticides to a row of plants versus fogging the entire crop.

The market for agricultural UAVs has been rapidly growing and several new ventures have emerged. According to market research by Price-Waterhouse-Coopers, the market size of agricultural UAVs is forecasted to grow to about $32.4 billion by 2050, accounting for about 25% of the global UAV market [32]. That being said, there are challenges faced, like high costs and technical issues, and in this article, we will try to address how we can resolve these challenges for advanced agricultural solutions.

In this article, we are also reviewing the European Ag Retailers market conditions and the way they deal with this advancement in technology for autonomous farming and take references from previous published IEEE papers. We focus on the challenges companies and farmers are facing in making use of UAVs and what might be done to push this technology into widespread use. High costs to acquire and maintain UAVs can be a barrier to entry for farmers. Technical issues and breakdown of equipment also present high costs to fix specialized equipment. In order to fully utilize UAVs, farmers will need to become familiar with the use cases and operation of UAVs.

Our scope of research is to find out the current state of companies in the United States, who sell drones to the Ag Retailers or farmers, specifically in the Midwest and Pacific Northwest regions, and suggest possible solutions for improvements. We will address the challenges faced by the companies in Gap Analysis and come up with mitigation strategies and propose a technology roadmap which will help the companies do better in convincing the farmers to adapt to this advanced technology for their betterment.

SECTION II

Overview of UAVs

UAVs, commonly known as drones, are a growing tool across many industries as they are very useful devices. Whether it's the traditional eye in the sky view or less traditional methods like burning trash off a powerline with a flamethrower, drones are a safe alternative to putting a person into a dangerous situation. UAVs are a combination of information and communication technologies, robots, artificial intelligence, big data, and the Internet of Things. Agricultural UAVs are highly capable, and their use has expanded across all areas of agriculture, including pesticide and fertilizer spraying, seed sowing, and growth assessment and mapping. They are the cheapest option for getting an aerial view and with some specific equipment can provide valuable insight from above, such as the Normalized Difference Vegetation Index (NDVI). They can also spray chemicals, providing a cheaper, safer alternative to having a human pilot fly low over fields.

UAV Methodology

UAV methodology composed of the aerial vehicle, the control scheme, the sensors for data gathering, and the communication method.

The types of drones are fixed wing, which functions similarly to an airplane, and rotary wing, which are either like a helicopter with a single rotor or like drones with multiple rotors, the most ubiquitous design being the quadcopter. They share the advantages and disadvantages of their larger vehicular counterparts, such as fixed wing being better in windy conditions and rotary being more maneuverable for taking pictures.

Many drones are manually controllable from a handheld controller, and some can fly a programmed flight path. A few drones like the DJI Agras MG-1P are capable of having flight paths programmed for multiple drones from one controller, which can when needed take direct control of one of the drones. A common communication protocol for drones is MAVLink, which transmits directions, GPS position, and speeds of the UAV. MAVLink is capable of up to 2km communication within line-of-sight, but should a drone lose connection it will return to the first position where communication was interrupted. There are other communication methods such as ZigBee and radiofrequency, and as cellular bandwidth increases, drones will likely use that for transmitting data.

Of the sensors a drone can be equipped with, the most common are visible-light cameras which can provide a bird's eye view of crops. Multispectral cameras collect near-infrared radiation (NIR) and ultravioler, and the NIR data is used with the visible-light data to create NDVI images. Thermal cameras can be used for water stress detection. Light Detection and Ranging (LiDAR) can be used to create 3D mappings of terrain and plant bodies. Hyperspectral sensors collect a narrow band of spectral data. In

combination the data from these sensors can be used to map many aspects of crops health and development. GPS and a compass are both used by the flight computer when software controlled for navigation, and to provide metadata to the images gathered. Anything lightweight enough to be carried by a UAV can be used, so the applications of UAVs will likely continue to grow with researchers' ingenuity.

Some examples are:

- Multispectral images were used to create maps of fruit quality areas [9].
- Lightweight snapshot cameras (cameras which record an image cube with one spectral and two spatial dimensions) were used to derive 3D hyperspectral information [4].
- Multispectral cameras and heat sensors were used to identify areas where water is scarce [1].
- RGB cameras and multispectral sensors were combined to detect infection in potato fields [1].

UAV Frameworks

UAV models in autonomous farming: farmers are using drones to perform their everyday tasks in agriculture. Most drones fall under the categories of rotary or fixed wing. A rotary style drone would be similar to a helicopter, while a fixed wing drone looks exactly like an airplane. A third type of drone is a hybrid, which has both rotary and fixed wings. A rotary drone is often identified by the number of rotors (propellers). An example would be the quadcopter which has four rotors, single rotor, multi rotor, hybrid vertical take-off and landing (VTOL), octocopter, blimp, flapping-wing(SmartBird), parafoil-wing(Tetracam).

Each of these drones has its own advantages and limitations. Multi-rotor and single-rotor (helicopter) drones do not require specific structures for take-off and landing. Fixed-wing systems are usually faster than rotor-based systems, and generally larger in size, allowing for higher payloads.

Drones are classified on a different basis on usage like drones for aerial photography, drones for aerial video surveillance etc. Drones can monitor any type of crop during its growing season, in any area. Drones can be operated in two ways: directly, with a human controlling the vehicle using a wireless remote, and autonomously, with the vehicle controlling itself and following a route based on data from GPS or other sensors.

To name a few drones, we have Rantizo DJI Agras MG-1P Drone, Sentera PHX Fixed-Wing Drone, DJI Mavik Pro and Sentera DJI Mavic NDVI Upgrade.

Rantizo DJI Agras MG-1P Drone:

Rantizo DJI Agras MG-1P Drone is built specifically for agricultural drone spraying, these industry-leading drones deliver liquid or dry inputs precisely where you need them, when you need them. They're nimble and spry, flying up and over fields to avoid soil compaction and costly crop damage caused by traditional implements.

Sentera PHX Fixed-Wing Drone:

Sentera's PHX Fixed-Wing Drone is a highly-reliable, easy-to-use, hand-launchable fixed-wing drone that gives the ability to view live HD video and capture a wide array of analytic data, including stand counts, weed locations, and plant health using the newest variants of the Sentera Double 4K sensor payload.The PHX is the best-performing and best-valued professional fixed-wing drone available today.

DJI Mavik Pro and Sentera DJI Mavic NDVI Upgrade:

Sentera offers the highly portable DJI Mavic 2 Pro drones, upgraded with High Precision NDVI sensors to produce actionable NDVI data. The Sentera High Precision NDVI Sensors transform the pocket-sized Mavic into an easy-to-use precision scouting tool. The High Precision NDVI sensor enables a grower to capture NIR imagery and produce normalized difference vegetation index (NDVI) crop maps while retaining the ability to use the Mavic's 12-megapixel sensor, capable of shooting 4K video.

SECTION III

Applications of Agricultural UAVs

The application of the UAV simply changes to fit the needs of the farmer. Agricultural UAVs perform numerous tasks in various working environments. Their demands are steadily increasing and they are used in rice paddies, fields and orchards. The agricultural UAVs are used to help optimize agriculture operations, increase crop production, and monitor crop growth.

Agricultural UAVs offer the potential for addressing several major challenges in agriculture. In addition, extreme weather events are on the rise, creating additional obstacles to productivity. Agricultural producers must embrace revolutionary strategies for producing food, increasing productivity, and making sustainability a priority. Drones are part of the solution, along with closer collaboration between governments, technology leaders, and industry.

Drones have emerged as a vital tool in agriculture, with a wide range of applications. Ideal for tackling challenges in the field and converting complex images into usable data, drones help maximize operational efficiency and transform agriculture around the globe. The number of application areas where UAVs become useful is almost unlimited as they are being integrated with emerging technologies, onboard sensors and computing capabilities.

Some examples of UAV use in agriculture are:

- Mapping, Scanning, Spraying, Planting
- Crop monitoring, Irrigation, Diagnosis of insect pests
- Artificial pollination, Weed recognition
- Assessment of soil electrical conductivity
- Remote sensing
- Data acquisition and analysis methods in UAV
- Monitor the growth of the vegetation and estimation of yield

Mapping
Mapping is the process of using a drone to map or survey crops. It is an important way to monitor land and manage future activities. It helps to understand and map different types of data regarding soil health and nutrition, slopes, water and irrigation systems. UAV-created 2D or 3D maps of an agricultural field can provide useful information. For example, model upgrades and efficiency might be based on the area of the farmland, soil conditions, and crop status. Drones provide instant mapping services that help create and process maps while in the field, regardless of the season, topography, or ground conditions.

Scanning and Spraying
Drones are ideal for crop spraying by scanning the field first and calibrating the exact amount of water or fertilizer to be sprayed in the correct areas. Compared to a speed sprayer or a wide-area sprayer, UAVs can reduce pesticide use and maximize efficiency. A drone may alter its altitude as the topography and geography change, avoiding collisions, using distance-measuring devices like ultrasonic echoes and lasers like those used in the light-detection and ranging. Consequently, drones can scan the ground and spray the correct amount of liquid, modulating distance from the ground and spraying in real time for even coverage. The result: increased efficiency with a reduction in the amount of chemicals penetrating into groundwater. In fact, experts estimate that aerial spraying can be completed up to five times faster with drones than with traditional machinery.

Crop Monitoring
UAVs are frequently used for Monitoring the growth of the vegetation and providing estimation regarding the yield. The lack of means for systematically monitoring the progress of cultivation is considered as one of the major obstacles to increasing agricultural productivity and quality. This problem is also compounded by the variability of weather conditions that alter the micro-climate of crops jeopardizing agricultural production. Regular collection of information and visualization of crops using UAVs, provides increased opportunities to monitor crop growth and record the variability observed in several parameters of the field. Drones allow farmers to constantly monitor crop and livestock conditions by air to quickly find problems that would not become apparent in ground-level spot checks. For example, a farmer might find through time-lapse drone photography that part of his or her crop is not being properly irrigated.

Irrigation
Drones with hyperspectral, multispectral, or thermal sensors can identify which parts of a field are dry or need improvements. Additionally, once the crop is growing, drones allow the calculation of the vegetation index, which describes the relative density and health of the crop, and show the heat signature, the

amount of energy or heat the crop emits.

Diagnosis of Insect Pests
Insect pest outbreaks are unpredictable and not uniformly distributed within fields. Current scouting methods are time consuming and provide incomplete coverage of these pests. Unmanned aerial vehicles (UAVs) are capable of collecting high-resolution imagery that offer more detailed coverage in agricultural fields than traditional scouting methods.

Assessment of soil electrical conductivity
Soil conductivity is a direct reflection on how well the soil holds moisture, which in itself informs how much water you can or should put into the soil during the growing season. Drones can be extremely useful in the beginning of the agricultural cycle. They produce precise 3-D maps for early soil analysis, useful in planning seed planting patterns. After planting, drone-driven soil analysis provides data for irrigation and nitrogen-level management.

Artificial Pollination
Drones that blow bubbles to delicately deliver pollen to flowers. As the world's honeybee population continues to decline, research into a robot pollinator has gained traction. As a result, the National Institute of Advanced Industrial Science and Technology (AIST) has created a small unmanned aerial vehicle (UAV) for pollination. To transport pollen, the robot employs animal hair that has been coated with gel. These UAV robots will be equipped with AI, GPS, and cameras, according to AIST. Pollination has also been carried out using the wind power generated from UAVs, rather than by direct contact.

Remote Sensing
Remote sensing is generally considered one of the most important technologies for Precision Agriculture and Smart Farming. It is commonly used for monitoring cultivated fields, providing effective solutions for Precision Agriculture in the last 35 years. Remote sensing can monitor many crops and vegetation parameters through images at various wavelengths. Remote Sensing is commonly used to monitor crop fields and monitor the growth of the vegetation and estimation of yield.

Data Acquisition and Analysis Methods
Agricultural UAVs provide a platform of data capture which gathers information from a large variety of perspectives in a short period of time. E.g., data gathered at the plant level on demand, which can make the difference between high and low yielding crops. By adding more and more data sources, we expect to find hidden relationships and make further improvements in farm management.

SECTION IV

Research scope

Like other industries, the agricultural sector has been using innovation utilizing convergence technologies. UAVs have proven to be highly utilized throughout the sector. However, agricultural UAVs face numerous technical limitations, such as battery efficiency, low flight time, communication distance, and payload. Technical limitations must be solved to provide the right approach for the next generation of agricultural solutions.

In our scope, we are going to define the problem(s) faced by UAVs (drones) in the agriculture industry in terms of the below mentioned parameters.

- Financial Challenges - Cost of UAVs, Return of Investment
- Cultural gaps - Mindset barriers
- Rules and Regulations - Government support
- Operational Issues - Technical problems, Maintenance issues
- Technology Maturity - Data collection

Our areas of focus are the Midwest and Pacific Northwest (NW) regions of the US. Our scope of research is the current situation in both regions, general findings across the United States, and findings specific to the Pacific Northwest, the challenges faced by the companies and the farmers, their opportunities and possible improvements.

Research Method

The research method has mostly been a review of publications and journals from IEEE literature, and interviews conducted with agricultural companies who are selling UAVs (drones) to farmers and Ag retailers. We also used some UAV and UAV sensors selling companies' websites for information on their products.

We conducted interviews with Precision Ag companies from the Midwest, like Sentera and Rantizo, who have given us insights on the current state of autonomous farming, their challenges and opportunities, how they can do things differently to achieve more involvement from farmers and Ag retailers, and their willingness to shift from traditional to automation farming.

We also discussed with Victor Villegas, a drone enthusiast, from the Computing Technology Unit at Oregon State University, who shed light on the usage of UAVs in Oregon.

With all these inputs, we plan to do gap analysis to identify the current agriculture trends in smart farming, the problem areas with existing UAV farming, and propose ways to adapt and resolve the challenges on the way to be resilient to changes. We plan to set the right goals and discuss the current state and the desired future state, based on the gaps in the existing system. We also plan to examine the challenges and limitations and provide direction on the prospects and possibilities for future research with the help of our technology roadmap as well as agricultural drones product businesses to better understand the requirements from farmers and Ag retailers which can help them collaborate with government agencies in the future to provide more sustainable solutions to existing agricultural problems.

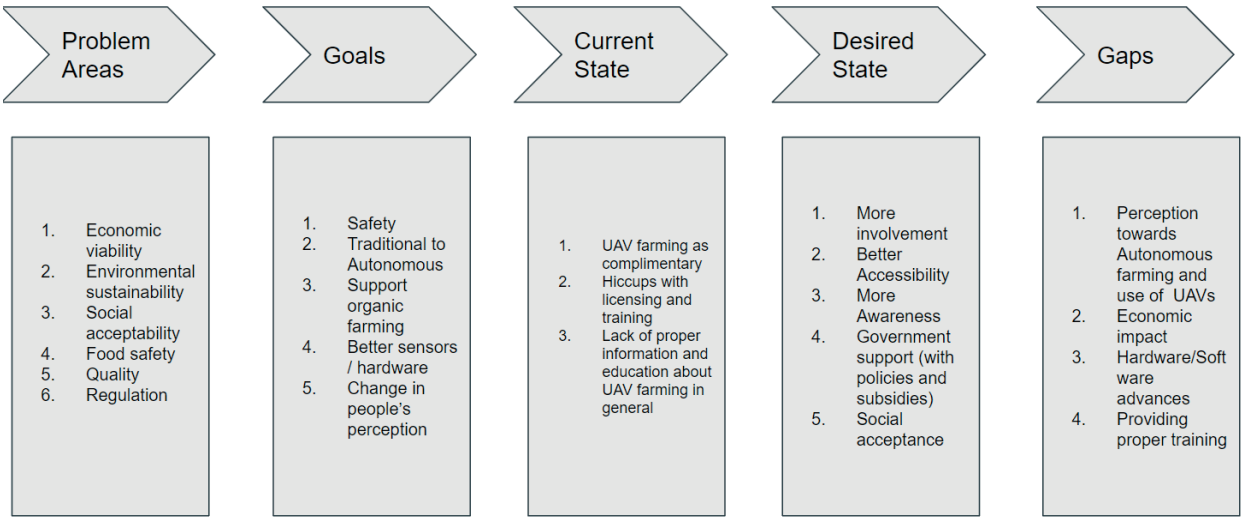
GAP Analysis

Nowadays, agricultural producers are increasingly attempting to combine computer vision methods with the output from unmanned aerial vehicles (UAVs) to automate farm operations aiming at speed, precision, and cost. In this context, time-consuming tasks such as crop monitoring may be solved in a more efficient and less error-prone manner. In particular, for estimating productivity and managing pests, a key task that may be automated is the characterization of crop regions into full-grown trees, tree seedlings, tree gaps, and background. In this paper, we address the classification of aerial images into these classes, targeting samples from a citrus plantation acquired by UAVs [36].

Managing a farm and its inventory monitoring of plantations in order to estimate productivity and to avoid possible losses to the farmer. When performed manually, this process can be extremely time-consuming

and exhausting, as counting and registering the state of each individual tree can take up to several weeks, depending on the total area of the plantation.

To bridge these GAPs, we will be identifying the problem areas and discussing ways to bridge the same. Below diagram will guide us through these 5 phases that our team carried out to bridge the gaps.



A gap analysis is a method of assessing the performance of a business unit to determine whether business requirements or objectives are being met and, if not, what steps should be taken to meet them. This helps to understand the trends which in-turn helps identify the problem areas which can be solved in a methodical way. Let's discuss gap analysis with respect to our scope and better understand how we can achieve the desired maturity state:

1. Problem areas - This helps identify the trends in our business domain and provide a base as to what the problem areas are and better understand it. For UAVs in agriculture we have identified these problem areas mainly being economic viability, environmental sustainability, social acceptability, food safety, quality and regulation.
2. Goals - Based on our problem areas above we can define our desired state to reach so that our business objectives can be achieved. Our desired state can be reached by the following goals:
    a. Safety and security - better hardware for safety and better software for secure system communication
    b. Traditional to autonomous - move from tedious traditional farming to better and more efficient autonomous farming
    c. Support organic farming - UAVs assist greatly in organic farming, which can help sustainable agriculture.
    d. Better infrastructure - better R&D in infrastructure can help lower the costs and be more accessible.
    e. Positive public perception - Marketing and educating the general public with information and training can help better spread the benefits of autonomous farming.
3. Current State - This is the existing stage where we stand in UAV farming. There is a long way to go but we need to identify our existing state so that we can head towards the desired state. Based on our interviews we identified that UAVs have been sidelined into a complementary service due to problems with licensing and training since it's not widespread. This combined with misinformation can be catastrophic which explains the current UAV farming situation in the US.
4. Desired State - The ideal state is for UAVs to be more involved in farming techniques and normalized with better accessibility of these services and spreading awareness among Ag

retailers and farmers. Another main lacking area is the support from government bodies which needs to be bridged along with social acceptance of UAVs as a viable farming solution.

5. Gap resolution - The desired state can be achieved by bridging the above discussed gaps. This can be done through changing perception towards autonomous/UAV farming. Going autonomous can have a larger economic impact since UAVs are very in-expensive compared to heavy farming machinery and get the work done at a fraction of the cost. Another gap resolution that can happen would be by providing better training opportunities to Ag retailers and farmers.

SECTION V

Discussion

Issues like aging rural population, farming interests, self-sufficiency, and declining labor force, and increase in minimum wage for laborers have ticked up the use of automation. Innovation is the key to help with these issues to feed the ever-growing population. Though UAVs have limitations, there are approaches to solve them. In this section, we are to discuss how the European Ag retailers' market deals with this advancement in technology for autonomous farming.

We are also going to discuss the observations, challenges, and opportunities for the two Midwest companies in the United States, based on our research interviews conducted with Sentera and Rantizo. These are Precision Ag companies and are involved in helping farmers directly or indirectly with autonomous farming and use of UAVs (drones).

We will also discuss our conversation with Victor Villegas, a drone enthusiast, from the Computing Technology Unit at Oregon State University, who has shed some light on the usage of UAVs in Oregon.

European Ag Retailers Market

Modern and efficient farm equipment lets farmers improve their produce, reduce input costs, reduce work, increase comfort, and more. Such precision agriculture equipment produces higher yields with reduced pesticides and increases the efficiency of the agricultural area.

With the advancement in technology, several companies are using drones and robots to improve crop production. While field robots are not commonly used, drones are taking off in precision agriculture. Drones are used to capture images and provide data to monitor crops starting from planting to harvest. With drones, farmers can react faster to threats such as weeds, climate change, etc. and take appropriate actions in real-time.

Much has been said and written about the revolution promised by unmanned aircraft systems (UAS) in the agriculture sector. And, make no mistake, there are drone-based service providers doing good business, making lots of money, in moderate numbers, across Europe. They're delivering highly valuable information and analyses on everything from plant numbers to ground water content to precise field measurements.
What one would like to see is a drone in every barn, alongside every silo and hovering above every field. That kind of uptake could have a shattering impact on the drone manufacturing sector, engaging new waves of software developers, and ultimately leading to real advances in terms of food production and environmental performance.

We found an interview online for a European drone company Height Technologies (Interviewee Robin

Schardijn), a global supplier of professional drone equipment based in Europe. He said, *"To really see drones in large numbers like that, really like basic farm equipment, I think that needs a generation, because it needs a younger mind. The farmers right now, in our area, are used to working in a particular way. They are happy [31]".*

"*Don't forget that it was only a few years ago that they made the step to positioning, using a GPS connection for their harvesting and things like that*," Schardijn said. "*Today, they have multi-constellation GNSS, and they are on their computers, checking the weather and all sorts of other information. Drone technology is something they are interested in, but all the associated sensor technologies and the way they collect data, it's still quite new for a lot of people [31]*."

While Schardijn may seem at first to paint a woeful picture, he and many of his colleagues are in fact far from fatalistic. The state of affairs must be seen as a challenge to overcome, and also as a massive opportunity to unlock.

The company or group or person who solves that puzzle stands to gain a great deal. Let's just say it's up to everyone, everywhere, by all means, to get cracking.

Insights from Sentera

Sentera is an agricultural service company in Saint Paul, Minnesota. It is the global technology leader for in-season data, analytics, and insights for growers, deployed at scale. Sentera's products make it easy for users to integrate in-field data insights with the digital ag platforms in use by more than 80 percent of the growers in North America. Sentera's equipment has flown tens of millions of acres all over the world, and processes hundreds of terabytes of new data for its customers every year.

Sentera offers individual cameras, sensors and drones, and complete solutions as well to their customers who are mostly the Ag Retailers in the area. Sentera has a digital FieldAgent Platform which is a complete agricultural data analytics solution that's with the user wherever they are — in the office or in the field. Coupled with a Sentera precision ag sensor, the FieldAgent platform can take them beyond aerial photography into essential data products with actual economic value, such as NDVI and NDRE zone analysis, population analysis, weed mapping, and elevation mapping.

Their marketing strategy is word of mouth publicity by the users who are already using their applications and products, and they specifically target marketing the uses of the data products, which helps the customers buy as per their needs.

The major challenge Sentera has seen is the people's mindset on accepting the new technology over the traditional methods of farming. Provided the drones would have been more mature in their usability, it would have been easy for the customers to accept them and use them widely, and not as a complimentary service. Technical limitations of the drones, limited knowledge on how to use them, and varying levels of user competencies have also been the driving force behind their non-acceptance in daily uses. So Sentera's strategy has been to educate the customers in a better manner, in such a way that they can utilize drones more in all applications like mapping, scanning, spraying, planting, crop monitoring, etc. for their own good.

Sentera does not offer direct training to the farmers, but they offer onboarding services to the Ag retailers and the ones who sell chemicals to farmers. They teach them how to fly drones and advise them on how to use their technology better. They also have third-party partners who do full-fledged training for their

contractors. They also provide custom application services, so they can spray fields for contracted farmers.

Sentera provides maintenance support for crashes or malfunctions in their business hours. They have offers for regular maintenance upgrades and documentation which the customers can refer to when needed.

The customers mostly buy the drones, and there are financing options available like leasing or bank loans for small or medium sized businesses.

Sentera shared an experience they had with a customer who didn't have a better way to evaluate his field condition and identify or rectify any problem areas. Before the farmer had bought the drone, he mentioned that the drone could have saved him $8000 had he had a drone. Hence it is obvious that drones can be cost effective and profitable with less manpower when used properly, though there still isn't any quantification available on specifics. Evolving technology and adding more features and functionalities is surely a deal for their customers. This is very much in a premature state and will need time, efforts, and mindset to fully utilize the advanced technology to reduce manpower, which Sentera foresees 20-30 years down the lane.

Speaking about technical challenges that the farmers might have shared with Sentera, they mentioned that since drones mainly operate through the controller and the cellular iPad, there is no impact yet on connectivity problems in rural areas. They might face issues in future when there is no field map available and the iPad which controls the drone isn't cellular. But in the present state, it is not a hindrance.

Sentera has come across farmers who are reluctant to use UAVs, as the technology is fairly new and still needs more knowledge around it, and people's perception towards accepting the advancements has been quite an interesting challenge. In such a case, they tried training or pointing their customers' to Sentera's training or supplement materials for gaining the required expertise.

There hasn't been any major problem with licensing yet, and they haven't been required to help in licensing as of now. They are not aware of any state regulations as such which prevent the farmers from chemical spraying by UAVs, as long as the customer or consumer group has a drone license to operate up to 400 feet above the ground. They currently don't have a lot of services to offer or collaborate with the government. But with increasing demand and disruption in the industry, they see possibilities for government collaboration and incentives in the future.

Sentera's business model mainly revolves around providing hardware and sensors to customers and Ag retailers, both organic and non-organic farms use their products the same way. Factors are based on the size of the farm, crops they grow, and the extent to which they can use the sensors to complement existing mainframe hardware.

Insights from Rantizo

Rantizo is an Iowa City based agtech company that uses drones to deliver ag inputs in the field precisely when they are needed where they are needed. The Rantizo turnkey system integrates with field imagery data to precisely deliver liquid and dry solutions using targeted drone-based agricultural spraying and applications. Rantizo is the only company approved for drone-based agricultural spraying in multiple states and recently became the first approved for nationwide swarming for spraying, as well.

Rantizo uses DJI drones at the core of their agricultural drone spraying platform. DJI is the market leader in the drone manufacturing industry and has over 70% of the market share worldwide. With their

reputation for being the leader in drone spraying for agriculture, Rantizo wanted to work with the best. They use the DJI Agras MG-1P currently, however, the Rantizo platform can easily adapt to other drone models should the market dictate that in the future.

Rantizo generally markets their products through social media and printing advertisements. They also rely on their customer acquisition database for the list of Ag retailers who are using their services. They have a Multilevel marketing (MLM) business model where they educate the contractors for the sale of their products and services.

Rantizo's major challenge has been reaching out to the right customer in today's tough market and intense competition. There are other companies who sell drones which might have legal issues, but sometimes the customers ask for such drones. That seems to be a tough call to address such issues and convince them to use Rantizo's. So, their strategy is to do more local marketing, get customers feedback, and provide them better training and education.

They also do not offer direct training to farmers, but they do so to the Ag retailers who buy their products and platform. They provide custom application services and training, such as to spray fields for contracted farmers. They also have a general training package with the product and offer options for partnership with third-party vendors who do full-fledged training.

Rantizo sends reminders for upgrades through phone applications and has 24X7 maintenance support. They don't offer for rent, so their customers only have the option to buy the drones. They do not have direct financing options available from them, but their customers can reach out to financing companies if need be.

This year in Iowa, and mostly regions in the Midwest, farmers had to spray fungicides on corn, and the airplanes were fully booked up. The only opportunity were UAVs (drones), so it was a huge success in July 2021 for Rantizo. Though there isn't any quantification available on specifics, their customers have mentioned that drones have made accessibility easier, and have increased efficiency, hence leading to more profitability. Majorly, the drones till now have mainly complimented their existing operations by making it more efficient for profitability rather than reducing human labor.

There isn't any WIFI connectivity required yet for the drones to operate, but Rantizo sees a future which will need broadband connectivity in the countryside for field map issues.

They have come across farmers who were reluctant to use UAVs. They are okay with the cost of the drone, but it's mainly the effort to make the switch from traditional to complimentary services which makes farmers hesitant. Better ways to market drones have helped them in such scenarios, like concentrating on the customer and their needs, and explaining to them about the results they can achieve. For customers who do not understand the UAV services, Rantizo provides training to explain their services, which complements their existing methods of farming, rather than as a whole new technique.

A chemical spray license needs to be acquired before the application. Like they mentioned, in California they need to get a licence for each county that they spray in, which becomes a pain at times. Similarly, Mississippi is very challenging to get a license since they have language in their rules which makes it harder to get a license for UAV spraying. They do not yet get any incentives or support from the government. As the industry matures, they might consider partnering up with the government for more initiatives.

They also shared that smaller farms with usage of non-commercial products to identify any deficiencies with a drone is easier than using heavy machinery. Drones can be used to drop beneficial insects onto organic farms for natural farming.

They monitor the UAVs when needed with some communication in pilot mode to observe and detect any problem or issue that the drone will either hover, shutdown or come back to base. So, they have protocols on what needs to happen when there are connectivity issues or loss of communication.

Conversation with Victor Villegas

Speaking with Victor Villegas from Oregon State University in an interview, he shed some light on existing advancements on drone usage in farming. According to him, UAV usage in the farming industry is still naive in the Pacific Northwest. It has mostly been in the research stage rather than implementation stage.

UAVs are still seen as a high maintenance approach since not everyone is well aware of the pros and cons of using them. He also pointed out that there is a lot of potential for growth for drones, but it has been limited due to the lack of knowledge and external factors. Some of the common concerns include the lack of robust hardware. Being a drone enthusiast himself he believes a lot of advancement has happened and will happen in this regard but will take its time which takes us back to our earlier point of maturity.

SECTION VI

Challenges and Limitations

This section is to address the challenges and limitations for the UAVs, the companies selling them and the Ag Retailers and growers who can benefit from the UAVs for autonomous farming.

Financial Challenges

Using technology in farming is not foreign to farmers as they have been using GPS equipped farming machines to improve efficiency in seeding and harvesting. These technologies proved to be easy to use and have good return on investment (ROI). Consequently, farmers moved to adopt these technologies when there was an economy of scale to use it. For example, corn farmers who plant and harvest over 1,000 acres would reap the benefit of owning or leasing a GPS equipped combine machine to perform the work.

In drone and UAV, the ROI has not proven itself yet, as it is still in the research phase when applied on thousands of acres. Consequently, the application of UAV so far is limited to companies as a third party who are serving farmers.

Cultural Gaps

Another limitation observed while selling UAVs in the market are the cultural challenges, specifically moving from the traditional methods of farming to adapting the advanced technologies. Mainly, the effort to make the switch from traditional to complementary services like UAV for their business unit.

To move from a set of farming practices to a new one with new technology requires the culture of adaptation and changes in the existing infrastructure that serve the existing practices. This is a gap that still exists among farmers and especially retail ones.

Companies who serve farmers, while marketing, can concentrate on explaining to farmers that they complement their existing practices instead of replacing it. It is another tool in the toolbox, how they can train the users to effectively use their services to spray specific patches or spots and reduce the cost of chemicals. They can train them on how they can use their services in the near future to improve efficiency.

Trying to convince the end customers (farmers) that this is in their best interest, and that the UAV service is an add-on service that complements their existing methods of farming, rather than seeing this as a whole new technique that they need to adapt to.

A decade earlier, there had been some bad experiences when the technology wasn't mature enough. This also restricts growers to accept the positive potential impact they can have while using the drones. Change in this perspective would definitely motivate farmers to use the equipment more. They know their agronomy better, so the companies will just have to show them that the data will be relevant to what they are currently doing.

Rules and Regulations

Since this is an emerging technology, regulations play an important role as they are in the process of formulation. There aren't many rules and regulations for flying drones and using them for agricultural purposes. Hence the growers and the company operators selling drones, have to explore various challenges these regulations pose in using UAVs for agricultural purposes in most of the United States. An example of this is below:

While not the first in the country to consider it, Three Rivers through a seven-month process became the first to be approved by the FAA for vector control drone spraying. They mentioned in an interview to a news channel, "The FAA wasn't sure how to test us — we had to submit our own rules for training, so we made our own set that now the FAA is following," Horvath said. "The local FSDO was really excited though, I guess they wanted to be the first [23]."

Operational Issues

There are operational challenges to UAVs like the line of sight (regulatory requirement) for flying drones in difficult terrains. In regard to FAA rules and regulations, drone pilots are expected to fly drones only in the visual range, though there are drones which have the ability to fly beyond it. "The potential value drones have for farming has largely been stymied because the Federal Aviation Administration (FAA) currently limits unmanned aircraft to fly within visual line of sight of their pilots in the United States [33]."

Dennis Lott, CEO of drone consultancy firm UAS Solutions in Jackson, Mississippi, who collaborates on small UAS projects for agriculture at Mississippi State University, is also an Ag Pilot. He mentioned in an interview that, "You can't cover the acreage needed to be covered with those restrictions," Lott said. "With visual line of sight one can see only about 2,500 feet, more or less, so I might be able to cover a mile end to end if I was standing in the middle of the field. You can't cover the fields that need to be covered efficiently if you have to constantly reposition yourself. It's just not a productive way to utilize an aircraft, to give farmers the information they need at the most reasonable, economic rate possible. It's a real hindrance to the successful growth of UAS in the ag community when you are limited to visual line of sight [33]."

Another major technical challenge with UAVs is battery and flight time limitations. To add to it, there are technical difficulties and breakdowns due to malfunctions. Battery management requires constant maintenance, causing increased periodic replacement, resulting in additional costs. Furthermore, improving the user interface can help users who are older or unfamiliar with UAVs to control the UAVs more easily. More specifically, human-centered user interfaces with easy usability, accessibility, and feedback are efficient to deal with multi-UAV systems.

Data storage and management is another huge problem which the users face, as drones generate a large amount of high-resolution data. One 30-minute drone flight may produce 500 photos, which can exceed 3 gigabytes in storage needs. Hence if everything is kept in house, desktop or laptop programs require significant storage and memory to process drone data, and processing requires a lot of expertise. Outsourcing flying and processing data can help farmers and Ag Retailers, but that adds to additional costs for costly computing power and software. As things scale larger, Internet-based processing and cloud storage are the best available options. Cloud storage allows team members to access data on multiple devices. Everyone can be looking at the same image at one time. However, access to cloud storage requires a strong Internet connection, which is another hitch in rural areas [34].

But cloud storage comes with concerns on data security and privacy. Drones and the data they carry can be hacked. To combat such issues, tech companies are working on security systems that protect against and deter rogue drone intrusions. Much more remains to be done in the area of security protection for each individual drone, including how to manually override automated systems in the drone from the ground when a security compromise occurs [35].

Technology Maturity

The drones serve two purposes, data collection and application of services. Drones can be equipped with sensors and cameras to collect data for the farmers to interpret and take actions according to the data collected. Sensors can detect stress levels in the crops which can be a measure to determine the irrigation need. Cameras can take photos of diseases on the crops which will help the farmer to determine the needed treatment and its location before it spreads to the entire crop. This is the ideal implementation, however, there are no current applications that can group this data and provide recommendations to the farmers. The link in the applications development between the data collection and the recommendations and implementation of the actions is still in its infancy phase. Consequently, farmers are not adopting this technology at a fast pace even though it has lots of prospects.

SECTION VII

Possible Improvements

There is a lot of scope in the Pacific Northwest region to advance to the next level. While not all the farmers are willing to adapt to the new technology, many are. For example, the Green Giant brand in California available at Walmart, Target or virtually every other major supermarket is a great example where we can see how much more work autonomous machines and drones are doing on the farm, as the minimum wage has increased in the state. Robots and drones are shouldering more responsibility at Church Brothers Farms in Gonzalez, California [27].

In this section we will explore opportunities for future uses of the technology and it's spread among companies and retail farmers and provide resolutions for the challenges faced by the companies and the farmers, in both Midwest and Pacific Northwest regions of the United States.

1. Managing Technology

Technology improvement can be done on different fronts:

i. Hardware technology:
   a. Improve battery life for meaningful use of the drones
   b. Improve data storage of the drones and computers
   c. Improved the connectivity between drones and controllers to transfer data and computer to cloud to analyze the data
   d. Improve technical support for the end users.

ii. Software and application
   a. Develop interoperable applications that can operate on different platforms
   b. Develop Agricultural applications that can analyze large amounts of data in a short time instead of manual shifting among data and photos to detect diseases and other data.

2. Managing finance

The implication of using drones on crops can be costly to own, to maintain, to update and to mitigate risk of malfunctioning. Agriculture drone manufacturers can provide a menu of options for companies and farmers to adopt this technology, such as a lease program instead of owning or trade-in options for older drones.

There are non-profit organizations that assist farmers in the Northwest such as Lagange and 4-H who can play a role in supporting retail farmers to adopt this technology. Government subsidies, low interest loans or grants for farmers who are open to use this technology, can also help.

3. Managing rules and regulations

Farmers and agriculture machining companies have a strong lobby in the Northwest and nationally. They can start conversation on relaxing the regulations for farming applications of drones while coupling it with specific training programs and permit requirements to issue licenses and formulate new rules to follow for flying UAVs.

This will help the industry to move forward by easing the strict regulations on flying the drones within the eye-site.

4. Managing training and education.

Oregon State University (OSU Extension) is an example of great agriculture research programs where education and training can be connected with the local communities to bring this technology to practical implementations. OSU extension had published documents on UAVs, their usages in Oregon and applications [39,40].

Similarly, California and Washington state's universities are well connected with the communities to provide research and technology implementation for the farming communities.

The companies can also do knowledge sharing with the already existing companies in the market, use

already available expertise in operating and using UAVs, and launch top-notch academic and research programs in agriculture.

There are a lot of experts in Oregon who can work on security and data privacy, as well as large and small tech companies who are interested in getting involved in these projects [6].

5. **Managing People**

The companies can work together to achieve a goal where autonomous farming will be able to replace traditional farming for major tasks like seeding, weeding, spraying, etc. which is time consuming and needs more manpower across huge acres of land, sometimes being difficult terrain.

Ag retailers can try ways to change perception in people to adapt to advanced technology to help in farming. Similarly, eagerness to learn and be trained on how to use drones more efficiently and effectively from the farmers' viewpoint is also needed.

They can talk to their customers to convince them about how UAVs have a positive potential to help the farmers get more insights on their field condition, and much more. They can help calculate the cost effectiveness with more profitability and less labor.

6. **Managing Operations**

Locked in steps with the technology management, the operation management will improve as technology maturity improves. Companies serving the farmer can be the first to improve their operations and proving to be successful in a niche market such as spraying or crop monitoring for timely harvesting of fruits that are hard to reach from the ground (cherry, apple, etc..) or crop that require significant manpower that can disrupt the farm ground in in wet seasons (strawberries and blueberries, etc..).

Technology Roadmap

A roadmap is an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of the change [37]. Technology roadmaps are gaining acceptance in industry and government laboratories, and now there are signs that the application of road mapping to agriculture and sciences may grow even faster.
The optimal process for gathering and selecting the content of roadmaps is to include as many practicing professionals as possible in workshops periodically in order to allow all suggestions to be considered and to objectively evaluate the consensuses that will more often than not emerge. Equal treatment should be given to minority views and individual advocacies.

Roadmaps allow industry leaders to communicate convincingly with those in government and business regarding their support of our goals. I believe a similar use of roadmaps in agriculture advancement would allow a fresh, positive approach for automated farming to emerge among farmers and Ag retailers. Similarly, business leaders would have a renewed interest in financially supporting UAV farming which can help resolve financial instability of the industry.

Based on our research, we propose the following business model canvas for the autonomous farming companies to be able to describe, visualize, assess and change their existing business models to create and earn more revenue, deliver more value, and overcome the challenges in their current operations.

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITIONS	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Partnerships with Ag Retailers Service Providers Government Agencies Competitors Advertising Agencies	R&D and Product development Application services Product maintenance Easy to use Apps Better marketing Finance Management	Positive Potential Cost reduction Easy use and access Reduced Manpower Product Customization Profitability	24*7 Customer support User friendly Systems Usability, better battery life Accessibility Positive mindset More Training and Education Easy Regulations to Fly Own Community with service users More Automation	Ag Retailers Growers (Farmers) Small Scale Business owners Ag Service Providers Large scale farming companies
	KEY RESOURCES		CHANNELS	
	Human Intellectual property Physical Financial		Right marketing Government support Less Legalities Lucrative offers Insurance Dealers and Retailers	
COST STRUCTURE		REVENUE STREAMS		
R&D expenses Training expenses Manufacturing Product roadmap Operation cost Licensing fees Copyrights of their product Legal expenses		Advertising Partnership Subscription Model Product sale Add-on Modules sale		

Key Partners:

Those companies manufacturing or selling UAVs can partner with Ag retailers, service providers and government agencies to optimize their business models, reduce risk, or acquire resources. They can also have strategic partnerships between competitors and advertise their product better and enhance buyer-supplier relationships.

Key Activities:

The key activities for the companies should be research & development, providing application services, maintaining the product, and providing easy to use applications. The companies should focus on better marketing and management, provide continuous training to the newly added Ag retailers and give more finance options, to help the Ag retailers and farmers be able to use the UAVs easily without facing major hassles and challenges.

Key Resources:

Key resources are human, intellectual, physical and financial. These companies need human key resources like Ag retailers and service users, like the direct farmers. They should also be able to retain the already subscribed farmers. They should rely on intellectual resources like Brand, proprietary knowledge, patents and copyrights, partnerships, and customer databases and company culture. If a new product is launched by any competitor, the company culture should be such that it can reflect on ways on how to better its product with enhanced learning, and not be resilient to the market competition. They should also partner with known and available brands in the market, as a brand always speaks for itself! They should also have physical resources like distribution networks, point-of-sales systems, etc. and financial resources like revenue streams.

Value Propositions:

These companies can create value propositions for the customer segments through a distinct mix of elements catering to that segment's needs. They can explain to the customers via different methods about positive potential to adapt to the new technology, which will help them in cost reduction, hence generating profitability. They can create value with easy use and access and reduced manpower. The customers can also customize applications for drones' usage based on their needs.

Customer Relationships:

The companies can establish good relationships with their customers through 24*7 customer support, providing more user-friendly applications, better user experience and access. They can have dedicated personal assistance to the customer and service users' community and provide more sophisticated automated processes to recognize customers and their characteristics. They can provide in-depth training and education at an individual level.

Channels:

They can reach out to their customers via right marketing, print advertisements, offering more lucrative deals on the cost as well as insurance to both dealers and retailers. They can also approach the government for more support and less legalities for their customers.

Customer Segments:

Their customer segments are mostly Ag retailers, but they can extend to directly sell their products to farmers and small businesses, and Ag service providers.

Cost Structure:

They can manage their business model to be value-driven instead of cost-driven and generate revenue while considering expenses for different divisions like R&D, training, manufacturing, operations, licensing fees, product roadmap, copyrights of their product and legal expenses.

Revenue Streams:

They can generate revenues through their customer segments by one-time customer payments or recurring revenues, like advertising, partnerships, subscriptions, product sale, add-on modules sale, renting or leasing, and licensing.

As we can see above, we have researched on coming up with a skeleton for a roadmap for Agricultural UAV business. This we think will help us attain below goals [38]:

- Portrays "structural relationships among science, technology and applications"
- Coordinates activities and resources
- Identifies, evaluates, and selects "strategic alternatives"
- Communicates visions
- Stimulates investigations
- Monitors progress
- Defines an overarching strategic objective and captures the major steps planned for achieving that objective.
- Provides predictability
- Articulates business goals & strategy to achieve them

Next question would be, does a roadmap really help accomplish anything valuable for an organization? The answer is it helps translate desirable futures, societal demands, or challenges in future markets into fruition, identifies opportunities and gaps in the agriculture domain, plans for the allocation of resources—time, financial, resources, and skills, enhances communications among business stakeholders and helps making better investment decisions [37].

SECTION VIII

Future Research Scope

The future holds a lot of research scope where we can have autonomous drone swarms, which is a networked entity that is not controlled by human operators at all. Operated by artificial intelligence (AI), it can continue its mission, even if it loses some drones during its mission. We can also have machine learning in agriculture UAV applications, where drones can fly on their own.

Based on our interviews, we see scope for companies to sell an automated system without the controllers, which can operate through the app, and the app will be automated to control how high it can fly, or, for the specified time it should return back to base. They can also consider expanding to the customers, including direct farmer relationships, to be able to use drones more efficiently to reduce human labor. All Ag precision companies can consider expanding their horizons from just a hardware provider to Ag services provider.

There is also scope of future research on financial modeling to evaluate and quantify ROI based on the usage of drones. There can be a ROI calculator which can help calculate the cost reduction with drones in just a matter of time. This will be an attractive offer to the customers who are interested in buying drones.

SECTION IX

Conclusion

Currently, there are a variety of growing pains that UAV assisted farming is going through in the United States. In this article, we have gathered these difficulties together and provided recommendations towards easing them. Through governmental assistance in improving certification processes and direct subsidization, companies improving the availability of their services, new businesses capitalizing on the gaps in the system, and farmers learning to accept the potential of new technologies, UAVs can improve their market adoption. This will of course take time, but with an effort from those involved, the improvements can be realized sooner than later.

Nonetheless, there is going to be a time soon, when we can say that “Old McDonald had a drone”

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INDEX TERMS

UAV - Unmanned aerial vehicle

NDVI - Normalized Difference Vegetation Index

GPS - Global Positioning System

ROI - Return of investment