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The Drones' Impact On Precision Agriculture

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THE DRONES' IMPACT ON PRECISION AGRICULTURE

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CHAPTER ONE: INTRODUCTION

1.1 Overview

The only constant thing in the agricultural sector is change, and as agricultural practices change in the 21st century, farmers have to adapt as well. This means applying cost-effective and technological sound practices that will lead to better results at the shortest time possible. Farmers today face challenges such as climate change and provisions of farm yields to meet the current global needs (Ahirwar, Swarnkar, Bhukya, & Namwade, 2019). In addition to that, it is estimated that by 2050, the world's population reaching approximately 9 billion, will lead to an increase of food demand by 70% and less arable land available for agricultural practices.

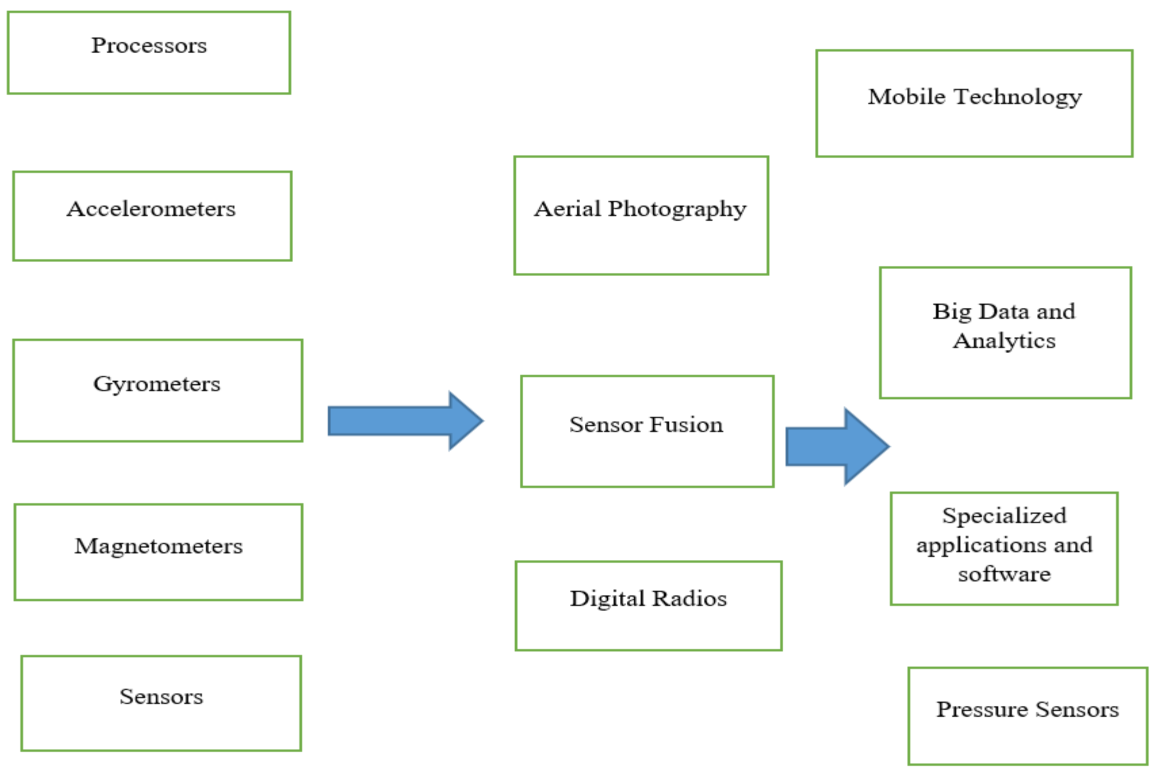
To achieve a 70% increase in food production means that farmers will need higher technological tools to help them better analyse the agricultural data that they collect by speeding up production, while ensuring that they are maintaining quality standards. It will also mean that the farmers will have to apply serious farming techniques to be successful. Smart farming or precision agriculture means that farmers are incorporating advanced technology as part of their farming practices to manage their crops and livestock as a measure to increase their yields without negatively affecting the quality of production (Al-Arab, Torres-Rua, Ticlavilca, Jensen, & McKee, 2013). One of the ways that farmers have used for years for smart farming has been the use of manned aircraft to survey the farm, apply pesticides, and monitor the livestock for ranchers. However, the estimated cost of hiring manned aircraft is between $60,000-$100,000 per year to hire a skilled agricultural pilot, which for many farmers is not a sustainable practice.

To achieve a balance between effective cost and high-quality yield production, smart farming technology developers and farmers are resorting to the use of drones. The use of drones will highly likely improve the farming practice, globally. It is important to point out that the drone technology on farming has been in existence for a couple of years, but with its prospects, it is highly likely to transform the farming or agricultural industry. The reason for this is that currently, drones can be fitted with devices such as a camera and other data-gathering devices, essentially providing an 'eye in the sky' for farmers (Allen et al., 2007). They can assist in the scouting for plant pests or identifying dry patches in the farm that can be watered to improve production. In addition to that, there are countries that have already began using drones as part of their farming practices. For instance, in Japan, pesticide is sprayed in a majority of the rice farms using unmanned helicopters. In the US, grape growers are experimenting on how drones can be used to increase their overall yield through surveying the farms and identifying areas that are considered to be of 'low vigor' because of lack of water or nutrients (Associated Press, 2014).

The advancement of the drone technology in the last few years globally has been necessitated by the following events: Unmanned Aerial Vehicle (UAV) technology becoming relatively affordable to the common person and organizations such as the Federal Aviation Administration (FAA) being more lenient on the policies of registration and operation of drones in the United States. These changes have had a positive impact on the overall advancement of the drone technology and its application in different industries. Although, initially, before the FAA relaxed its policies, the farming industry was the least affected because of the low-altitude usage of drones to capture images and conduct other farming activities, the moderation of the laws and policies have had a huge impact on ensuring that drones are today used for a majority of the farming activities (Borra-Serrano, Peña, Torres-Sánchez, Mesas-Carrascosa, & López-Granados, 2015).

A few years ago, drones for farmers meant, bees, which were essential in the pollination process in their farms. Today, it means an affordable technology that they can use for precision farming, an eye in the sky whose uses and activities in the farming lands continue to increase as drone technology advances. In the past, farmers, especially the large-scale ones, relied on satellite images or images that were taken by manned aircraft to provide them with information on their farms (Fengbo, Xinyu, Ling, & Zhu, 2017). Drones can provide farmers with this information in a closer, highly accurate, affordable, and a continuous perspective of their farms, which can be divided into manageable zones. These drones are equipped with the right tools and specialized information, which contributes to precision farming.

The following are some of the tools in a drone that make them effective in terms of being applied for different farming applications:



According to different experts, the use of drones in the agricultural sector will have a positive impact on the overall farming yields for the farmers. For instance, an MIT technology review on the use of agricultural drones stated that the relatively cheap drones that have been equipped with advanced sensors and imaging capabilities are ensuring that farmers have new ways in which they can increase their yields and also reduce the overall crop damage (Gupta, Bansal, & Husain, 2018). A report by the National Geographic also stated that farming technology has, over the past few years, been rapidly advancing and evolving. The use of agricultural specific drones has ensured that farmers are able to identify plants that have been affected by diseases and pests at a quicker pace than when using traditional methods, to monitor water during the irrigation process, and apply fertilizers in different areas of the farm according to the soil needs.

The use of drones is predicted to become a common occurrence in the farms in both the developed and developing nations. For instance, in the US, experts believe that drones will transform US agriculture and contribute to precision farming in the next few years. In countries such as Australia, universities such as The University of Southern Queensland has over the years invested in this new technology with the intention of making drones as common as traditional farming equipment by 2025. In China, farmers are already using drones for crop spraying purposes. In developing countries such as Kenya, Uganda and Tanzania, the use of drones can be implemented to alert farmers that their livestock have wandered of their ranches, provide them with information about the status of their animals, and prevent wildlife conflicts that are rampant in some parts of these East African countries.

Despite advances in industrialization and urbanization sectors, agriculture still forms the basis of a majority of the economies globally. Agriculture is not only essential in feeding the population of a country, but the yields that are generated can be exported to other countries and therefore boost the GDP (Gross domestic product) of a nation, especially in the developing countries (Hassan-Esfahani, 2015). The importance of farming is an indicator of how the advancement of technology in this sector is crucial and how smart and precision farming can contribute to it becoming a more successful industry. The application of drones by farmers can be instrumental in helping them deal with the following challenges: water related issues, climate changes, and even pollution.

1.2 Uses of Drones

The aerial images provided by the drones help a majority of the farmers in conducting assessments, signals, warnings, measure, detect, and even respond to the variability of crops. The other uses of drones in the agricultural sector are:

Real-Time Crop Monitoring

For farmers who have vast lands that is used for farming, the UAVs can provide them with more accurate images and videos of their farms. These images are essential in terms of monitoring the health and progress of the crops, assist them in determining the crop health, monitor the soil, warn them against impending hazards such as pests and animals, examine the damages from natural disasters, and live video feeds of intruders (animals and humans) in the ranches (Hassan-Esfahani, Torres-Rua, Jensen, & McKee, 2015).

Assessing the Crop Stages

The farmers are able to use the aerial images to assess the different stages of the crops from the sowing to the harvesting period. Based on the progress of the crops, the farmers can effectively make plans in relation to the watering needs and pesticide application. In addition to that, a farmer's response to any issues that are affecting his or her plants will be prompt because of the easy access to this information.

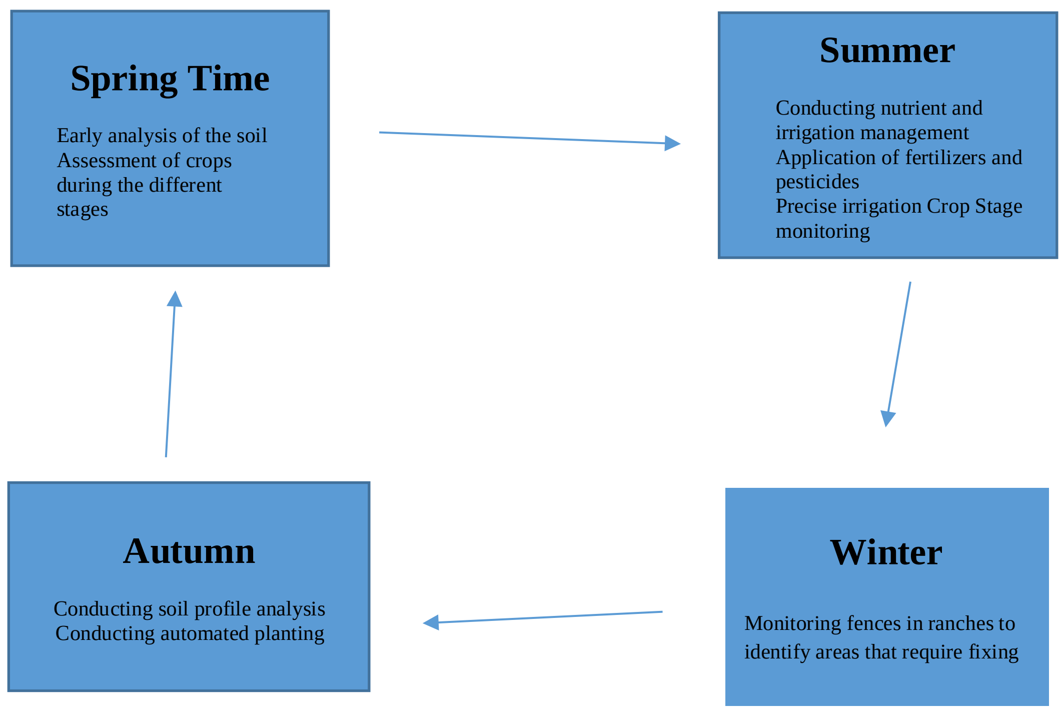
Soil Profile Analysis

The 3-D maps that are generated by drones can help or assist farmers to determine the soil health. The data is crucial in maximizing farmers' yields as they are aware of which parts of the land are most fertile and therefore can be planted or which areas need to be left bare and fertilized to improve the soil nutrients level for the next crop. The data that is provided by the drones can assist farmers in terms of plotting effective irrigation techniques as well.

Nutrient and Irrigation management

Field analysis has been made to be extremely easier with the use of drones as input from the data that is captured by the drones helps them to identify areas that have a scarcity of nutrients and water (Herwitz et al., 2002). The drones are also essential in the determination of the factors that impact crop growth and ensure that adequate corrective measures have been undertaken.

The following chart illustrates how drones can assist farmers in promoting precision agriculture during different times of the year.



1.3 Benefits of Using Drones in the Agricultural Industry

The following are the benefits or advantages of using drones during the farming process:

- It leads to the improvement of crop monitoring, scouting, and control.
- It ensures that there will be accurate data collection on required farming information.
- It contributes to precise analytics of required farming information.
- If used appropriately it will lead to an improvement in the return of investment.
- It increases or improves the quantity and quality of the yield.

1.4 Challenges of Using the Drones in the Agricultural Industry

There are various expected challenges for farmers who are currently using drones on their farms. These include:

- The cost of set-up and maintenance

- It may contribute to airspace interferences, especially for the manned aircrafts
- There are flight time limitations, which has a negative impact on the distance that can be covered at any given time
- The image quality is affected when there are heavy rains

1.5 Research Questions

- How has the use of drones in agriculture contributed to precise farming?
- How can small scale farmers despite having small tracts of land, and in most cases lack adequate capital investment be in a position to fully utilize drones in agriculture in a cost-effective manner?
- Do the farmers have the right technological skills to fully utilize the information that they record with their drones? Are they able to interpret the data that they have collected from their farms?
- In the current state of the drones from a technological perspective, is the information collected by the drones as accurate as the information that may be collected by hiring a qualified agricultural pilot who uses manned aircraft for assessment purposes?
- What is the expected outlook of drones in the near future i.e. what will be their impact in the agricultural sector?
- Can the use of drones improve the agricultural practices in developing countries?

1.6 Significance of the Study

Although there is a lot of information on how drones can be used or applied in the agricultural sector, a majority of the information was either a trial project in a specific farm, or a potential benefit that has not been tried and tested with results published. The researcher hopes to assess some of the potential benefits and explore how drones can be effectively used in small scale practices. The researcher feels the need to assess whether or not drones were made specifically for large farms only, or if they can be used in small farms as well to improve the farming yield and also ensure that the applied practices are cost-effective while maintaining, or even improving the quality of the products. The significance of the study is to add to the current scholarly body on how drones can be used in precision agriculture. By interviewing farmers (both large and small scale), and drone experts, future readers will have a better understanding of the impact of drones in the agricultural sector. The researcher hopes that the findings of this study will assist governments in both the developing and developed nations to fund the use of drone projects in their countries. It could also assist policy makers and agricultural educationists to develop appropriate guidelines and regulations of the use of drones in precision agriculture.

1.7 Purpose of the Study

Commercialization of drones have resulted in Unmanned Aircraft Systems (UAS) that are user-friendly, affordable, small in size, convenient, and a fundamental tool that in most cases is portrayed as a ‘fun’ device for hobbyists and an essential tool that can be used in a variety of industries. Commonly referred to as the ‘domesticated drones,’ there are more than 270 uses for the UAS such as in the agricultural sector, law enforcement, structural inspections, search and rescue, cinematography and also for news gathering purposes. There is a whole new targeted market audience that can use these devices to conduct activities that ten or fifteen years ago was considered unfathomable because of their history as military designed devices that could be used to carry out lethal missions.

According to FAA (2015), the ‘domesticated’ UAS weigh from a few ounces to 55 pounds. They can fly at speeds of up to 110 miles per hour and are limited to an altitude of 500 feet. Interested parties can purchase these devices, depending on their uses and specifications, from a few hundred dollars to tens of thousands. In retrospect, their affordability, small size, and easy-to-use design has made drones convenient and fundamental tools that can be used in a variety of industries. They are also a source of entertainment for hobbyists who fly them for fun and capture what most assume are fun photographs and videos or can be used to race.

However, currently, the commercial use of drones, especially in countries such as the United States, are highly regulated. For instance, in the United States, people who do not have proper permits and licenses provided by the FAA are not allowed to fly drones. News coverage on drones portray a negative picture of how these devices are used by people. Common news stories are people flying drones into the White House, private property, sporting events and even around airports, which does not only infringe on the privacy of people, but in some cases comprises people’s safety. Although there has not been a reported accident resulting from the collision of a manned with an unmanned aircraft, tests conducted by the University of Dayton showed that drones can cause significant damage on a manned aircraft that can lead to a crash (Lewis, 2018).

Such incidents coupled with the news stories of the military drone strikes in different parts of the Middle East that has led to the destruction of villages and deaths of civilians make it a less appealing technology to the public. Furthermore, there are lingering questions by the legislative bodies and federal agencies such as the Department of Transportation (DOT) and

FAA on who should be allowed to possess a license to fly drones, the purposes of commercial drones that should be legalized, and how bodies such as the FAA should regulate the commercial use of drones.

In addition to that, the commercialization of the UAS technology is a relatively new concept and therefore there has been little research that has been conducted to assess the benefits and challenges in its diverse uses, especially assessing the ethical issues in using these tools in the agriculture industry. There are various potential benefits that have been identified if farmers are allowed to use drones to enhance or improve their farming activities such as: conducting crop assessment, livestock monitoring, easy and faster identification of diseases, and application of pesticides in the farms. Even though the use of drones is highly to provide cost-effective techniques and providing the highest or the most yields, it is important to point out that the agricultural industry is mainly considered a low margin business. For many farmers, they lack the capital to make investments in these devices which have not yet been fully tested to assess their effectiveness and reliability.

Even though farmers are struggling to afford UAV use in their farms, there has been significant research on how UAVs can increase crop production particularly in food scarce areas. Food insecurity in the developing countries is an imminent threat. According to a report published by UNICEF, *The State of Food Security and Nutrition in the World 2018*, the number of people affected by food shortage, or the ones who lack an adequate supply of food in 2017 was 821 million, or one in every nine people (UNICEF, 2018). Evidence in the report pointed out that severe food insecurity has been on the rise in the sub-regions of Africa and South America (UNICEF, 2018). Climatic changes and an increase in the overall production costs have been attributed as the main factors that impacted food security in the recent past. According to

UNICEF 2017 statistics, there is a need to increase the current global food production by 50 percent by 2050 to satisfactorily feed a population of nine billion people. The current agricultural practices coupled with depleting resources such as land and water make it a tall order to accomplish.

The key players in the agricultural sector have to adapt effective farming practices that counter the climatic and other challenges that have been mentioned. There is a need to research and look at the applicability of emerging technologies as effective solutions to some if not all of the challenges that have been mentioned in this introduction section through the provision of accurate, reliable, and timely information to the key stakeholders in the farming industry. Recently, there has been an increase in the use of unmanned aerial vehicles (UAVs) in the agricultural sector mainly for evidence-based planning and data collection purposes. It is important to point out that drones have successfully been used in various industrial sectors such as in the military, humanitarian relief, disaster management, and it is now an emerging technology in the agricultural sector. According to a PwC (2016) report, the agriculture drone market is currently estimated to be worth $32.4 billion. Drones or UAVs are currently being used in the agricultural sector to facilitate crop production, livestock monitoring, provision of early warning systems, disaster risk reduction, fisheries, forestry, and even in wildlife conservation.

The purpose of this study is to assess the overall impact of drones in the agricultural sector. This is mainly by taking into perspective farmers in developing countries who lack the resources to purchase drones, but who if drones are used in their farms will bring about higher yield by helping them to assess their crops, identify areas of diseases, while at the same time reducing the overall cost of farming in these countries. The researcher is building a drone with a farmer's preference for guidance that will be effectively tested in a farm to assess whether the potential benefits that have been discussed in the background section can be applied.

1.8 Limitations

There are various limitations identified in this study are:

- A majority of the available research on this subject is mainly speculative in relation to the commercial use of drones in the agricultural industry.
- There are limited cases of drones applied in the farming sectors in different parts of the world.

CHAPTER TWO: LITERATURE REVIEW

2.1 History of Drone Development

Considering that the term ‘drones’ refers to any aerial device that is unmanned, the earliest unmanned aerial vehicle in history was first reported in 1839 an Austrian soldier attacked the city of Venice with unmanned balloons that was filled with explosives. It is important to point out that the use of these vehicles even in its earliest forms was for military purposes. The Ruston Proctor Aerial Target developed in 1916 was the first pilotless winged aircraft that was controlled with radio control in a similar manner as the majority of the drones that are in existence today (Herwitz et al., 2002). The Aerial Target was built with the hope that it will counter the German Zeppelins that were used to carry explosives during World War I. In 1917, the Americans developed the Hewitt-Sperry Automatic Airplane also known as the Kettering Bug, which even though had impressive results and could be mass produced, its timing was a little bit late to be used in World War I and therefore was never deployed in combat.

The UAV technology greatly improved during World War II and even the Cold War where it is alleged that it was used for surveillance purposes in particular taking aerial photographs of military bases by the US and former USSR intelligence. However, genuine reports of whether this is true are classified. UAVs were extensively used in modern day warfare in 1982 when Israel used a combination of manned aircraft and UAVs to conduct attacks against the Syrian fleet with minimal losses. In particular, the UAVs were used to identify the Syrian army’s position, jam their communication lines, and act as decoys and ensure manned aircraft executed attacks with little or no retaliations. The success by the Israeli’s military generated international interest in the drone technology and led to countries investing millions of dollars in this sector (Huang & Thomson, 2010).

The first non-military drones were deployed or began to be used in earnest in 2006 by government agencies that were responsible for disaster relief, border surveillance, and wildfire fighting for surveillance purposes. Also, corporations began to use drones to inspect pipelines and spray pesticides on their farms. It is also important to point out that the FAA issued its first commercial drone permits in 2006, and for the next eight years, it issued an average of two permits per year. Things changed in 2013 when the Amazon CEO Jeff Bezos announced that the company was considering using drones to deliver parcels to its customers and this generated a public interest into the use of drones. In 2015, the FAA issued 1,000 drone permits and one year later provided 3,100 permits.

2.2 Popularity of Drones

The Unmanned Aerial Vehicles (UAV) are increasingly being used today for tasks that were previously being executed by the manned aircraft. However, the widespread or increased use of UAVs in civil airspace has been mainly prohibited or curtailed by civil authority bodies or agencies in different parts of the world mainly because of its historical purpose in the military. Therefore, there is a need to justify why UAVs should be allowed to share the airspace with other aircraft simply by pointing out their potential uses and benefits. The focus of this study is to analyse the use or application of UAVs in the agriculture sector.

The UAVs have traditionally been used in different military applications since the First World War, where they were mainly used for target practice purposes. The UAVs have been mainly used for reconnaissance purposes, air observation for artillery, and target practice drones (Laliberte, 2009). Recently, UAVs have been used to carry out deep strike missions whereby precision guided bombs and missiles have been dropped deep inside hostile territory in areas such as Afghanistan and Iraq.

UAVs can be configured for specific functions such as: maritime patrol, search and rescue, and border patrol; survey, surveillance and aerial photography; atmospheric and environmental research; agricultural applications; telecommunications; and cargo transport. In a majority of these applications, they have not been fully exploited in the past, or they have been fulfilled using expensive technologies such as satellites. These satellites are expensive to operate, have a short shelf-life, cannot be repaired, and they spend little dedicated time over their target. For manned aircraft, they are mainly limited by their mission time and specific human factors (Lausch et al., 2013). As has been pointed out before, in a majority of the countries, UAVs have traditionally been used in military and government operations.

Climatic changes, and an increase in the overall production costs, have been attributed as the main factors that have had an impact on food security in the recent past. According to UNICEF 2017 statistics, there is a need to increase the current global food production by 50 percent by 2050 to satisfactorily feed a population of nine billion people. The current agricultural practices coupled with depleting resources such as land and water make it a tall order to accomplish.

The key players in the agricultural sector have to adapt effective farming practices that counter the climatic and other challenges that have been mentioned. There is a need to research and look at the applicability of emerging technologies as effective solutions to some if not all of the challenges that have been mentioned in this introduction section through the provision of accurate, reliable, and timely information to the key stakeholders in the farming industry. Recently, there has been an increase in the use of unmanned aerial vehicles (UAVs) in the agricultural sector mainly for evidence-based planning and data collection purposes. Drones have successfully been used in various industrial sectors such as in the military, humanitarian relief, disaster management, and it is now an emerging technology in the agricultural sector (Leonard, Savvaris, & Tsourdos, 2013). According to a PwC (2016) report, the agriculture drone market is currently estimated to be worth $32.4 billion. Drones or UAVs are currently being used in the agricultural sector to facilitate crop production, livestock monitoring, provision of early warning systems, disaster risk reduction, fisheries, forestry, and even in wildlife conservation.

Drones are increasing becoming popular mainly because of the diversity of their functions. Chapa (2013) stated that he imagined a time when there would be more than 30,000 UAVs in the US skies like a scene from a science fiction, which will soon become a reality. McAdams (2015) reported that according to the Consumer Electronics Association's predictions is that by 2025, the US skies will be filled by as many as one million drones per day. Clark (2014) noted that the increase in the number of drones can be attributed to technological advances that have made these devices to be much more functional and affordable. In addition to that, there has been an increase in the market-size that has had a positive impact on investment in this sector.

2.3 Effectiveness of Drones in the Agricultural Sector

For years, humans have been experimenting with unmanned aerial vehicles (UAVs) to determine their applications apart from its military use. However, the rapid development of the consumer (mainly hobbyists) and professional drone market in the past few years can be credited to miniaturization of the device, development of long lasting batteries that allow drones to be flown for hours and cover larger distances, and the ability of different sensors to be added such as cameras for imagery purposes and remote communications. Indeed, the global drones in 2016 were $8.5 billion, and it is estimated that by 2021, expected sales will reach $12 billion.

The application of the drones in different industrial sectors has also increased the popularity of the drones in the recent past, such as in the transport, security, and infrastructure also in the agricultural industry (Mammì & Rossi, 2017). Majority of the proponents of the drones have made the argument that the use of drones will ensure faster and more precise results than the use of the traditional processes and methods, which rely on large human workforce. The use of drones is also expected to reduce the overall cost of farming and compliance related costs and improve safety levels when conducting different agricultural practices.

2.4 Drones in the Agricultural Industry

Historically, one of the most effective ways that farmers have used or applied to meet and overcome the constant changes and challenges that couple this sector and meet the growing food demands has been adopting new technologies such as the Internet of Things (IoT), Big Data and Artificial Intelligence (Meivel, Dinakaran, Gandhiraj, & Srinivasan, 2016). The application of these technologies has resulted in the enhancement of new, and at times, existing farming practices and tools that have already been deployed on the farms. For instance, the use of connected tractors is one of the most popular new technologies that are currently being used in the farming sector to improve yields.

Drones are currently considered a relatively recent, and even less mature tool in relation to the new technologies that are currently being used, or applied in smart, or precision agriculture. Currently, there are two types of drones that are used in the agricultural sector: medium sized (which are mainly used for the analysis applications) and larger drones (which are used for planting and spraying of pesticides in the field).

The first UAS in the agricultural sector were developed in the 1980s for crop dusting purposes. Over the years, the advancement of technology in the agricultural sector has mainly been in the following areas: the precise aerial application of pesticides and fertilizers over the agricultural areas and aerial imaging to support both crop field mapping and growth monitoring (Mone, Shivaji, Tanaji, & Satish, 2017). A majority of the agricultural UAS are Micro Air Vehicles (MAVs), fixed-wing or rotary-winged helicopters that are considered to be of low cost, low speed, low ceiling altitude, light weight, and they have a low payload weight with short endurance period. As a majority of the farming applications require only low-medium endurance capability, a majority of the UAS are gasoline or methanol-fueled or are electric-powered and therefore use rechargeable batteries or solar power. It is important to point out that even though the UAS (which use rechargeable batteries) are mainly for short endurance runs whereas solar powered UAS can last for a longer endurance period. For instance, the UAS that has been fitted with pesticide spraying has a higher payload weight requirement, and therefore, they are able to support longer flight endurance (Pathak, Barzin, & C. Bora, 2018).

The less researched area in the agricultural applications of the UAS is the aerial application of water, fertilizer, and pesticides for small-scale farmers. The application of water, fertilizers, and pesticides is crucial for farmers who want to increase their crop yields. While the aerial application method has been proven to be effective for large scale farmers, it can be an ineffective and cumbersome application method in small scale production systems that are common in a majority of the developing countries such as African countries. However, it is important to point out that the advantages of the UAS over existing technologies is based on their maneuverability, low operation costs, safety, and accuracy.

In 1983, Japan was the first country to attempt to use drones for the aerial application of fertilizers with its development of the Remote-Controlled Aerial Spraying System (RCASS) by Yamaha Motor Corporation. It contributed to Japan's rice, soybean, and wheat crops to increase their yields as they could use drones effectively to control pests that could have affected their overall production. In 1990, Yamaha developed the R50UAS helicopter, which had a payload capacity of 44lb. Subsequently in 1997, the R-MAX (unmanned helicopter) was developed, and by 2000, it had been equipped with an azimuth and Differential Global Positioning System (DGPS) sensor system (Sadeghi, Jones, & Philpot, 2015).

Currently, in Japan, 90 percent of the crop protection is achieved through the use of drones which have facilitated pest control in the country. The case of Japan farms proves that drones can effectively be used for pesticide spraying and fertilizer application for a majority of the farms in African countries. The reason for this is that the two regions have a comparable farm size per farmer. In Japan, the average farm size is 3.7 acres, while in Africa, it is 2 acres.

The aerial application of water, fertilizers, and pesticides is seen to be highly beneficial in farms that have narrow rows of crops and a relatively hilly terrain as these can be obstacles for tractors. A study that was conducted by the University of California on the vineyards in the state comparing the use of tractors or manual labor. In the study, the use of the UAS in the application of pesticides are economically viable than the use of tractors or backpack sprayers. In addition to that, the use of the UAS was seen to be more precise, especially when the pest problem is on a certain portion of a farm and it is also time effective. The RMAX was used in the California study, and data showed that even though it was flying at 12mph it still was able to cover the area 10 times faster than was the case for tractors (Associated Press, 2014).

The UAS can be used for aerial spraying in insect infested areas particularly in the eradication of mosquitoes and tsetse flies in a region. Huang et al. (2009) developed a spray system that fully utilized the autonomous UAS. Their research proved that a spray system can be successfully placed on a UAS, leading to pest management and vector control.

2.5 Agricultural Applications for the Drones

The versatility of the drones means that they can be used for a variety of agricultural applications that will be discussed further in this section.

2.5.1 Crop Assessment

The use of the traditional methods to monitor farming fields requires a lot of manpower and time to successfully complete. However, the use of drones for this purpose means that a farmer is able to fly the device over the farm, take stock, inspect if there are any slow-growing plants that may need additional nitrogen, or supply water to improve their growth. These drones are fitted with sensors that are able to measure specific wavelengths of light that is absorbed and reflected by plants, which leads to the generation of color contrasted images that highlight the problem areas in a crop field (Van Loon, Speratti, & Govaerts, 2018). The images that are generated from the data the drones collect include normalized difference vegetation index (NDVI) maps, which were previously created through the use of satellites and airplanes through calculating the ratio of the difference of the near-infrared and visible light radiation.

A combination of the sensor tool and GPS allows the images and videos that were taken in the field to be in a single layer, which can then be analysed and geo-referenced. It is important to point out that only when the images are in this format can a farmer use a GPS-enabled smartphone or any other device to walk to the identified location, inspect the problem area, and come up with an appropriate solution (Van Loon, Speratti, & Govaerts, 2018). As has been pointed out before, sensors are able to capture images that provide crucial information to the farmers. For instance, they can inform the farmer about the health of a plant as they absorb light for photosynthesis purposes. However, there are wavelengths of light that are reflected such as the near infrared (NIR) photons because they do not have enough energy to facilitate the photosynthesis process but have lots of heat. Plants normally reflect the NIR light, however, the ability or mechanism of reflection of light by a plant's leaves normally breaks down as the leaves die. Therefore, the near Infrared sensors are designed in such a way that they are able to monitor the difference in the NIR reflectance and visible reflectance, through a calculation known as normalized difference vegetation index (NDVI). A strong NDVI is indicative of a high density of plants in an area while weak NDVI can be interpreted as identification of problem areas on a crop field. Figure 1 shows the difference between a healthy and dead leaf using its reflected light.

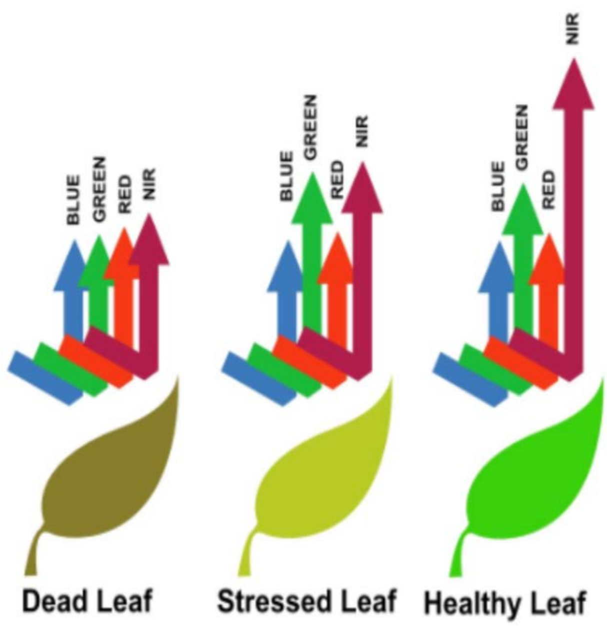


Figure 1. NDVI and plant health. Reprinted from (*E-Agriculture in Action: Drones for Agriculture* (p.3), by Gerard Sylvester, 2018, Bangkok.)

As has been pointed out, an NDVI report can help farmers to distinguish the area of the field where crops are growing well and where they are not. A farmer can then create zones in the farm whereby different amounts of fertilizer will be applied, depending on the needs or requirements of the field. In addition to that, as plants react to stress, an NDVI image can reveal to the farmer if there are presence of pests, weeds, and/or water damage that is leading to crops failing to grow as they should. The farmer is provided with necessary information that will help him or her identify problems in the farm and come up with cost-effective solutions.

There are two approaches that farmers can use when selecting an NDVI camera to capture the images of a farm. The first approach is using an expensive, purpose-built camera with the capability of capturing precise wavelengths (Xiang & Tian, 2011). Its added value is that it is able to capture narrow-based frequencies which can provide a farmer with better information on his or her farm health. However, this type of camera is considered to be only useful in specific cases and its effectiveness does not match its high price. On the other hand, a farmer can convert a high-quality consumer camera which can then be fitted on a drone for agricultural imaging purposes. The use of these two approaches will contribute to the delivery of high quality NDVI data for the farmers which they can use to assess the overall health of their farm.

Another approach that farmers can use in the assessment of their crops is through remote sensing, which can detect the differences in crop growth and the condition of the soil through variations in the spectral responses. The information that a farmer gets from remote sensing can assist in the identification of nutrient deficiencies, diseases, water status, weeds, damages, and plant populations (Xiang & Tian, 2011). Remote sensing (RS) can also be used to detect changes in a pest attack or disease infested plant before they become visible to the human eye. The following are the attributes, or benefits of using RS for data collection purposes of farming information: a non-disruptive method, a systematic manner of data collection, accuracy, efficiency. These benefits of using the RS will lead to an increase in crop yields and also help the farmers to be in a position whereby they can meet the growing demands of food supply globally.

The UAS have a variety of advantages over the other existing technologies when it comes to providing farmers with information in relation to their crops or livestock health. For instance, unlike the case for satellites, they allow for independent timing of the aerial passes, and therefore, a farmer tends to avoid the inadequate frequency of the satellite surveys, or disturbances that are brought about by cloud cover conditions (Yanbo Huang, Wesley Clint Hoffmann, K Fritz ASABE Member, & Yubin Lan, 2008). They are also able to provide ultra-high resolution to the degree of centimetres. They are also safer to operate in lower altitudes, especially under extreme weather. They have a lower operational cost in comparison to manned aircraft and have a higher time flexibility. This is evident in remote areas where there are few manned aircraft, and they are also affordable in comparison to purchasing or hiring manned aircraft for different farming applications.

2.5.2 Crop Nutrient Monitoring

One of the major economic activities in farming is the application of fertilizers such as nitrogen, potash, and phosphate as well as micronutrients such as sulphur and magnesium. In a majority of the farms, application of fertilizers is conducted by on-ground equipment such as tractor powered sprayers and pressurized irrigation systems, whereas in large farms with higher revenue they use manned aircraft to facilitate this activity (Zarcotejada et al., 2005). When using manned aircraft, farmers mainly use a single application rate for all the areas of the fields that are being sprayed which affects the precision of the fertilizers that are inputted in a farm. In addition to that, the changing wind speed and direction conditions as well as change in elevation of the aircraft during the process of fertilizer application makes precise application to be a nearly impossible activity. The ground equipment application is mainly used to stabilize the crop nutrient status during the irrigation season.

In a study by Mone, Shivaji, Tanaji and Satish (2017), the researchers provide an argument in support of the use of drones for the purpose of spraying fertilizer and pesticides. The researchers provide evidence from the World Health Organization whereby, it is estimated that there are 3 million cases of pesticide poisons that occur every year and there are 220,000 deaths that are reported annually, mainly in the developing countries due to the wrong application of fertilizers by farmers in their farming fields. The researchers note that drones can be equipped with an automatic spraying mechanism, which ensures that farmers avoid the harmful effects of fertilizers by ensuring that the right quantity of fertilizer is applied in different parts of the farm.

In another study by Meivel, Dinakaran, Gandhiraj and Srinivasan (2016), the researchers investigated how a quadcopter UAV, fitted with a fertilizer and pesticide spraying system, can be applied in precision agriculture. They pointed out that the Quadcopter UAV that has been fitted with a spraying module does not only lead to precision agriculture, but allows farmers to reach, or access and apply pesticide and fertilizer content in areas that are not easily accessible by the farmers. In addition to that, these researchers pointed out that the multispectral cameras that have been fitted on the drones can help farmers capture remote sensing images and identify areas that fertilizers and pesticides have not been applied to properly.

2.5.3 Counting and Accounting for Livestock in the Farm

Most of the cattle ranchers who have lots of acres or land are using drones as an effective way to keep track of their livestock and conduct surveys of different parts of their farms where the fences require fixing. In addition to that, they are fitting their drones with high-definition thermal imagers and night-capable cameras to survey if there are unwanted animals in their farms that are preying on their livestock. It is important to point out that such drones are currently being utilized at India’s Kaziranga National Park to track human poachers who are targeting the horned rhino. In addition to that, there are ranchers who are using this technology to survey the quality of their pastures.

During pasture surveying, the aerial images that are provided by the drones helps ranchers to map the vegetation health, height, and to monitor weather damages as well as areas that require irrigation on the property. The drones are also used for herding and directing cattle that are on different parts of the farm to a desired location (Zhang & Kovacs, 2012). The drones in the cattle ranches can also be used to check or assess the condition of the water troughs and the gates in the remote locations of a farm. In case there is a water trough that is not functioning, the farmer will not only be aware of it, but he or she will be able to go to its location and fix it. A farmer who is aware of the location of his or her cattle in a big ranch will know where to go and gather cattle that require treatment as well as separate the calving cattle from the rest of the herd and the ones that need to be transported for slaughtering purposes.

The use of this new technology for herding purposes has the potential of introducing active tags to the cattle, which will be instrumental for the ranchers in terms of helping them acquire information at a quicker pace than was the case when using passive Radio-Frequency Identification (RFID) tags. The reason for this is that, in the passive RFID tags, a farmer has to be within one or two meters from the animal to read, however, when using active RFID tags, a farmer can be able to read and acquire information of the animal from a distance. This means that instead of a farmer having to scan the whole pasture to know the location and condition of an individual animal, he or she will just use a drone high enough so that it can spot the herd, and use RFID sensors to read the tags of the animal of interest.

2.5.4 Monitoring for Diseases

For a farmer to be able to harvest the highest possible yield, it is essential to regularly assess the crop health and try to spot bacterial or fungal infection in the plants. In the past, farmers had to go to their farms and physically assess the condition of their plants, which can be physically tasking and time-consuming for the farmer (Zhang & Kovacs, 2012). However, today, the application of the drone technology means that farmers are able to cover a large piece of land at a short time without the need to physically travel and assess the condition of the plants.

The use of drones to monitor for diseases has been tested in different parts of the world with considerable success. For instance, in Sri Lanka, the eBee drone has been used by farmers to warn them about their plants that have been infested by diseases or pest 10 days before they can see them with their 'naked' eyes. According to Salman Siddiqui, who is the head of IWMI GIS remote sensing and data unit, through the use of near-infrared, a farmer can be able to identify the stress in the plants 10 days before it becomes visible to the eye through capturing the photosynthetic activity images.

The 10-day warning can help farmers reduce or prevent large-scale crop losses. In addition to that, other farmers in a region where it has been affected by certain diseases or pests can be informed, and therefore take adequate measures to prevent the spreading of the diseases and pests which will have a positive impact on a region's overall yield production. In the developing countries such as Kenya, the UN's Food and Agriculture Organization is researching on ways the data collected from drones can help them to provide training and education sessions to the farmers on how to deal with diseases that affect them. In particular, the foot and mouth disease (FMD) has been proven to be a problem that affect small dairy farmers and research programs are currently being conducted in Nepal and Kenya on how drones can be used to reduce the negative impact of the disease on these farmers. For instance, the Food and Agriculture Organization (FAO) trial in Kenya uses the Huginn X1 drone and the researchers found out that in most cases the drones are able to complete their survey on the livestock distribution in a region, provide data to the veterinary personnel who are able to access the affected regions, and provide treatment to the sick animals.

In Virginia, drones are being used to identify and kill high-flying pathogens even before they land on the plants. In this case, drones are currently being used to capture the airborne spores of pathogens such as Fusarium graminearum that affects wheat and corn before they reach these fields. In addition to that, for farmers who are aware of an impending pathogen outbreak in a nearby area, they are able to conduct air samples and then prepare themselves against the impending attack. In addition, government agencies are conducting large scale surveys in the vulnerable areas and helping farmers to be prepared before an outbreak occurs (Hassan-Esfahani, 2015).

2.5.5 Crop Spraying

In the previous section, it has been briefly discussed that the use of drones can assist a farmer in identifying that the plants are diseased 10 days before the disease is noticeable by the human eye. In addition, the use of images from the drones helps farmers assess whether or not their plants have been attacked by pests, fungi, and/or weeds (Fengbo et al., 2017). An important feature to take note when using drones is their ability to easily adjust their altitudes and use different flight paths in accordance to the surrounding topography and geography, which is achieved by additional equipment that is fitted to the drones such as radar and LiDAR, a light detection and ranging system. They have made it possible for drones to be highly effective for crop spraying purposes. In addition to covering farming areas at a faster period, than when using manual labor, these devices have the ability to scan the ground and apply the liquid pesticides with great precision. There is the argument that crop spraying using drones is estimated to be five times faster than the use of regular machinery. The figure below illustrates how drones are effective in crop spraying.

Figure 2 is an illustration of a drone spraying crops in a region of the farm where tractors and even human sprayers may fail to reach because of the crop density. Reprinted from (*Technology of Business reporter, 2018 by Chris Baraniuk)*

2.5.6 Conducting Water Watch

A majority of the farming fields are not uniformly flat and, therefore, even though a farmer may be watering the field, there are some sections that may dry out faster than others or in some cases get missed by watering equipment. This can easily be identified by a farmer who is using a drone which is fitted with the right sensors (Gupta et al., 2018). The reason for this is that both the spectral and thermal imaging may help the farmer to identify the dry spots whereby the crops will either have low yields, or at times may wither. The imaging process can also assist a farmer to detect if there are leaks in the equipment and the irrigation canals.

Farmers can additionally assess the topography of their farming land through the use of airborne laser scanning technologies, or an imaging software, and develop 3D maps. Such maps can be crucial during the farming process as the farmers identify the water catchment areas, help in the identification of the water-flowing direction in the plants, and other land features that influence both the health of the crops and even provide the farmer with information on whether soil erosion occurs or not.

2.5.7 Irrigation

Agriculture accounts for approximately 70% of the water that is used globally, and it is more than twice the amount which is consumed in the manufacturing and industrial sector. With the growing scarcity of this precious commodity, and given its importance in growth and sustainability of the crops, farmers have for years wasted water during the irrigation process (Lausch et al., 2013). This has been achieved by leaky irrigation systems and wasteful field application techniques. The use of drones in the irrigation process can help to ensure that water is used effectively in the farming lands and also in the identification of areas that are contributing to the wastage of water in the farming fields.

This will be achieved by using drones that are equipped with special monitoring equipment, which as has been pointed out before, to help farmers identify areas that are currently experiencing ‘hydric stress’ i.e. inadequate supply of sufficient water. It is important to point out that the use of infrared and thermal sensors will allow farmers to take snapshots of their farms and therefore identify the areas that are receiving too much or too little water (Lausch et al., 2013). The use of these drones will allow farmers to conduct the vegetation index by calculating or determine the density and health of the crop that is being calculated, all while the crop is still growing. This provides the farmer with the right information, which will lead, or contribute to better crop management.

2.5.8 Evapotranspiration and Soil Moisture

As has been explained before, effective use of water in the farm is one of the most cost-effective measures that farmers want to improve because of the increasing scarcity of water. Therefore, from an irrigation management perspective, there are two factors that a farmer needs to take into consideration to estimate a farm's watering or irrigation needs: evapotranspiration (ET) and soil moisture (SM). Evapotranspiration is defined as the amount of water that a crop uses which is based on the amount of water that is available at the root zone, the type of plant in consideration, weather and seasonal conditions. On the other hand, soil moisture is defined as the amount of water that is retained at the root zone and it varies in different farms depending on the soil type, organic matter, and depth.

These two factors or components can be used to estimate the irrigation needs of a farm through a process known as water balance accounting. Estimation of ET using a drone requires it to be fitted with both Red and NIR spectral filters and a temperature camera sensor (Lausch et al., 2013). The farmer will also be expected to have the local weather station information to be able to interpret the data that he or she gets from the drones. The information that is presented by the farmer from the drones can then be inputted in the irrigation valve zones, which the irrigation technology supports in a specific farm. Currently, soil moisture estimation using drones is an area that is currently still under investigation.

2.5.9 Aerial Planting

As the agricultural technology advances, in the near future, farmers may plant their crops using the drone-planting systems. If this is achieved, it will significantly reduce the labour costs as farmers will be able to use compressed air in the drones to fire seed pods directly into the farming area.

2.6 Automated Drones in Agricultural

There has been much research done within the last couple of years on automated drones for agricultural. Most the of these studies focus on crop spearing or surveying, but there are not many studies on drones that can detect birds with artificial intelligent (AI). One of these drones that is commercialized and found in the market is ProHawk.

ProHawk is a drone that is designed to scare the birds away with sound system that emits predator sounds that is equipped with sonic bird repeller. The way it works is simply to fly the drone around the farm or the area you targeting to scare the birds away, once the drone is above the area you want it to be, turn on the sound system to have the desired effect. ProHawk is an effective bird pest control device especially when the flight path is set so the drone can fly with the intended pattern. ProHawk flight time is 15–20 minutes depending on the weather condition and the battery use (Daily dot, 2016), not to mention the drone range which is one-mile radius with speed of 30 miles per hour. Drone specification gives the user more than enough time to scare the birds and fly back to the landing zone. The ProHawk drone has been proven to be affective at scaring pestering birds but does not have a coding system (AI) that locks down to follow the birds to chase them away.

Australian Research Centre for Aerospace Automation (ARCAA) was able to develop a drone integrated (AI) and equipped with a thermal imaging camera to survey animals that are threatened or invasive to the area. The article states that the drone can stay up for 20 minutes in the air using 1500 mAh 6s battery not including the sensor imagining system (Luis,.Glen.,2016). This system was test and proven to be more cost effective than using conventional ground stations which can be time consuming and don't cover vast lands as the drone can especially with real time imaging and sensors that can detect, analyse, and count animals.

Moreover, Rostock University (G. J. Grenzdörffer.,2013) conducted a research to make a UAS that can detect and count gull to decrease time and cost of manual labour in the islands where they use to count pestering birds manually. Researchers at Rostock university were able to develop a UAS that can generate data of high-quality imagery which can classify the gull as well as get a head count, for instance in 2011 the UAS was able to detect 1,568 gull birds based on the image that was processed. What is more interesting in this research is the bird reaction to the drone at the correct flying zone. Flying the UAS between 300 to 400 meters won't scare birds, they just ignore it, even when it flies at a closer range of 15 meters. Figure 3 is a picture that shows the UAS surveying the island Langenwerder (red dots represent a bird object that was detected).

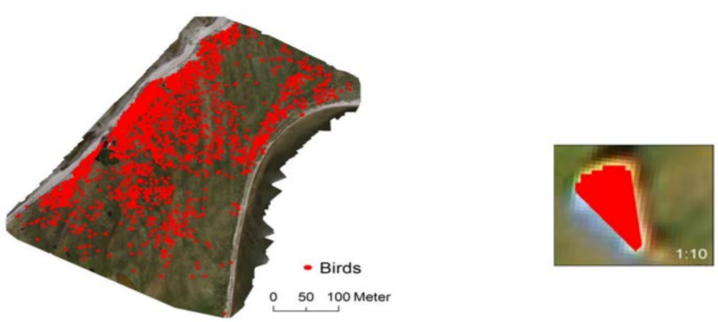


Figure 3. Red dots bird objects identified. Reprinted from (UAS-based automatic bird count of a common gull colony (p.171), by G. J. Grenzdörffer, 2013, Rostock, Germany.)

CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter outlines the approach of the research adopted in carrying out this study. It defines the research design, data collection methods, research procedures and data analysis methods.

3.2 Research Philosophy

The aim of this research was to assess how UAS can be applied to farms that are affected by bird problems to lead to better yields and control of pests for small scale farmers. The study will help determine how the use of drones can reduce the impact of the bird problem for farmers. This research implemented an appropriate new design for UAS, which was built based on UAS farming research design. It is important to note that the design of UAS was adopted for this research to find a solution to the overwhelming bird problem. It denotes that social reality is a phenomenon that can be observed, achieving factual knowledge in regard to whether the adoption of UAVs by small scale farmers in the United States will help address their current problem of birds. This was achieved through data collection, analysis, and interpretation of the results that were collected for this study. The researcher will also have to take an independent position to get positive results in this study. The research aims to derive knowledge from measurable facts.

3.3 Research Design

The researcher will build a hexacopter drone using frame Tarot 690s capable of lifting heavy weights as much as 10 to 15 pounds. It will provide the readers with the framework of how the research was conducted and guidelines on how they can replicate it to get similar results in the future. Also, the description of the process that the research has undertaken during the study in the design approach, data collection, instruments used, and research procedures that were implemented will be provided. As an appropriate structure in which a specific research is implemented, a hexacopter drone design framework used and described with detailed steps of how the drone was built with the main parts listed such as the frame, flight controller, motors, electronic speed controller, battery, receiver, props and landing gear.

3.4 Design Target

The design is to target pestering birds in an effective way without harming them. The elements that the research aims to study is to focus on small or midsize farms that are located in different parts of the United States.

3.5 User Requirements

The requirement for the user is to meet with farmers that have a pestering bird problem, design a drone that can assist with the needs of the farmers that is user friendly and easy to assemble or fix if need be. The following are the requirements that were specified by farmers:

- Minimal flight 10 minutes
- Predator sounds system or siren to scare pestering birds
- Carbon fiber frame
- Options to install a camera
- GPS technology
- Low maintenance and easy to operate
- Cover large areas more effectively than the old traditional way
- Operational in extreme weather conditions (hot or cold)

3.5.1 Parts list

In this study, most of the parts were purchased from the internet to better the outcome of the drone based on the preferences of the farmer's needs. The researcher also designed and printed specific parts to make the UAV more efficient to reach the study's goal. If farmers need to fix or want to modify the drone, they can find various parts online or contact the researcher for the blueprints. The following is a list of the parts that was used to build the drone.

- **Frame:** Tarot 690s pro full 6 axis carbon fiber aircraft frame 3K folding
- **Flight Controller Kit:** APM2.8 APM 2.8 Multicopter Flight Controller 2.5 2.6 Upgraded Built-in Compass
- **Motors:** 6X750KV Brushless Disk motor
- **Receiver:** FrSky Taranis X9D Plus 2.4GHz
- **ESC:** 6X Platinum-30A-Pro 2-6S 30A Speed controller
- **Props:** 6XCarbon Fiber props
- **Battery:** ZOP 5200mah 6s Battery
- **Landing Gear:** HML650 Retractable
- **GPS with Compass:** L5883 25cm Cable
- **Servo Extension:** Lead Wire Cable MALE TO MALE KK MK MWC flight control Board for RC Quadcopter
- **Plug Male Connector:** Silicone Wire With 11.5CM 14awg
- **Hook & Loop:** Fastening Tape
- **Bullet Connector:** 18x3.5mm (banana plug)

- **U-BEC UBEC:** Input 9-30V 3-8S Lipo battery 8-24Nimh R7
- **GPS Folding Antenna:** DJI Antenna Mount Holder Metal
- **Channel Transmitters:** Frsky L9r
- **VTX:** Eachine VTX03 Mini FPV Transmitter 5.8G
- **Camera:** Foxeer Predator Mini V4 Super WDR 1000TVL FPV

3.5.2 Testing

Testing will take place in Alamogordo, New Mexico. It will be conducted throughout the day with good weather visibility. A ranch owner will be present for safety and will give their diverse farming experience to provide the researcher inputs with the challenges that they have encountered with the birds. Working with the rancher will provide valuable data on how the use of drones could assist them in dealing with the aerial pest to further increase their crop yields.

Figure 4. Picture shows flight path of unmanned aerial systems (UAS) Reprinted from (*Best Drones for Agriculture. 2019 by ANDREW NIXON)*

3.6 Sources of Data

There are two sources of data that a researcher can use in a dissertation- primary and secondary sources. A primary source is defined as any data or information that a researcher collects first hand from drone data system, mainly flight planning software (Mission Planner). This software was designed to program flight controllers, camera sensors, PID (Proportional, Integral, Derivative) settings, ground speed, flying height, control commands, forward/side overlap, and arming commands. The software is compatible with a 64-bit Windows PC or Apple iOS-based tablet/phone or Android-based tablet/phone. However, it is important to note that the data is considered as authentic, reliable, and objective because the software uses effective tools to collect, store, and analyze the data. On the other hand, a secondary source is any form of information that has been collected, recorded, and reported during testing when the drone is in motion. In this study, I'll be using the secondary sources as the primary source of data collection.

3.7 Data Collection Method

This research incorporated the use of a drone to collect data, the primary data collection is flying the drone over the farm at a low altitude. During the flight, the drone will record using a video camera to ensure that the information that was collected is accurate and has the information on file for future reference. This test is designed on whether or not the birds will react once they see the drone in motion and how the camera system will locate the pestering birds and identify the health of the crop. It is important to point out that the test of this drone will be conducted according to the Federal Aviation Administration (FAA) rules for small unmanned aircraft (UAS) operations, flying will take place during the daylight 30 minutes before official sunrise and 30 minutes after official sunset according to the local time. The maximum altitude for this test will be 200 feet above the testing area with max speed no more than 100 mph (87 knots). Safety is essential during testing especially with no flying over populated areas or directly over testing personal. Before the test will perform, pre-flight inspection will take place to make sure all communications are working and linked between the UAS and the control station.

CHAPTER FOUR: FINDINGS AND ANALYSIS

4.1 Overview

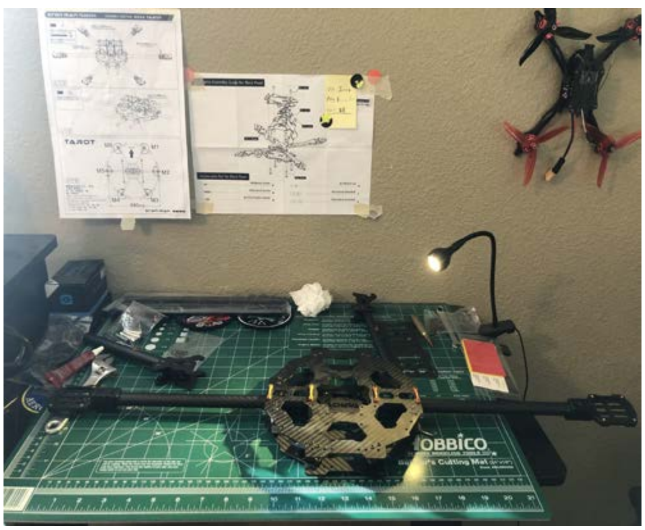
As it was pointed out in the introduction section, the primary purpose of this study was to assess the impact of the use of drones in the agricultural sector. In particular, the use of these devices is to help small scale farmers practice smart farming despite having small tracts of land and encountering a natural hazard that threatens to destroy their potential crop yields during every harvest season. The research was interested in identifying the current challenges that farmers in Alamogordo, New Mexico face dealing with pestering birds in the areas that favour cherry growth (favourable growing conditions for the drought resistant plant). Given this information, the researcher was interested in finding out, from the farmers, if the use of drones could have a more effective measure in controlling an ‘aerial’ pest than the methods that they have used in the past.

4.2 Building Process

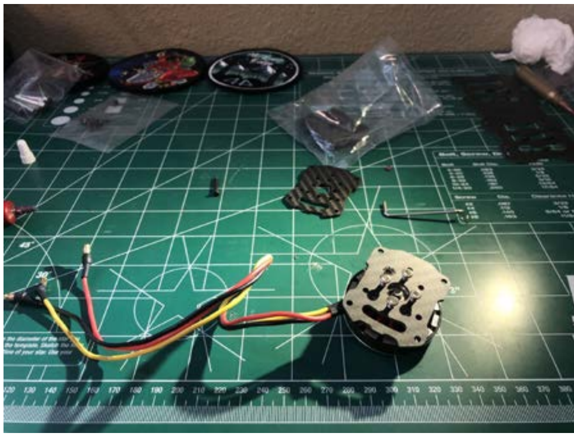
The parts and all the materials needed to build this hexacopter were all purchased individually to better specify to the farmer’s needs. Each specification will create a new and improved technology for farmers to use on a daily basis. Below is a detailed explanation of how the drone was built:

Step 1: buy all materials

Step 2: assemble the Hexocopter carbon fiber frame with Locktite 242 blue thread locker

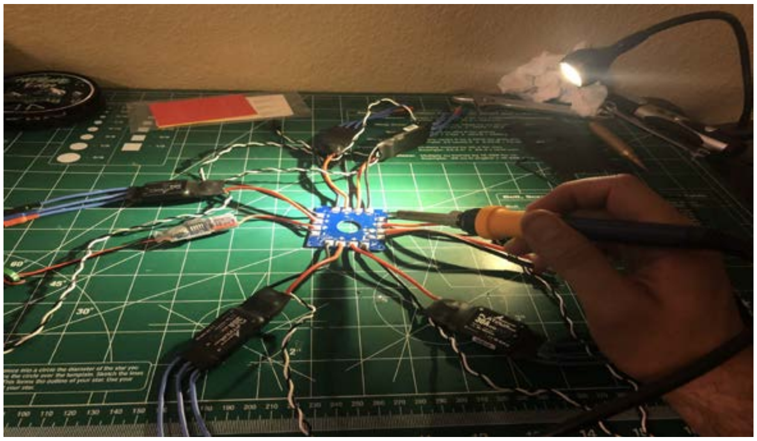


Step 3: add the base to the motor and feed the wires through the arms of the frame

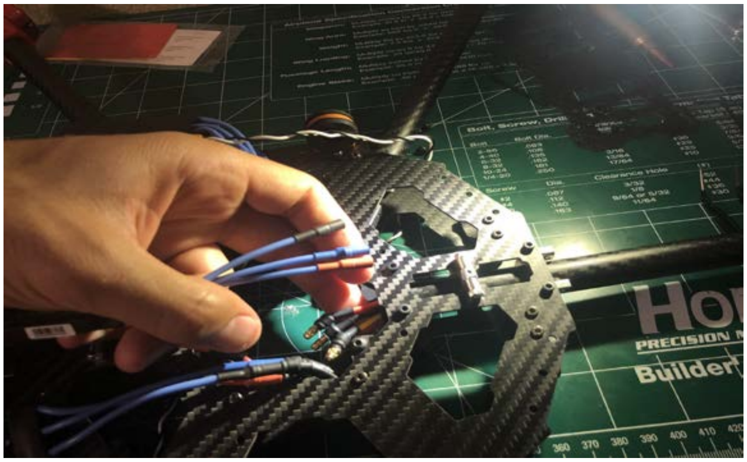



Step 4: connect the remaining four arms to the frame with the carbon fiber pipe buckle

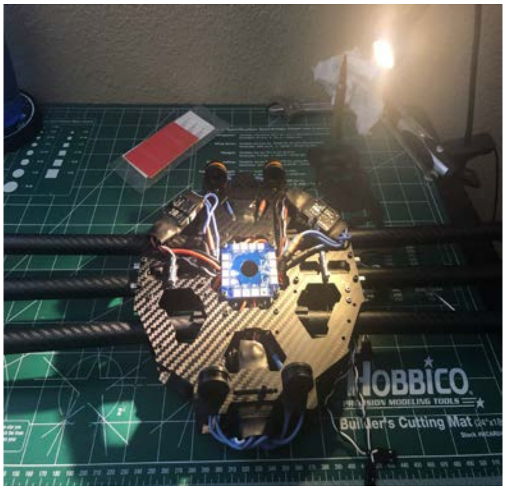

Step 5: solder the electronic speed control to the circuit board (red wire to + and black wire to -) and test the connections

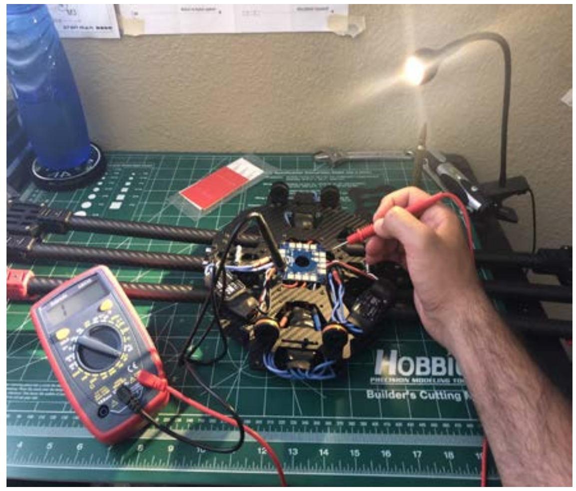


Step 6: connect the electronic speed controls to the motors: red to red, black to black, yellow to blue [clockwise]-red to black, black to red, and yellow to blue [counterclockwise]

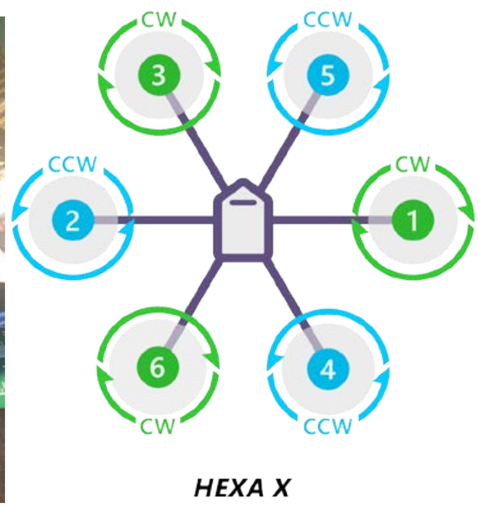


Step 7: install the electronic speed controller and circuit board to the carbon fiber frame with the included screws and zip ties, then test the connection with the multimeter

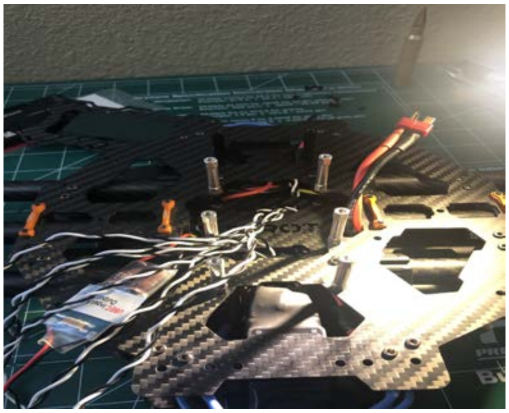


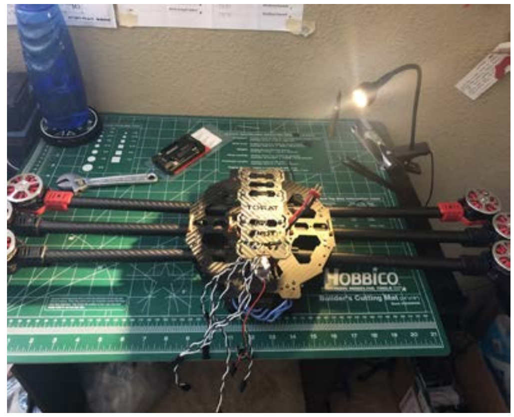


Step 8: mark each motor by number according to the motor rotation of the Hexocopter

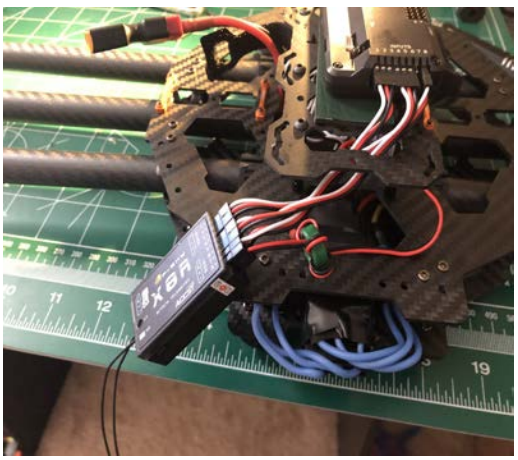


Step 9: install the carbon fiber plates that hold the flight controller and add velcro to hold it in place





Step 10: connect the receiver to the flight controller along with the GPS system and power wire



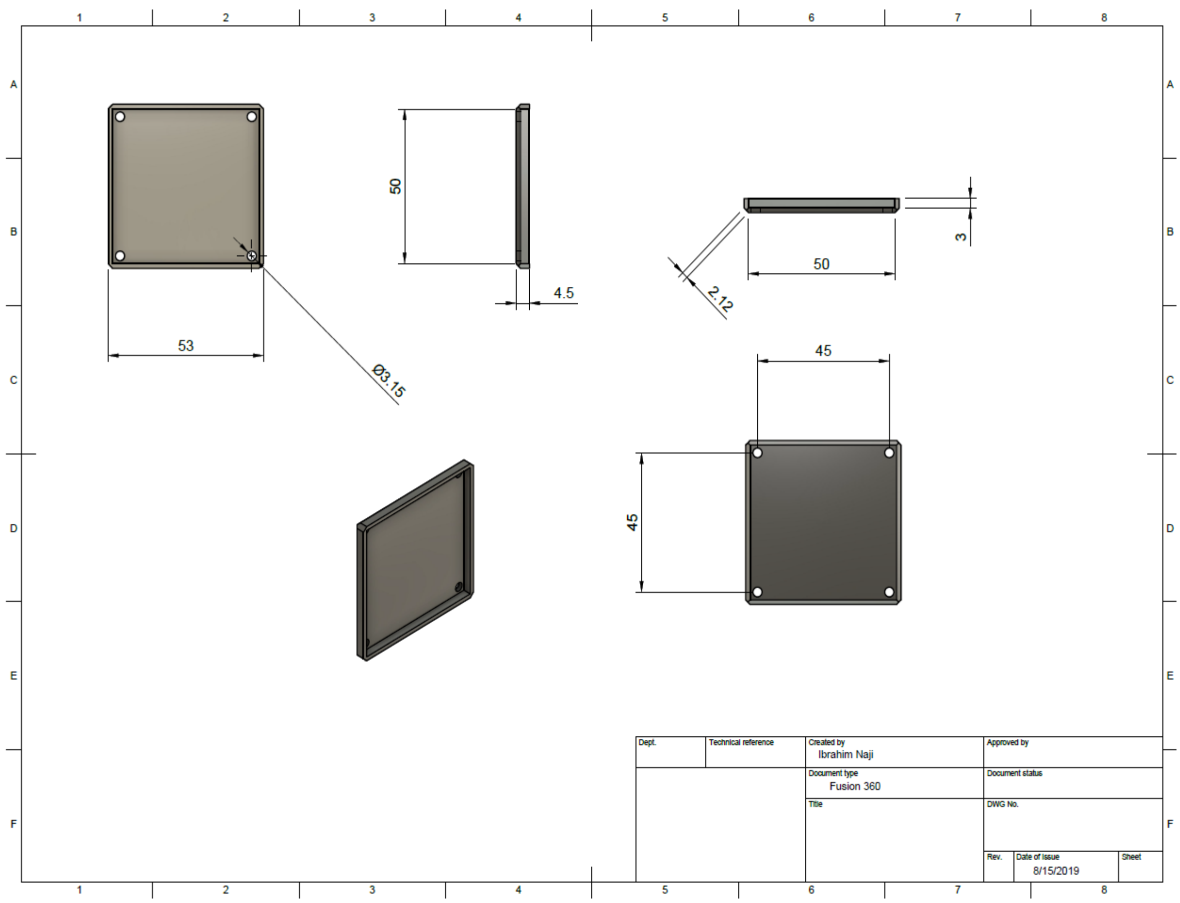
Step 11: connect the drone to the computer using USB cable and install mission planner

Step 12: programming flight controller and PID tuning

Step 13: test fly the drone

Once everything was deemed functional during the test flight, any vulnerable spots that can interfere with circuit board, electronic speed control, or the flight controller were focused on to fine tune the drone. The circuit board is wide open and that could be hazardous. Water, sand, and high winds can damage the drone circuit board when it is flying or when it is arming before take-off. This damage can cause the drone to crash or even worse losing control which can lead to a serious injury or property damage.

Designing a cover to protect the circuit board is essential, the dimensions of the circuit board were added to Fusion 360 software to design the cover: four sides of 90-degree angles consist of 53mm long, thickness of 3mm to cover the circuit board with screws half an inch long to secure the cover to the circuit board. Below is a picture of a schematic diagram showing the dimensions of the circuit board cover using the program Fusion 360 which was used to design and print the cover by 3D printer.



Schematic diagram showing the circuit board cover

4.3 OpenCV

The drone Proportional Integral Derivative (PID) is tuned and functional. The Open Computer Vision (OpenCV), which is a coding program that can be modified and installed to the Raspberry Pi to assist the drone on tracking the pestering birds. OpenCV is a real time computer vision that can be trained to track objects, created by Intel and written with computer language C/C++. The program is an open source that has packages that share hundreds of codes and computer algorithms. What the program does, the program uses a computer vision library which can be trained to recognize objects, it allows the computer to see and process visual data like the human visual system. Computer vision works by analyzing data that produce useful information to identify faces, objects or items.

Most Tech companies nowadays use OpenCV, for instance Apple, Facebook, and Microsoft. Tesla on the other hand been using OpenCV for their self-driving cars, which does car detection, tracking, lane detection, distance calculations, and traffic sign detections. Tesla has a team called "Autopilot vision team" their job is to research then design and code algorithms for autonomous driving. The main task of this team is machine learning which is to perform visual recognition and detection using OpenCV (Tesla).

This program will be coded and installed into the Hexacopter drone to detect pestering birds on the farm. By integrating Raspberry pi 4 with the flight controller allows the drone to recognize certain birds and objects thus making it a smart drone. Python is the primary programming language that will be used to program OpenCV with Windows PowerShell running the commands.

4.3.1 Code explanation:

The computer programming that is used to code called PyCharm, is an IDE integrated development program specifically used for python language. Windows10 used as operating system to run the codes by installing OpenCV packages and add Cascade Classifier to run OpenCV. Imported all necessary packages from GitHub Inc. for the video import videostream. Then an argument parser was constructed for a videocapture that allows the drone to pick up on objects. The video capture was to read the webcam or video play during code testing and actual drone simulation. While True code loops the video frame to keep capturing the desired image. The full code write-up is listed below:

```
# import the necessary packages
from imutils.video import VideoStream
import argparse
import datetime
import imutils
import time
import cv2
# Added Classifier to run the code
bird1_cascade = cv2.CascadeClassifier('bird1-cascade.xml')
bird2_cascade = cv2.CascadeClassifier('bird2-cascade.xml')
# Cap is for Video or camera capture!
cap = cv2.VideoCapture("bird.mp4")


# construct the argument parser and parse the arguments
ap = argparse.ArgumentParser()
ap.add_argument("-v", "--video", help="video path")
ap.add_argument("-a", "--min-area", type=int,
                default=500, help="minimum area size")
args = vars(ap.parse_args())

# if the video argument is None, then we are reading from webcam
if args.get("video", None) is None:
    vs = VideoStream(src="bird.mp4").start()
    time.sleep(2.0)

# otherwise, we are reading from a video file
else:
    vs = cv2.VideoCapture(args["video"])

# initialize the first frame in the video stream
firstFrame = None
prevFrame = None
i = 0
```

```
# loop over the frames of the video
while True:
    # grab the current frame and initialize the occupied/unoccupied
    # text
    frame = vs.read()
    frame = frame if args.get("video", None) is None else frame[1]
    text = "No"

    # if the frame could not be grabbed, then we have reached the end
    # of the video
    if frame is None:
        break

    # resize the frame, convert it to grayscale, and blur it
    frame = imutils.resize(frame, width=500)
    gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
    gray = cv2.GaussianBlur(gray, (21, 21), 0)

    # if the first frame is None, initialize it
    if firstFrame is None:
        firstFrame = gray
        continue

    # compute the absolute difference between the current frame and
    # first frame
    frameDelta = cv2.absdiff(firstFrame, gray)
    thresh = cv2.threshold(frameDelta, 25, 255, cv2.THRESH_BINARY)[1]

    frame = imutils.resize(frame, width=500)
    if i > 5:
        firstFrame = gray
        i = 0
    # firstFrame = firstFrame * (0.25)
    i = i + 5
    # dilate the thresholded image to fill in holes, then find contours
    # on thresholded image
    thresh = cv2.dilate(thresh, None, iterations=2)
    cnts = cv2.findContours(thresh.copy(), cv2.RETR_EXTERNAL,
                            cv2.CHAIN_APPROX_SIMPLE)
    cnts = imutils.grab_contours(cnts)

    # loop over the contours
    for c in cnts:
        # if the contour is too small, ignore it
        if cv2.contourArea(c) < args["min_area"]:
            continue

        # compute the bounding box for the contour, draw it on the frame,
        # and update the text
        (x, y, w, h) = cv2.boundingRect(c)
        cv2.rectangle(frame, (x, y), (x + w, y + h), (0, 255, 0), 2)
        text = "Yes"

    # draw the text and timestamp on the frame
    cv2.putText(frame, "bird detect: {}".format(text), (10, 20),
                cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0, 0, 255), 2)
    cv2.putText(frame, datetime.datetime.now().strftime("%A %d %B %Y %I:%M:%S%p"),
                (10, frame.shape[0] - 10), cv2.FONT_HERSHEY_SIMPLEX, 0.35, (0, 0, 255), 1)

    # show the frame and record if the user presses a key
    cv2.imshow("Bird Feed", frame)
    cv2.imshow("Thresh", thresh)
    cv2.imshow("Frame Delta", frameDelta)
    key = cv2.waitKey(1) & 0xff
    if key == 27:
        break

    # if the `q` key is pressed, break from the lop
    if key == ord("q"):
        break

# cleanup the camera and close any open windows
vs.stop() if args.get("video", None) is None else vs.release()
cv2.destroyAllWindows()
```

4.4 Testing Results

The results of flight time were included in the table chart below.

Drone kit’s	Time
No speaker and camera attached	25 minutes
Speaker attached below the drone	20 minutes
Camera secured on top	23 minutes
Speaker and camera attached	15 minutes
Two 6s batteries 5200mAh with everything turned on	19 minutes
3s battery 2200mAh	5 minutes

Some of the testing was done by flying the drone in high winds which is not recommend, it made the drone lose altitude at 300 feet. During this high wind flight, vibration of the GPS antenna made the drone fly out of range due to GPS interference. Once the drone passed the Geofence, RTL (return to land) mode kicked in and made the drone fly back to the landing location. Even though the return to location kicked on, the drone crashed and cost damage to one of the arms and the landing gear. These parts had to be replaced which slowed progress on the project.

4.5 Code Results

The lines of codes were downloaded to raspberry pi 4, once they were added researcher setup raspberry pi on test location with camera facing a bird eating on the ground. As soon as the code and classifiers turned on it begins to detect birds. Text display in the red color (Yes) shows the drone recognizing a bird and it displays (No) for no recognition. Also, the code consists of a time stamp showing time and date. In the test, code display (Yes) input on the screen with lock on bird eating in the garden indicating the system can recognize a live object and lock onto it.

More testing was conducted using video simulation to see the code output in flying mode while the birds are in air. In addition, anther video was used to simulate a bird feeding on the farm surrounded by trees. In figure 5, the code system displays three screens locking on a bird using video input as a simulation of the bird in real time. In the first screen, the code displays a live feed in the drone's view point. The second screen is the thresh display and the third screen is the delta frame.

Figure 5. Shows the code detecting birds using video input.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The purpose of this study is to assess the overall impact of drones in the agricultural sector. The specific goal was to provide a drone system to ward off pestering birds from crops to allow for better growth and an increased yield. Along with providing the user-friendly coded drone system for farmers that is cost effective, this project has inspired other areas of use for the drone. The other areas of use could be in surveillance, military applications, drones hunting (detect to take down drones), and use for airport flight lanes to clear birds from the runway.

There were some safety concerns regarding the drone crashing which happened multiple times during the test. Flight testing was performed at empty parks in Alamogordo, NM and El Paso, TX. The location of the empty parks were chosen for any safety concerns, and if it crashes it will crash on an area site clear of by-standers and properties. Other safety concerns are collision of larger aircrafts so finding a place away from airports and flying zones was addressed. During the flight testing, FAA guidelines were followed by flying below 400 feet which is maximum altitude that is allowed to fly drones.

Learning how to code was a challenge in this research especially not having a software engineering degree with a short time constraint, but with that being said it opened up a whole new door to this research. OpenCV have limitless applications that can be applied to agriculture from precision farming to drones in farming. Open computer vision with drones are revolutionizing agriculture and making things that were impossible couple years back very possible nowadays with fast expansion of drones in the industry.

There are some concerns from farmers that are slowing down the progress of drones in agriculture, some of those concerns are data privacy. To address this concern researchers can improve the security of the drone data when operating in the field or downloading/uploading data to the computer. Quality of data that the drone is capturing was another concern since this is a new technology. Farmers want to know more about the system and how it works. A project could be implemented in building a blueprint/manual of the drone with a hands-on demonstration from an experienced flyer to show how to master the drone especially during non-optimal situations.

Various factors can affect the drone during flight that can deter from optimal function. Therefore, testing was conducted to test the limits of the drone specifically in strong winds or challenging terrain. Wind resistance was a concern and due to the limited power supply high wind resistance would drain the battery twice as fast as the drone tries to keep altitude and speed. Hence, the drone should not be flown during high winds to prevent battery depletion and possible crash landings.

Solutions have been proposed to farmers and were happy with data that was provided along with the design of the drone. Farmers also pointed out that having this drone in the farm is essential to keep birds away and to monitor the farm without the hassle of walking in the field which is time and labour intensive. Through the research on the need for drones in agriculture, building a compliant drone with a coding system that is user friendly, and ironing out some limitations, the project is finally ready for application.

5.2 Limitations

The project was a success and exceeded the research expectation in the given 10 months allotted. The data that was collected and applied to this research opened up new project interests if some limitations were improved.

- Due to the time constraint and budget limitations the research was not able to include data from a test flight at an actual farm. There have been many test flights to assess the drone capability and any errors to fix before use in agriculture.
- There was an issue with parts of the coding system accuracy. The code ran well except there could have been more updates to allow easy use of the drone for farmers.
- The flight controller had issues with its system. The GPS accuracy was out of balance with the drone which made landing difficult. Also, the power input could not withstand the 6S battery required for the drone to function.
- The original flight controller that was added to the drone is APM 2.8, which appeared Arducopter firmware stop supporting and replaced with Pixhawk 2.4.8
- Lastly, more testing could have been done to provide data that could help improve the drone system

Furthermore, there were some issues with the flight controller and the magnetic field that led the drone to drift when it flies. This issue kept recurring which led the drone to have bad landing, position holding, and return to land. As for the code it needs more filtering to allow for more accuracy and precision. In testing, the code was recognizing other objects that were not birds as the camera began to vibrate. Other issues with the code system that occurred involved recognizing multiple birds that were flying all at the same time.

5.3 Future studies

The research of drone use in agriculture could be furthered now that the hiccups of building and coding the drone are manufactured with the ease of use for farmers in mind. The next step would be to fine tune the system and send it out for a test run in a farm to collect data on recognition of pestering birds. Once the test flight in the farm is conducted, the data could be analysed to increase the drones flight system as well as the coding system. There is more room for improvement on the coding system by adding more code lines to the current system and physically integrating raspberry pi 4 to the drone to test the code while the drone is in flying mode.

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