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Evaluation of unmanned aerial vehicles and analytical software for creation of a crop consulting business

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Evaluation of unmanned aerial vehicles and analytical software for creation of a crop consulting business

By

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Chapter 1

Introduction

Satellite imagery has been used to provide imagery since the 1972 starting with Landsat I (Vogt and Werspan, 2016). For the public to get imagery from satellites, the imagery must be licensed to the public, with this licensing process it makes it difficult to create products from the imagery that satellites provide (Vogt and Werspan, 2016) due to meeting the licensing standards. In addition, the resolution of satellite imagery has a high degree of variability depending upon the satellite's altitude, image resolution, and weather conditions (clouds) when the imagery is taken ("Price Wars", 2017). When an image is taken from a satellite it cannot be taken accurately when there is a large amount of cloud cover to hinder the imagery. I currently use Climate in my current job. This application uses satellites and it may take an image of the field weekly to every sixteen days. The amount of days between flights at times is to long as a crop issue may not be captured within the day that the flight is made with a satellite. The 2018 crop year growers experienced changes rapidly with the nitrogen losses from excess rainfall. With a drone, a flight can be done quickly depending upon weather and availability of the drone. Many times, the data can be available within a couple of hours.

Normalized difference vegetative index referred to as NDVI is a form of imagery that can be used to measure crop heath. Green imagery on a NDVI image is referred to as healthy or low stress and red is referred to as not healthy or high stress. Variable rate fertilizer spreaders can utilize less than 6 cm resolution at 400 ft when utilizing imagery such as NDVI. Satellites that use Landsatt operate at a level of 30M by 30M resolution (UAV VS Satellite, 2018). One area that this NDVI imagery is used in agriculture is with variable rate nitrogen application. Nitrogen can be applied as a rescue treatment after viewing drone imagery and in split application throughout the season after drone flights. This imagery can be of benefit to farmers up to and including pollination. The amount of flights is also of benefit as a grower can easy deploy a drone within a shorter period versus a typical flight of Landsat which is on average four to five times a month. The 2018 growing season saw the need for additional nitrogen and a quick flight by a drone meant the ability to get the nitrogen applied versus being delayed and having to wait for imagery after inclement weather in a grower's field.

Aerial imagery taken from airplanes have been used to supplement satellite imagery when concerns about quality imagery are present. With airplanes there are expenses which include fuel, pilot expense, and an expensive aircraft (Price Wars, 2017). Given these factors there has been a rise in the use of drones in agriculture to collect data for agricultural uses by businesses and by private farmers. Drones can be flown by a pilot that has acquired a drone pilot license from the federal aviation administration FAA. When the pilot is certified with the FAA they can conduct flights per the knowledge that they have acquired through the testing process to acquire the drone pilot license.

Drone flights have an advantage over aircraft and satellites in terms of the cost and the flexibility of flights. The drone market is expected to reach 20 billion dollars by 2020 (Drone deploy, 2017). The flexibility of using a UAV platform such as a DJI Phantom drone has a cost of 2-

3000 thousand dollars versus the 300,0000-dollar cost of an aircraft that would be used to conduct imagery of a farmer's field (Price wars, 2017). Drones often called UAV (unmanned aerial vehicle) provide the ability to capture data from a field of interest within a short period of time. The flight can be captured without great expense or great time in planning a flight. The time that is it takes to fly a field once a pilot arrives at the field is around 20-25 minutes. When the flight is completed the imagery can be taken back to an office for analysis. Sometimes this processing time can take two to three hours.

The use of drones for imagery has increased over the past couple of years. Precision agriculture using drones can help optimize agriculture and crop production. This optimization is done through creating an understanding of the crops that are grown through drone flights. The flights that are conducted and the understanding of the crops through the imagery has led to improved management of crops that are grown in farmers' fields. Improved management of insects and weed pressures can be seen through imagery taken with a drone. Wet areas of the field are also easier to understand through drone imagery, and drainage decisions can be made using imagery (Choosing the right, 2016). The imagery that is gathered in the farmers' field is analyzed and further used to make management decisions for improvements and management of the crops that are being grown.

Near infrared imagery, referred to as the abbreviation NIR gives the user a representation of crop health sooner than Red Green Blue Imagery which uses the abbreviation RGB. NIR colors that are bright red refer to vigorous crops and weaker crops or bare soil are in a gray color. RGB is imagery that is a standard imagery in many cameras and is imagery that is commonly seen in a standard photograph. NIR Data from drones detect crop stresses faster than color images that can be detected by a normal RGB camera (Choosing the right, 2016).

Computer programs that help analyze data have improved since drone technology has been developed. There are many programs such as Drone Deploy, Agribotix, Precision Mapper, and Sentera that have been developed and used in the agriculture imagery. This improvement and availability of programs has allowed small business owners and farmers to be able to conduct a UAV flight and gather data in a format that can be utilized by a grower. The flexibility of conducting UAV flights and gathering data for agricultural uses is important for farmers and ranchers as it allows them the ability to gather information quickly from a drone flight giving farmers data in a timeframe that a management decision and change can be made quickly to improve yield (Choosing the right, 2016).

Through the increased use of drones, I had the opportunity to be a drone pilot. I flew a Falcon 8 drone with my previous employer. With the missions that I flew I was able to take detailed imagery of soybean plots. The flights looked at traits that were compiled and analyzed by a central computer system, and this system was developed specifically for the flights that were being conducted. The drone missions that we conducted saved hours of manual labor of notes in the field when a flight. This compared to a drone which could be completed in under a half an hour. After the drone flight the data could be taken back to the office and within a day the results of the flight including the time it took to process the images would be ready for analysis by the team. The flight saved 2-3 people 4-5 hours a day of note taking. With the drone flight

one person was needed for a half an hour and one person was needed for 2 hours to run the analysis on the computer program.

Purpose and Objectives

The research that was completed for this creative component is important to me and is of interest to myself for the development of a business to serve farmers and businesses in the area in which I live. The formation of the business in the winter of 2018 will utilize drones also called UAV for use in agricultural imagery of corn and soybean crops. Researching the technology and methods of data collection that is required is important to help me understand the technology and the data collection methods that are needed to create my business.

The purpose of this creative component is to research unmanned aerial vehicles that could be used in precision agriculture for use in businesses. The second purpose of the creative component is to research the software for the business and use this research to select a software program and company that will be able to create maps and imagery for my customers. Imagery that can be used by the programs such as NIR, NDVI and RGB are considerations that are supported by the companies will be considered. The research that is conducted through this creative component will be beneficial in understanding the software that is available on the commercial market and for understanding and using the data (imagery) that has been collected through the drone flights that I will be conducting for my customers.

Companies such as Drone Deploy, Agribotix, Precision Mapper, and Sentera are important, as they offer programs for stitching images together to be used in formats that are useful to customers. The programs that the companies offer also use imagery that is collected by the drone to create maps that use RGB, NDVI, and NIR. The maps that are created can give the drone user as well as the grower a understanding of what the plant health is in the field.

- **Objective 1**

Interpret through this study a drone (UAV) and camera for purchase that will provide imagery to adequately meet the needs of my business as well as the needs of my customers.

- **Objective 2**

Identify through the research that is conducted, software that is available in the commercial market for purchase for my business, in addition to developing an understanding of the imagery that can be utilized in a manner that is beneficial to the business as well as the customers that I will be serving.

Need

In the winter of 2018 I will open my own business in which I will utilize the use of a drone for aerial imagery of corn and soybean crops in northern Iowa and southern Minnesota. This creative component is needed and important for the formation of a crop consulting company that I plan to create using the technology that is described in this creative component. The research

that is conducted will help me with selection of the appropriate drone for purchase and utilization in the business. Through the research for this creative component I will be able to research all aspects of the drone platform and the drone imaging software to decide on a specific purchase of a drone and software that will make the business successful.

Aerial imagery provides data and imagery that is created from the programs to consult farmers on the condition of the crop. This imagery is analyzed to provide farmers a view of the growing conditions in the field during the time of the flight. Understanding what type of imagery that can be produced with the drone assists in understanding the product produced for the customer. Drones provide a benefit as a drone can be deployed and data can be gathered timely as conditions in the crops change due to environmental and biological changes versus other forms of data collection such as aircraft and satellites imagery.

Definition of Terms

- **Agribotix-**Publicly available program that allows the user to stitch and modify images that are used in data collection.
- **Drone-**Unmanned aircraft also called UAV see description under UAV.
- **Drone Deploy-**Publicly available program that allows the user to stitch and modify images that are used in data collection.
- **FAA- (Federal Aviation Administration)** The branch of the government that has authority to govern civil aviation in the United States.
- **GPS Geotagging-** A way of aligning where the pictures are taken with a specific GPS coordinate.
- **Imagery-**Photos or video that is taken from a drone.
- **NDVI Image-**Stands for normalized difference vegetative index. This imagery uses green for high values and red for low values. NDVI values have been used to access the field conditions over time as well as access crop health (VanderLeest, Bergman, Darr, &Murphy, 2016).
- **NIR Image-**Stands for Near Infrared Imagery, this type of imagery uses a method that uses colors that give a representation of the health of the crop. This type of imagery is helpful as it gives a representation of crop damage before it can be seen with standard color imagery (VanderLeest, Bergman, Darr, & Murphy, 2016).
- **Precision Mapper-**Publicly available program that allows the user to stitch and modify images that are used in data collection.
- **RGB Image-**RGB stands for red, green, blue, these images have been described as similar to those that a human would see from an airplane (VanderLeest, Bergman, Darr, &Murphy, 2016).
- **Sentera-**Publicly available program that allows the user to stitch and modify images that are used in data collection.
- **Stitching of Images-**Method of utilizing overlaps and ways of combining images using computer software to create a desired image for use in agriculture flights.
- **TSA-(Transportation Security Administration)** a branch of the government that is responsible for security of travelers, the TSA was formed after the September 11, 2001 attack on the World Trade Center.
- **UAV-**Unmanned aerial vehicle or an aerial vehicle that has a controller on the ground and a form of communication between the two.

Chapter 2

Literature Review

I researched drones that are available for purchase in the commercial market. Through the research online of drones that are used in commercial agriculture several offerings were found. Through the reading of reviews, I was unable to decide on which drone to purchase for the crop consulting business. Looking at the reviews was extremely confusing, and I was not able to discern which features of the drone were of greatest importance.

Therefore, an extensive literature review of the drones and software companies that will be used in the crop consulting business was conducted. I have found through the research for the creative component that the technology has changed quickly within the year that it has taken to write this creative component. I would recommend that a researcher wanting to do an extensive review of UAV and software to conduct the review in a shorter time frame. The shorter time frame would allow for the writer to keep up with the technology changes without having to rewrite part of their research to keep up with the advancing technology of the UAV as well as the software companies that provide the user images.

Through researching this creative component, I found an article from Iowa State University that described imagery that was available and the uses of the imagery. The article described RGB imagery, NIR imagery, and NDVI imagery (VanderLeest, Bergman, Darr, & Murphy, 2016). This imagery is described as standard imagery for companies providing drone services to the farmer or rancher (VanderLeest, Bergman, Darr, &Murphy, 2016). The use of imagery provides a farmer and drone operator the ability to access crop differences along with providing a snapshot at the time of the flight the health of the crop. It also provides the ability to understand compaction issues that may have resulted from machinery operation as well as factors such as water stress, and weed outbreaks in the field (VanderLeest, Bergman, Darr, & Murphy, 2016). Imagery using drones provides the farmer the ability to fly the field at intervals that are critical for development of the crop and to analyze the information from the flight and use this to establish differences and provide ways of improving the crop through the imagery. Websites that evaluated drones were reviewed. Articles such as the article by (Nixon, 2018) analyzed drones for agricultural use. This article was helpful but was not customized to the needs and requirements of my use for my business, as the article only gave background information and an overview of software and imagery that a drone can create for a farmer or a business.

Literature was reviewed that looked at the accuracy of the drone and its ability to create quality imagery. It was found that the multiple rotor design enables the drone to fly lower and slower when it is gathering imagery (Nixon, 2018). A higher payload capacity is also possible with a multi rotor design (Drone Deploy, 2017). This information is critical to create quality imagery that is important to the customer.

Through a review of the articles and texts it displayed the need for the UAV platform to be readily supported in the industry through the software that is available to analyze the data that is collected in the flight. Through my personal experience at DuPont Pioneer and through the information that is provided on the mapping software company Drone Deploys website, I have found that DJI drones are supported in the precision agriculture industry (Work smarter, 2017). They have good performance and reliability as well as being commonly used by professionals in

the industry (Work smarter, 2017). DJI drones come in many different packages and options with some recent new platforms that are being offered in the precision agriculture industry (Agriculture maximizing yields, 2017). Literature was reviewed for the DJI Mavic 2 Pro, DJI Phantom 4 Pro and the DJI Inspire 2. The Mavic 2 Pro and the Phantom 4 Pro are similar in costs and the Inspire 2 is a drone that costs more but can be upgraded to the needs of the user, I will review the costs of the drone in the coming pages of the creative component.

DJI's website was not helpful in selection of a drone, therefore articles on websites by other professionals were read and analyzed in the process of selection. The ability to change a camera to go from RGB to NIR or to modify the RGB camera to utilize NIR imagery is important to the data collection that will be conducted for the business (Drone Deploy, 2017). Ratings on DJI UAV's with a package camera that can be changed or modified to capture imagery in these formats is important for collection of data for the company.

DJI drones were then looked at based upon aspects such as flight time, payload capacity, and ability to carry camera that offers RGB and NDVI imagery. The ability of cameras to be changed and modified on the drone platform is important as it would allow the camera to be upgraded with new camera functionality when improvements are made to future camera designs.

Literature was also reviewed online for companies that provide computer programs that can stitch images together after drone flights were conducted. Stitching of images is important in that it provides one map that can be viewed and gives the viewer the ability to see the entire field in one picture (Drone Deploy, 2017). In researching the companies that provide services for stitching of images I found that it is important to have a company that can provide the ability to provide support for the program. The support would be important to me as I am starting the company and would not have the knowledge and the experience to troubleshoot technical problems with the stitching that would occur. Through my research I discovered a company called Drone Deploy (Drone Deploy, 2017). Using this companies' information as an example, subscriptions can be purchased from companies that will provide services. Subscriptions range from free to a custom pricing plan based upon the number of pictures that are used per map and the resolution of the image (Drone Deploy, 2017).

A review was conducted of the agriculture imagery that can be created through red, green and blue colors also called RGB or through NDVI imagery (Drone Deploy, 2017). RGB is the most common form of imagery that is collected from drone flights. This imagery is collected using a digital camera that is mounted to the drone platform. RGB is a method of capturing imagery through cameras that capture red, green, and blue light. Through my research I have found that there are items to look for when selecting an RGB camera for use in drone flights. The first selection would be to select a camera that is of high quality (Drone Deploy, 2017). This way the camera that is currently the best at the time of purchase will have the newest developments and the quality is as good as it can be at the time of the purchase. Factors such as pixels and having a camera with the highest pixilation as well purchasing a camera with a pixilation of 12.3 or higher so that the points can be matched correctly with the drone mapping software in programs such as Drone Deploy (Drone Deploy, 2017). Purchasing a camera with a mechanical shutter (Drone Deploy, 2017) allows for the images that are captured to be clear versus images that are captured without a mechanical shutter often called an electronic shutter. Photos taken in motion with an electronic shutter could develop a warped image. Warped images increase the difficulty and

chances of the drone mapping software to be able to align the images that were taken (Electronic versus mechanical, 2018).

The second form of imagery that can be used is near infrared imagery or NIR. This imagery is used in precision agriculture to understand plant health (Drone Deploy, 2017). Light from the vegetation is used to understand the chlorophyll that is available in the plant at the time of the imagery. When a plant has a high amount of chlorophyll present it will reflect more NIR light (Drone Deploy, 2017). Therefore, a plant with more chlorophyll is considered healthier.

NIR **RGB** **NDVI**

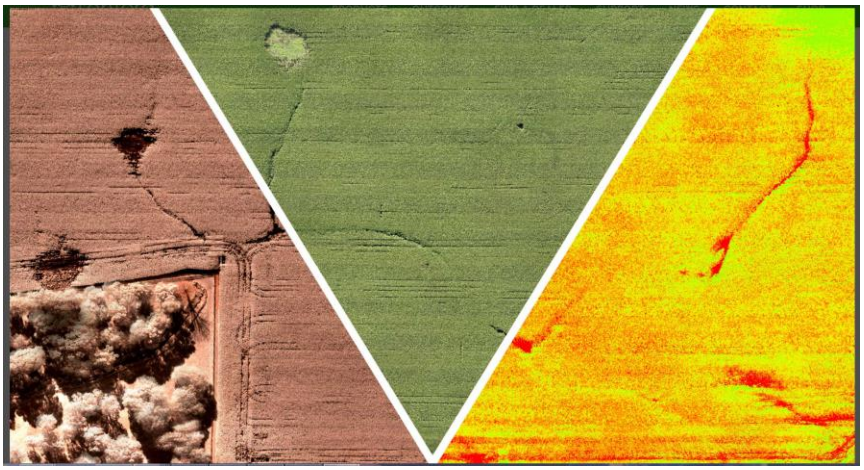

Photo 1 Illustrating the three different resolutions of imagery that are available with a drone flight (Sentera.com, 2018)

NDVI stands for normalized difference vegetation index. This form of imagery is used to measure soil and water availability, yield potential, and the vigor of the plant (Micasene, 2018). RBG stands for red, blue, green. This imagery is standard, RGB imagery works well in that it can create orthomosaic maps, which is a map of the field that has been stitched together to form one overall image of a farm fields (RGB Versus NIR, 2018). The NIR camera image uses the red and NIR signals from light to create a difference between a healthy and non-healthy plant (RGB Versus NIR, 2018). A NDVI image can be used by an agronomist to make decisions based upon the NDVI maps. One benefit of a NIR over an RGB image is that the NIR image can detect problems or defects in the crop sooner that using an RGB image (RGB Versus NIR, 2018).

Upgrades can be added on the three drones for an additional cost. The cost of adding on the NIR and NDVI on a Phantom Four series drone, along with the DJI Mavic is $2199. The cost for the NIR and NDVI add on for the Inspire 2 is $3469 (Available DJI NDVI, 2018). With the Inspire 2 the payload can be completely changed as the RGB camera can be removed and the NIR can be mounted to the drone in its place.

After I reviewed the literature I asked the following question. What type of drone should be purchased based upon current features and abilities of the UAV, and what type of software should be used to analyze the images that are captured by the UAV?

Chapter 3

This chapter will describe the UAV's that will be used in the study as well as the population of programs that will be used to analyze and stitch the images into a format that can be used by myself and by the customers that I am serving. A review of the methods and procedures that are used to make the selection of the drone (UAV) will also be presented as well as the software for the creation of the business.

Sample Population

The study of a drone that is to be used in the study for purchase for the business were selected and available for purchase from manufacturer DJI. They were analyzed for their ability to be used in a crop consulting business. DJI drones selected for performance and reliability. DJI drones are known for their use in the agriculture industry. Due to this use, DJI drones will be looked at for the crop consulting business. The population will include only multi rotor design drones (Best agricultural, 2017). This design versus a fixed wing design enables more controllability of the drone and ease of use (Best agricultural, 2017).

Drones or UAVs that were researched were selected were the DJI Phantom 4 Pro a platform that is in the consumer series (Phantom 4, 2017). The Phantom style of drone is widely used by agriculture professionals since its introduction in 2016. The second UAV is the DJI Mavic 2 Pro a consumer drone that has become extremely popular in the agriculture industry this past year. The final drone that will be analyzed is the DJI Inspire 2. This drone is new to the agriculture industry and is a drone that is used in precision agriculture jobs (Inspire 2, 2017). These drones were considered because of their ability as a reliable platform and the support that is provided by mapping software companies Drone Deploy, Precision Hawk, Sentera, Agribotix. The three drones are also recommended by DJI (Agriculture maximizing, 2017) for their ability and design for crop consulting. This population represents the top of the line equipment for crop consulting (Agriculture maximizing, 2017). Two of the drones are very close to the same price point and offer some of the same features, they include the DJI Mavic 2 Pro and the DJI Phantom 4 Pro. The Inspire 2 is on the top range of costs and is more customizable offering additional options some of these options include the camera that the Inspire 2 offers. This creative component will help me decide if I need to spend the extra money for the Inspire 2 drone and which drone is the best option for the business. The extra features will have to be studied to determine if they are needed by the business that I plan to create or if the Phantom 4 Pro or the Mavic 2 Pro would be a fit for the business. A chart will be created to understand the features that each drone provides in a way to understand the features that each of them provide.

Drone software that was considered was Drone Deploy, Precision Hawk, Sentera, Agribotix. These programs were selected based on their ability and use with precision agriculture and their experience with the agriculture industry. The selection population did not include software companies or programs that did not work with agriculture.

Reviewing the software company's websites individually was quite difficult to understand and compare side by side to understand what each one of them offered. It is important to understand what each of the companies offer to the agriculture industry and the value that each one of them provide. Therefore, I found a way to evaluate each of the drone software companies through creation of a table that would provide what each drone software company offered. I created a summary sheet for each of the companies and what they provide to the user.

Methods and Procedures

To operate a drone in the United States for my business, a requirement by the FAA is to obtain a remote pilot certificate for operation of the UAV. I obtained this last year through testing over the FAA part 107. A background check was conducted by the TSA which was also part of the certification process. Study guides were available on the internet to study and this was used to pass the exam. Having the certification will allow me to fly the drone and operate the drone in a method to operate my business. A two-year retest will need to be taken to maintain my license to be current with the FAA.

Being certified to operate a drone, I developed a procedure to select a drone that was free of subjective selection from myself. Creation of a Likert scale was developed to effectively evaluate the purchase. The questions that were developed were made to evaluate the features of the UAV as well as the drone analysis software. This scale looked at all aspects of the purchase so that an effective decision could be made. Using this scale allowed me to effectively rate the purchase. A 5-point Likert scale is often used by businesses to understand purchasing decisions that are made by consumers (Risen &Risen 2008).

The scale in Exhibit 1 will be used to analyze and understand what is important for the features of the drone as well as the drone software that will be used to analyze the images. Questions were then developed that were pertinent to the specs of the drone and software. I sought information from the manufacturer DJI on the DJI website for creation of a table and functionality topics to be evaluated on the 5-point Likert scale.

Exhibit 1 Scale	**Intent Probability**
5-Completely meets the needs of the company	.99
4-Likely meets the needs of the company	.75
3-Might work for the needs of the company	.5
2-Probably won't work for the needs of the company	.25
1-Definatly won't work for the needs of the company	.01

(Risen & Risen, 2008) suggest that the 5-point intention scale can be translated into an intent of probability. Exhibit 1 shows how the scale can be translated into a percent of intent of making or translating a purchase. Utilizing the scale of 5 a user would be 99 percent probable of using the product and a 1 would indicate a .01 percent chance of using the product. Exhibit 1 displays the scale of probability of purchase that I will use to select a brand of drone software as well as a specific drone model. The points given from the Likert scale using (Risen & Risen, 2008) the probability scale will be translated into a percent of probability of purchase for the drone and the software.

I utilized a Likert scale as it gave me a method of determining what I felt was important and removed as much of the bias as I could in analyzing what was important in determining the functionality of the drone for purchase. It helped me think about the importance of the program and the features that were of importance and how those features could help my business improve the data that I would generate for my future customers.

Questions developed are tailored to a feature of functionality of the drone. Table 1 describes feature topics of the three drones that are linked to the design and functionality. The values of each of the features will be evaluated against the Likert scale intent of probability that is displayed in Exhibit 1. The UAV as well as the software that receives the highest score utilizing the Likert scale will be selected for the business. This provided a method to evaluate the drones on a scale of functionality against each other and will help in my determination of which functionality features are important to me and the business.

Table 1 UAV features that will be evaluated

Functionality
Max speed
Max flight time
Max wind resistance
Max takeoff weight
Max ascent speed
Camera
Ease of use
Obstacle sensing system
Operating temperature range
GPS hovering accuracy
Camera mechanical shutter
Camera changes
Transmitter range of transmission
Cost

Table 2 describes the feature topics of the drone software programs Drone Deploy, Agribotix, Precision Hawk, and Sentera. The features of the programs will be analyzed using the 5-point Likert scale and are demonstrated in the Appendix. The 5-point Likert scale and the intent of probability was used for each of these functionality sections of the software programs to determine which program was selected for the business. The program that gets the higher score based upon the Likert scoring using the intent of probability (Risen & Risen, 2008) will be selected for purchase for the business.

Table 2 Drone software program parts that will be evaluated

Android/IOS app
NDVI elevation layers or variable application report
Photos per map
Map and 3D processing
2D resolution
Support
RTK coordinates
Cost of the plan
Automated Flight Supported
Partners that the company works with
Ease of use

Chapter 4

The Likert scale that was developed for this creative component helped me with the selection of a drone and software, allowing me to analyze the aspects of the drone and the features that are important. Along with the Likert scale a chart was also developed that indicates the differences in all three drones. These differences can be confirmed and contrasted against the results utilizing the intent of probability results (Risen &Risen, 2008) of the questioner that utilized the Likert scale. These two processes work hand in hand to find the appropriate drone as well as the most appropriate software for the company that I am developing.

Additionally, the Likert scale results were also compared against the programs that are used to create the data. A chart will be used that contains all the abilities of the programs and this will be used to compare against the Likert scale results to determine what the best program will be for the drone business. The cross analysis with the chart along with the Likert scale will provide an excellent way for me to determine a software program that will perform adequately with the drones that I am operating for my business.

Much of the ability of the drone to perform will be analyzed upon the ability of the drone to provide outstanding imagery for the client. With the images it will provide quality data for the client as well as the business. The data will allow for the ability to make good decisions based upon the data. Following is the Likert instrument for the drone and the Likert instrument for the software.

Likert Instrument Drone

	Completely meets the needs of the company	Likely meets the needs of the company	Might work for the needs of the company	Probably won't work for the needs of the company	Will not work for the needs of the company
1. Is flight speed provided by the drone meeting the needs of the missions that are going to be flown?					
2. Will the flight time that the drone provides meet the needs of the company?					
3. Wind resistance meeting the needs of the company?					
4. Is the ascent speed of the drone safe?					
5. The product is easy to use?					
6. Is the camera MP appropriate for the drone?					
7. I am likely to recommend the product to others?					
8. Does the obstacle sensing system acceptable for the drone?					
9. Is the operating temperature applicable to the environment that it will be operating in?					
10. Is the GPS hovering accuracy accurate enough for the business?					
11. Is the camera mechanical shutter providing at least 12MP images?					
12. Is the drone able to support camera changes in the future?					
13. Is the transmitter range within a reasonable amount of distance for the drone?					
14. Is the cost acceptable for the business?					

Likert Instrument Software

	Completely meets the needs of the company	Likely meets the needs of the company	Might work for the needs of the company	Probably won't work for the needs of the company	Will not work for the needs of the company
1. Does the software support android or IOS?					
2. NDVI elevation layers supported by the software?					
3. Are the photos that are applicable to each map acceptable?					
4. Do the programs support 3D processing?					
5. Do the programs support 2D resolution?					
6. Do the programs provide adequate support?					
7. RTK coordinates supported and appropriate for providing good imagery?					
8. Is the cost of the program acceptable and able to be absorbed by the company allowing it to be successful?					
9. Are crop reports provided?					
10. Program have agriculture partners that it works with?					
11. Ease of use with the program?					
12. Supports automated flight?					
13. Webinars or learning experiences available?					
14. Support or sales of equipment?					

A chart was created to help the taker of the Likert instrument and compare the data that each drone and each program can provide. The chart will be beneficial to understand the quality of data or ability of the program or the drone's abilities. Using the chart and Likert Scale together was beneficial to help understand the pros and cons of each detail of the program and drone.

Drone Comparison Chart

	Mavic 2 Pro	Phantom 4 Pro	Inspire 2
Is flight speed provided by the drone meeting the needs of the missions that are going to be flown?	20m/s (S-Mode) 12 m/s(P-mode)	20m/s (S-Mode) 12 m/s(P-mode)	25.9 m/s (s-mode), not published (P-Mode)
Will the flight time that the drone provides meet the needs of the company?	31 minutes	30 minutes	23 minutes
Wind Resistance	8-10.55 m/s	10 m/s	10m/s
Ascent speed	5-m/s (S-mode), 4 m/s (P-mode)	S-mode 4/ms P mode 3m/s	P-Mode 16 ft/s, S- Mode 19.7 ft/s
Camera MP	20 million 1" CMOS (Pro), 12 million with the Zoom Camera	1"CMOS Effective pixels of 20M	24 MP Still Photo capture, (Zenmuse X5S)
Obstacle Avoidance System	Front-66 ft away, Bottom-36 ft, Sides-has a side sensor unknown distance, Back-16 feet, Top-25 feet	Front Rear and Bottom-will work at a speed of 13 MPH	Front, Rear, Top and Bottom-at 31 MPH at 30 meters. Top side distance is 16 ft
Operating Temp	14 to 104 deg F	32° to 104°F (0° to 40°C)	4° to 104° F
GPS Hovering Accuracy	Vertical, plus or minus .1m with vision position on and plus or minus .5 m with GPS position. Horizontal-plus or minus .3 m when vision position active and plus or minus 1.5 m with GPS positing.	Vertical, plus or minus .1m with vision position on and plus or minus .5 m with GPS position. Horizontal-plus or minus .3 m when vision position active and plus or minus 1.5 m with GPS positing.	Vertical: ±1.64 feet (0.5 m) or ±0.33 feet (0.1 m, Downward Vision System enabled), Horizontal: ±4.92 feet (1.5 m) or ±0.98 feet (0.3 m, Downward Vision System enabled)
Pixels and shutter	20 million 1" CMOS (Pro), 12 million with the Zoom Camera, with Electronic Shutter: 8–1/8000s. Only has an electronic Shutter	1"CMOS Effective pixels of 20M, mechanical shutter 8-1/2000s, 8-1/8000s Electronic Shutter	20.8 MP Still photo Capture, (Zenmuse X7), Electronic shutter speed 1/8000-8s, Mechanical shutter speed 1/1100-8s
Transmitter Range	4.97 miles	4.3 miles	4.3 Miles
Cost	$1500	$1500	$2999
NDVI Upgrade	$2199	$2199	$3469-$3718
Total Cost Drone with NDVI	$3699	$3699	$6468-$6717
Battery Voltage	15.4V	15.2V	22.8V
Battery Type	3850 mah Lipo 4s	Lipo 4S 5870 mah	Lipo 6s 4280 mah
Camera Lens	FOV about 77 deg, 35mm Format Equilivant:28MM Aperture/2.8-F11 Shooting Range:1 M to 00	FOV 84 deg 8.8 MM/24 MM (35 MM format equilivant) f/2.8-f11 auto focus at 1m-00	FOV 84 deg 8.8 MM/24 MM (35 MM format equilivant) f/2.8-f11 auto focus at 1m-00
Camera ISO Range	Video 100-6400 Photo 100-3200 auto, 100-12800 (Manual)	Video:100-3200 (Auto) 100-6400 (Manual) Photo:100-3200 (Auto) 100-12800 (Manual)	Photo: 100 – 25600, Video: 100 – 1600 (EI mode on); 100 – 6400 (EI mode off)
Takeoff Wt.	907 g	1388g	7.58lbs or 4250 g
Diagonal Size	335 MM, when folded H83mm, W83mm, L 198 mm	350 MM diagonally	In flight mode-48 cm wide, 47 cm long, 32 cm high. Transport Mode-53 cm wide, 47 cm long and 21 cm high.
Supported SD cards	Micro SD Card Max Capacity 128 GB	Micro SD Card Max Capacity 128 gbm Write speed_>15mb/s	128 GB SD Card
Gimbal Mechanical Range	Tilt: -90–30° Pan: -75–75°	Pitch: -90° to +30°	tilt: +_40 deg to -125, pan +_300 deg, Roll +_20 deg

Software Comparison Chart

	Drone Deploy	Agribotix	Precision Mapper	Sentera (Field Agent)
Costs of the plans	**Explorer-Free** **Pro-$83/mo., Business-$250/MO, Enterprise-depends on the business.**	**Basic-$89/mo., Professional $159/mo.**	**Precision Mapper Free Tier-Free** **Precision Mapper Professional Tier-$3500/yr.**	**Free Mobile version, $12 viewer version, FieldAgent is $30/mo or $250/year subscription price. If you need services performed such as stand count or image stitching that is .25/ac.**
Image stitching supported	**Yes**	**Offered at both levels**	**Yes**	**yes**
Variable application report	**Yes**	**Offered at the professional level.**	**Yes**	**Yes**
Partners	**Accenture, CaseIH, New Holland, John Deere, Climate, SoftBank S&S**	**John Deere, Climate, Winfield, AGCO**	**None**	**Apex, SST, My John Deere Operations Center, SMS, Farm Works Software**
Is automated flight supported	**Yes**	**Yes**	**Yes**	**yes**
IOS or Android supported	**Both**	**Both**	**Both**	**IOS only**
Are crop reports provided	**At the Pro and Business level.** Automated reports of entire field of crops, stand count and plant populations.	**Available at Basic and Professional**	**Professional tier**	**Weed, Plant Populations, Elevation, Spot Scouting**
Ease of use	**Easy**	**Easy**	**Difficult**	**Easy**

Chapter 5

Though the work with the creative component I selected Drone Deploy as the software company and the Phantom 4 Pro as the drone platform for the company that I plan to create. The Likert scale was taken and the results from taking the exam helped me with my decision on what drone was selected for the company that will be formed. The Phantom 4 Pro received an 87.6% result from the instrument and in second was the Inspire 2 at 78 % and the Mavic 2 Pro was at 76% probability of purchase. I utilized the probability scale of purchase that was demonstrated by (Risen & Risen, 2008) to calculate the percent of purchase for the drone and calculated the mean based upon the score from each category. Looking at the results from the Likert instrument as well as the chart that was created I learned from this creative component what I needed in a drone. The Mavic 2 Pro was the lowest scoring but there was only 2 percent difference in the probability scale of purchase to the Inspire 2. After taking the Likert, it demonstrated to me that I disliked the Mavic 2 Pro camera as it only had an electronic shutter and the drone was smaller allowing it to be moved easily in higher winds.

When looking at the drones in a head to head comparison the Phantom 4 performed well and was able to perform the necessary tasks that were needed by my crop consulting company. Through the analysis of which drone to select for the business, I found which features were of importance to the company. What I learned from this creative component is what situations I would be using the drone in as well as what type of software was needed to analyze the images taken by the drone. With this knowledge I found what drone was the correct drone to purchase as well as what software to purchase.

The Inspire 2 drone had many features that would not be used. Starting the business with a drone that meets the needs and does not overcomplicate the business leading to down time is important. The Inspire 2 is at the top of the price range for the drones that were selected for the Likert instrument. The Inspire 2 costs along with the NDVI upgrade is 2769 dollars more than the Mavic 2 and the Phantom 4. The total cost of the Inspire 2 is 6468-6717 dollars versus 3699 dollars for the Mavic 2 Pro and the Phantom 4 Pro with the NDVI upgrade package.

With the flights that I would be taking with the drone, along with the results from the Likert instrument I selected the Phantom 4 Pro over the Inspire 2 and the Mavic 2 Pro. I had concerns with the Mavic 2 Pro and its ability to hold up to wind resistance. The drone is quite small and would be moved easily in the air by wind gusts. Where I live in northern Iowa it is quite windy and having a drone that is more stable would be a better option. The ratings are 8-10 m/s wind resistance for the Mavic 2 Pro compared to a solid 10 m/s with the Inspire 2 and the Phantom 4 Pro. The camera on the Mavic 2 Pro also does not have a mechanical shutter. This was a drawback of this drone's design.

Through my research I found that many of the options that were available in the Inspire 2 were not needed for my company. The RGB camera and the gimbal on the Inspire 2 drone was a step above the Phantom 4 and the Mavic 2. Features such as the high-level Zenmuse camera available on the Inspire 2 was nice but not completely needed as the camera on the Phantom 4 was adequate for the business. The Mavic 2 Pro and the Phantom 4 Pro all utilize a 20 MP camera. According to software provider Drone Deploy a 12.3 MP camera is the minimum camera that allowing the points to be matched with the software and providing enough pixilation for a good image (Drone Deploy, 2017).

The gimbal on the Inspire 2 provided better tilt, pan, and roll versus the Phantom 4 Pro but I would not be using these features for my business as they were not needed. The Mavic 2 Pro also provided a greater angle of vision as well as the ability to pan -75 to 75 degrees. The illustrations below show the angle that the Mavic 2 Pro as well as the Phantom 4 Pro gimbal performance. What I found through my research was that the -90-degree angle was all I needed to focus on as the objects directly below the drone is all that would be photographed. Therefore, the additional camera angles provided by the Mavic 2 Pro and the Inspire 2 were not needed.

Mavic 2 Pro Gimbal Angle

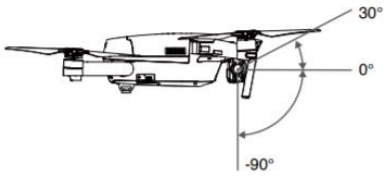

Image from Mavic 2 Pro user manual (Mavic 2 Pro user, 2018)

Phantom 4 Pro Gimbal Angle

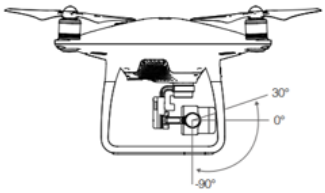

Image from Phantom 4 Pro user manual (Phantom 4 Pro user, 2018)

The Phantom 4 provided an advantage over the Mavic 2 with the mechanical shutter. The mechanical shutter is a moving shutter compared to the electronic shutter that reads the light as it enters the photo. The cons of the electronic shutter are that it takes 1/15th of a second to take a photo and for the shutter to read (Electronic shutter versus mechanical, 2017). With a fast-moving object there could be a skew effect if the drone is moving. The 1/15th of a second for the electronic shutter to take the picture causes a flaw in the photo. The Mavic 2 only has an electronic shutter and the Inspire 2 and the Phantom 4 Pro have an electronic and mechanical shutter, but the cost of the Inspire 2 with the camera is considerably more than the Phantom 4 Pro. The performance of the camera with the electronic shutter is similar with the Phantom 4 Pro versus the Mavic 2.

An electronic sensor reads the photo line by line across the sensor. The process of time to read the individual line takes 1/15th of a second (Electronic shutter vs mechanical, 2017). This can cause issues with light. As light fluctuates having too high of a shutter speed can cause banding or issues with the photo because of the light (Electronic shutter vs mechanical, 2017). Electronic shutters are rated faster in speed, but the processing time of reading the photo line by line causes issues with drone imagery (Electronic shutter versus mechanical, 2017). Fast moving objects can be skewed using the electronic shutter. Issues can be seen with motion if a drone is changing direction while taking photos (Electronic shutter vs mechanical, 2017).

I was excited to see the results of the drone software after taking the Likert exam. The results from taking the Likert for the drone software yielded the results of 96% for the Drone Deploy, 90% for Sentera, 83% for Agribotix, and 71% for Precision Mapper. The results for the drone software were much closer than I thought that it would be. Drone Deploy had the best results as it offers more training and has been a company that has been around longer than the other programs, in addition this company works with other data collection software such as John Deere and Case IH. In second was Sentera a company that provides software as well as upgrades that include packages such as NDVI and NIR imagery cameras.

A factor of consideration for me was the ability of the program to provide support to the user as well as partnering with other major companies such as John Deere and Case IH. Having a relationship with partnering companies is very important as it allows the ability of the data to be imported into the growers' data storage device much easier. In my current role, I work with Climate and this application can import data from drone flights. An individual rating was given to companies and the depth of scale that they worked with the companies was evaluated.

This creative component has helped me with the difficult decisions of selecting a drone for the business as well as selecting a program that would make the data usable to the user or customer that the data is being collected for. There is a tremendous amount of data and different options that each program and drone can provide to a business. The format of the chart as well as the Likert scale that was created helped me to determine which product to select for the business. The process of the creative component was important for me to research and understand what parts are important to me and helped me research and understand the features of the drones as well as the programs that were available.

In reflection, I thought about how fast the field of drones and imagery has changed over the past few years. When I started the creative component, it was hard to find companies that had software for analyzing images. When I was working on finishing the creative component there were several new software companies. Each one of these programs provide different options and have a different package that is part of their component of service that they offer. Costs varied greatly for the programs that offered imagery services for drones. Laying out the packages in a chart allowed me to see what was offered and see the levels of service that each company provided at each price range. This was beneficial and allowed me to think about the costs in relation to how much work that I would have starting the business and what price levels were available.

The chart that I developed to understand the drone software companies helped me to understand the elements of service that each company offered their customers. There were many options that each company offered, the Likert scale and the chart were important in keeping track of the offerings by each company. The only way that I could organize the information in a logical manner was to form a chart. This gave me a way to group the information in a way that I could compare to other software companies. I then developed the Likert instrument to look at all these elements to make a logical decision and utilize the intent of probability for purchase (Risen & Risen, 2018).

The chart and the Likert instrument took a bit of time to create but I felt that this was well worth the effort to develop. The chart made me research the drone software, learning that there were many different options and plans for creation of data. The drone software company selected will become a partner with my business as my business grows. The software company will need to

be able to support any questions that I may have as the business grows and look for ways to improve and offer more to the customers of the business as the business grows.

A similar analysis was performed for the drone. I did not want to get wrapped up in a certain aspect of a drone therefore I created the chart as well as the Likert instrument. Without the chart I would not have been able to understand the individual abilities of each of the drone platforms. I feel that I would have taken past prejudices and would have went and selected the drone that I have seen or heard about in the past.

The technology in the drone market and drone software companies changed quickly over the period that I worked on this creative component. I would change the way I prioritized the creative component by completing the creative component in under one year. I found myself having to go back and edit portions of the creative component as the technology changed over the period that I worked on this project.

The second item that I would change about this creative component would be to trial the drone software and test the drones first hand. Testing the drones would allow the ability to work with the equipment first hand and understand what the positives and negatives of each are. I was able to test the Phantom platform and was a pilot for the Falcon 8 at my former employer in 2017. I found that the Phantom 4 was a nimble drone that was easy to handle as well as work with. Additional first-hand testing of the Mavic 2 Pro and the Inspire 2 would be helpful.

The Phantom platform and the consumer market drones are easy to fly and have automated takeoffs and landing built into their programs. These programs allow for the amateur drone pilot to have a better experience. They also help with a newer pilot as they include automation to help the pilot with obstacle avoidance. These points were acknowledged when selecting the drone for purchase for the business.

I feel that testing the drones were beneficial at learning the pros and cons of the drone and understanding the positives and negatives that each drone provided to the user. With the use, understanding, and familiarity provides a great deal of learning to the user of the drone. Unfortunately, I did not know anyone that had the Inspire 2 or the Mavic 2 Pro, so I was not able to test the drone first hand for an in-depth analysis. What I ended up doing through this creative component was to analyze the specifications that were given by the manufacturer and the abilities of each drone. My future drone business through utilization of this creative component would select the Phantom 4 Pro and the software company called Drone Deploy.

Appendix 1 Likert Instrument Results

Mavic 2 Pro Likert Instrument

	Completely meets the needs of the company	Likely meets the needs of the company	Might work for the needs of the company	Probably won't work for the needs of the company	Will not work for the needs of the company
1. Is flight speed provided by the drone meeting the needs of the missions that are going to be flown?	X				
2. Will the flight time that the drone provides meet the needs of the company?	X				
3. Wind resistance meeting the needs of the company?			X		
4. Is the ascent speed of the drone safe?		X			
5. The product is easy to use.	X				
6. Is the camera MP appropriate for the drone?			X		
7. I am likely to recommend the product to others.		X			
8. Does the obstacle sensing system acceptable for the drone?		X			
9. Is the operating temperature applicable to the environment that it will be operating in?	X				
10. Is the GPS hovering accuracy accurate?		X			
11. Is the camera mechanical shutter providing at least 12MP images?				X	
12. Is the drone able to support camera changes in the future?		X			
13. Is the transmitter range within a reasonable amount of distance for the drone?	X				
14. Is the cost acceptable for the business.	X				
15. Is the size of the drone acceptable?			X		

Result: Mavic 2 Pro-76%

Phantom 4 Pro Likert Instrument

	Completely meets the needs of the company	Likely meets the needs of the company	Might work for the needs of the company	Probably won't work for the needs of the company	Will not work for the needs of the company
1. Is flight speed provided by the drone meeting the needs of the missions that are going to be flown?			X		
2. Will the flight time that the drone provides meet the needs of the company?	X				
3. Wind resistance meeting the needs of the company?	X				
4. Is the ascent speed of the drone safe?			X		
5. The product is easy to use.	X				
6. Is the camera MP appropriate for the drone?	X				
7. I am likely to recommend the product to others.	X				
8. Does the obstacle sensing system acceptable for the drone?		X			
9. Is the operating temperature applicable to the environment that it will be operating in?		X			
10. Is the GPS hovering accuracy accurate enough for the business?	X				
11. Is the camera mechanical shutter providing at least 12MP images?	X				
12. Is the drone able to support camera changes in the future?		X			
13. Is the transmitter range within a reasonable amount of distance for the drone?	X				
14. Is the cost acceptable for the business.	X				
15. Is the size of the drone acceptable?	X				

Result: Phantom 4 Pro- 87.6%

Inspire 2 Likert Instrument

	Completely meets the needs of the company	Likely meets the needs of the company	Might work for the needs of the company	Probably won't work for the needs of the company	Will not work for the needs of the company
1. Is flight speed provided by the drone meeting the needs of the missions that are going to be flown?	X				
2. Will the flight time that the drone provides meet the needs of the company?			X		
3. Wind resistance meeting the needs of the company?	X				
4. Is the ascent speed of the drone safe?	X				
5. The product is easy to use.				X	
6. Is the camera MP appropriate for the drone?	X				
7. I am likely to recommend the product to others.	X				
8. Does the obstacle sensing system acceptable for the drone?	X				
9. Is the operating temperature applicable to the environment that it will be operating in?	X				
10. Is the GPS hovering accuracy accurate enough for the business?		X			
11. Is the camera mechanical shutter providing at least 12MP images?	X				
12. Is the drone able to support camera changes in the future?	X				
13. Is the transmitter range within a reasonable amount of distance for the drone?		X			
14. Is the cost acceptable for the business.					X
15. Is the size of the drone acceptable?			X		

Result: Inspire 2- 78%

Drone Deploy Likert Instrument

	Completely meets the needs of the company	Likely meets the needs of the company	Might work for the needs of the company	Probably won't work for the needs of the company	Will not work for the needs of the company
Does the software support android or IOS?	x				
NDVI elevation layers supported by the software?	x				
Are the imagery that is created applicable to each map acceptable?	x				
Do the programs support 3D processing?	x				
Do the programs support 2D resolution?	x				
Do the programs provide adequate support?	x				
RTK coordinates supported and appropriate for providing good imagery?		x			
Is the cost of the program acceptable and able to be absorbed by the company allowing it to be successful?		x			
Are crop reports provided?	x				
Does this program have agriculture partners that it works with?	x				
Ease of use with program?	x				
Support Automated flight?	x				
Webinars or learning experiences applicable?	x				
Support or sales of equipment?	x				

Result: Drone Deploy- 96%

Agribotix Likert Instrument

	Completely meets the needs of the company	Likely meets the needs of the company	Might work for the needs of the company	Probably won't work for the needs of the company	Will not work for the needs of the company
Does the software support android or IOS?	x				
NDVI elevation layers supported by the software?	x				
Are the photos that are applicable to each map acceptable?	x				
Do the programs support 3D processing?	x				
Do the programs support 2D resolution?	x				
Do the programs provide adequate support?			x Chat or email		
RTK coordinates supported and appropriate for providing good imagery?	x				
Is the cost of the program acceptable and able to be absorbed by the company allowing it to be successful?		x			
Are crop reports provided?	x				
Does this program have agriculture partners that it works with?		x			
Ease of use with program?		x			
Support Automated flight?	x				
Webinars or learning experiences applicable?				x	
Support or sales of equipment?		x			

Result: Agribotix- 83%

Precision Mapper (Precision Hawk) Likert Instrument

	Completely meets the needs of the company	Likely meets the needs of the company	Might work for the needs of the company	Probably won't work for the needs of the company	Will not work for the needs of the company
Does the software support android or IOS?	x				
NDVI elevation layers supported by the software?	x				
Are the photos that are applicable to each map acceptable?	x				
Do the programs support 3D processing?	x				
Do the programs support 2D resolution?	x				
Do the programs provide adequate support?		x Has Phone number as well as email and chat.			
RTK coordinates supported and appropriate for providing good imagery?	x				
Is the cost of the program acceptable and able to be absorbed by the company allowing it to be successful?	x				
Are crop reports provided?			x At professional tier.		
Does this program have agriculture partners that it works with?					x
Ease of use with program?				x	
Support Automated flight?		x			
Webinars or learning experiences applicable?				x	
Support or sales of equipment			x		

Result: Precision Mapper (Precision Hawk)- 71%

Sentera Likert Instrument

	Completely meets the needs of the company	Likely meets the needs of the company	Might work for the needs of the company	Probably won't work for the needs of the company	Will not work for the needs of the company
Does the software support android or IOS?				x	
NDVI elevation layers supported by the software?	x				
Are the photos that are applicable to each map acceptable?	x				
Do the programs support 3D processing?	x				
Do the programs support 2D resolution?	x				
Do the programs provide adequate support?	x				
RTK coordinates supported and appropriate for providing good imagery?	x				
Is the cost of the program acceptable and able to be absorbed by the company allowing it to be successful?	x				
Are crop reports provided?	x				
Does this program have agriculture partners that it works with?	x				
Ease of use with program?	x				
Support Automated flight?	x				
Webinars or learning experiences applicable?			x		
Support or sales of equipment?	x				

Result: Sentera- 90%

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