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From the Field to Fork

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Precision Agriculture: From the Field to Fork

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Do you ever take the time to think about where a GPS came from, how it works, or the many uses it has? For most people these questions are not relevant but in the agricultural industry, GPS has become such a strong suit that we must educate ourselves about it. Most people think of GPS's as a device you would use to get you to your vacation destination but in reality these devices require extensive planning and task completion to use them. Global Positioning System (GPS) is a network of orbiting satellites that send precise details of their position in space back to earth. The signals are obtained by GPS receivers, such as navigation devices and are used to calculate the exact position, speed, and time at the vehicles location (Corp., 2018).

These systems have catapulted us into a completely new era of doing particular things such as traveling or recreational activities. Because of this new technology, we no longer rely on maps to get to our destinations. GPS was first developed in the 1960's to allow ships in the United States Navy to navigate the oceans more accurately (Corp., 2018). Originally, it were developed for the military so they would have the upper hand on their enemy. You can see the leaps and bounds that the military made just from the advancements in GPS units. Our military can send in drone strikes by a simple push of a button and all they need is a location. In general, there are a five uses of GPS: Location, Navigation, Tracking, Mapping, and Timing (Kyes & Ravikumar, 2017). Many specifics go into the creation and makeup of GPS. Figure 1 exemplifies that a Global Positioning System (GPS) is made up of three parts; satellites, ground stations, and receivers. Satellites act like the stars in constellations—we know where they are supposed to be at any given time. The ground stations uses radar to make sure they are actually, where we think they are. A receiver, like you might find in your phone or in your parent's car, is

constantly listening for a signal from these satellites. The receiver figures out how far away they are from some of them. Once the receiver calculates its distance from four or more satellites, it knows exactly where you are.

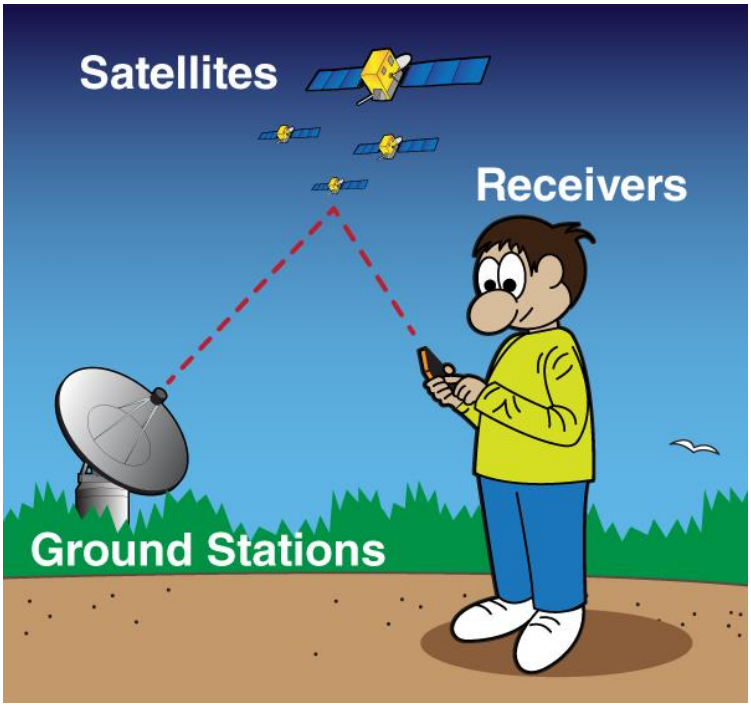


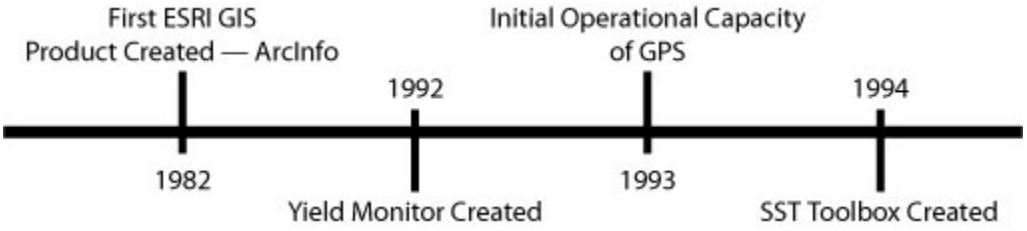
Figure 1: NASA Space Place Image

Farming takes places across the majority of the United States seasonally. Humans have relied on agriculture and farming since the beginning of time and for some, it seems to be their primary choice of survival. Although farming has been a primary food source for many generations, technology has allowed us to evolve over time enabling the enhancement of equipment and techniques. Due to our involvement with technology, farmers must always stay updated with the latest technological advancements to be prepared from season to season, more commonly referred to as Precision Agriculture.

Precision Agriculture seeks to use new technologies to increase crop yields and profitability while lowering the levels of traditional inputs needed to grow crops (land, water,

fertilizer, herbicides, and insecticides) (Rogers, 2014). As you may have guessed, many farmers have had a difficult time transitioning from traditional farming techniques to the new and improved precision of agriculture. Time has shown us that farmers live by the unspoken rule that "you don't fix something unless it's broken." Consequently, some will be very hesitant to try newer technological advancements. A constraint in the target market for whom we foresee having challenges in changing their farming techniques are our older/oldest generation of farmers.

In the late 80's and early 90's the beginning of what we now know as precision agriculture originated. (Delmar,n.d.)



It was originally introduced for the use of controlling tractors from a satellite to make farming easier. Overtime, it has enabled mass production of more crops while seeing a higher population demand for food. Moreover, there are so many things that play a role in precision agriculture besides GPS's including crop yield monitors, variable rate technologies (VRT), self-driving tractors, remote sensing systems, drones, and much more (Precision Agriculture What is it and Why should you care?, 2018).

Now that an understanding has been established as to how Global Positioning Systems relate to precision agriculture, we can dive deeper into the many areas that it covers. To start, we must understand yield monitoring. (Farms.com, 2018) describes yield monitoring as an aspect of precision agriculture that helps to provide farmers with adequate information to make educated decisions about their fields. Yield monitors are a rather recent development and allow farm

equipment such as combine harvesters or tractors to gather a huge amount of information, including grain yield, moisture levels, soil properties, and much more. Due to the fact that yield monitors provide farmers with so much information, they are much more able to assess things such as when to harvest, fertilize or seed, the effects of weather, and much more. To further explain, yield monitors work in three steps: First, the grain is harvested and gathered onto the grain elevator, which is encompassed with sensors whose job is to measure the amount of moisture that is contained in the grain. Second, while step one is taking place, other sensors are measuring grain yield. In unison, as both are gathering information, it is all being sent to the driving cab and portrayed on a screen so that the information is readily available and visible. Another bonus is that all of the information is being geo-referenced so that it can be mapped at a later time. This phenomena is referred to as yield mapping which is interrelated to yield mapping.

The sensors that gather all of this information are the fundamental pieces of a yield monitor. Although many monitors slightly vary, it can be established that there are some defining pieces of equipment, which make it so advanced. For example, you will find in the monitor a "mass flow sensor" which provides information regarding the establishment of grain yield measurements. To simplify, mass flow sensors are located at the top of the grain elevator and when grain is being harvested and fed through the combine, it accumulates inside and eventually builds up to the top where it touches the sensors. When the sensor is set off, electrical signals communicate the message back to the monitor and that is how the information is gathered (Farm.com, 2018.) Another fundamental piece of yield monitoring is a "moisture sensor." As seen in step one, the job of a moisture sensor is to be aware of the amount of moisture in grain harvested. The importance of knowing the moisture content in grain helps the farmer to obtain an

accurate market value on their crop. Moisture sensors are mounted just about anywhere and measures the moisture by testing the amount of electrical charge the grain can maintain.

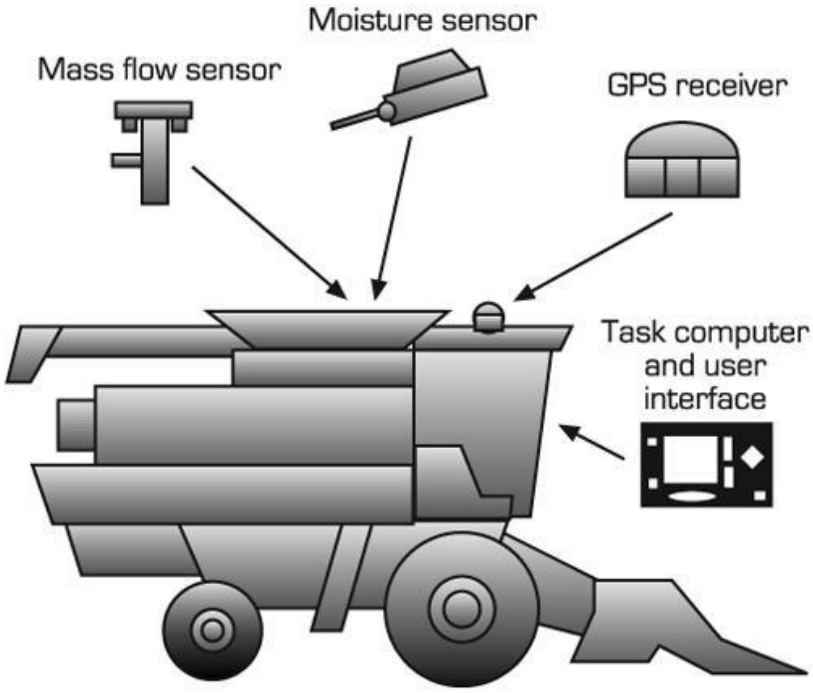


Figure 1: Image that depicts where all parts of the yield monitor are located on a combine. (Ext, 2009)

As one may guess, yield monitors provide farmers with many benefits. The main benefit that we can recognize is the monitor's ability to provide accurate and sometimes geo-referenced data. With the ease of accessibility that the yield monitors provide, a farmer (specifically older generation farmers) can more accurately plan harvests for upcoming years and better estimate future profits/losses. In addition, yield monitors can save information on a field-by-field or load-by-load basis to which enhances flexibility and allows for quicker access to specific information. If a farmer wanted to know the amount of crop yield for one particular field in accordance to a span of one large farm, the farmer can easily go to the labeled field (i.e. Field #7) and gather any information needed. All of the above allow farmers to save precious time and money which can

be put right back into the pocket of the farmer to spend on other things that might amplify profits.

Figure 2: Pictured above is a yield monitor that a farmer is using to locate a specific field. (Heacox, 2015)

With the savings that farmers are cutting back on by using yield monitors comes with a price to pay. Entry-level yield monitors start out at roughly $2000 and increase in expense according to the amount of technological advancements added to the device. When farmers make the decision to buy a yield monitor, they should take into consideration all of the benefits while also keeping in mind the initial expense. From all of this information we can conclude that yield monitors are definitely existential to increase profit margins and speed up the processes of harvesting. For more information on yield monitoring it is highly recommended that you visit (www.farms.com/precision-agriculture/yield-monitoring/) to gather a more in-depth detail.

Variable-rate technology (VRT) is another form of precision agriculture that describes any technology that enables producers to vary the rate of crop inputs. VRT combines a variable-rate (VR) control system with application equipment to apply inputs at a precise time and/or location to achieve site-specific application rates of inputs. A complement of components, such as a DGPS receiver, computer, VR software, and controller are integrated to make VRT work

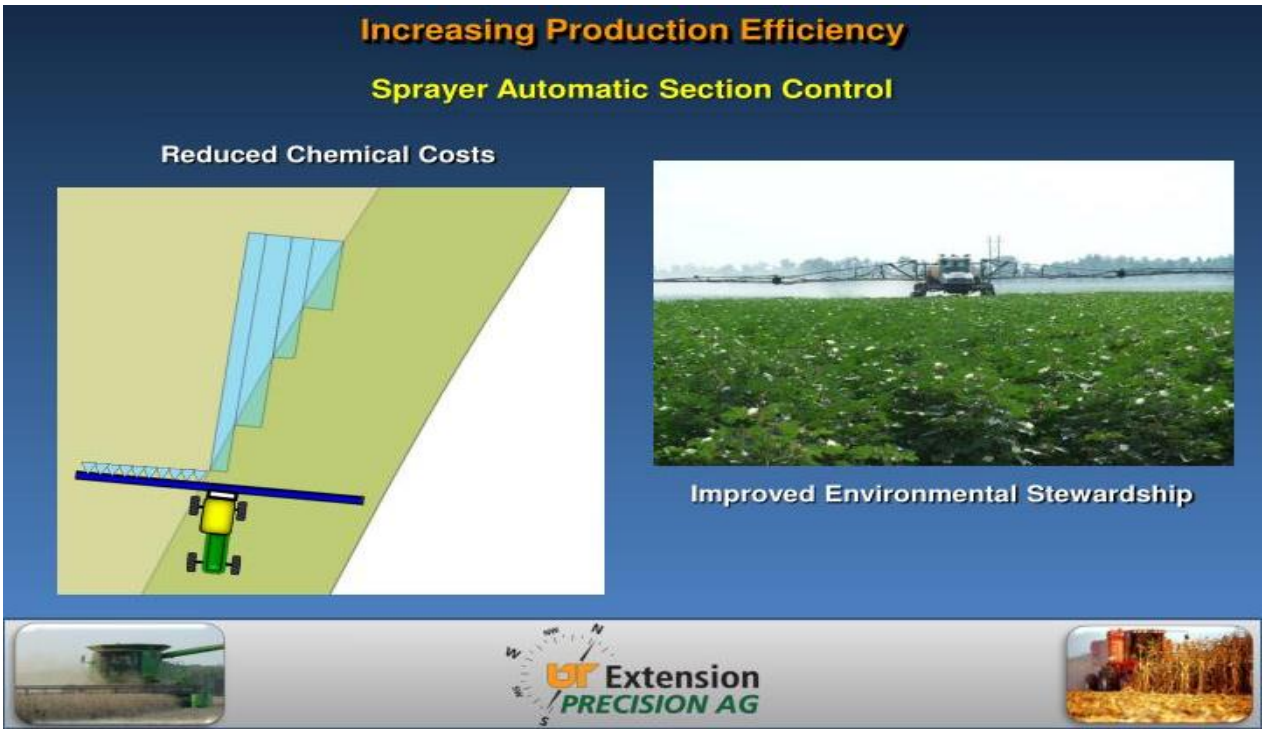
(System,2018). Variable Rate Technology, just like most of the precision agriculture techniques, is new to the industry of farming. Variable Rate Technology is comprised of many different processes that enable it to function so productively. Automatic Section Control is one of the many processes and is implemented on four different pieces of equipment; sprayers, planters, side dressers, and spinner spreaders.

Spinner spreaders are commonly used to apply both organic (e.g. litter) and inorganic fertilizers along with lime (System, 2018). Farmers sometimes find it difficult to know when to turn on/off the spreaders when applying the fertilizers to the field. This is difficult because it is hard to see where fertilizer has already been spread. Thankfully, with the Automatic Section Control you will no longer have to be concerned with where you have already spread, or not knowing where you have not been. This system has the ability to automatically turn on/off the spread while using a GPS and rate controller with Automatic Section Control capabilities (System, 2018). The farming industry has accepted this form of technology even though it is far from the ordinary techniques used while flourishing in this industry. Old habits die-hard and some of your older generation farmers may not adapt to it simply because they do not want to spend the money. It may also be troublesome to learn something new about such extensive technology when, what they have done for years, still works.

For this process to operate correctly you, must have a GPS/GNSS receiver, a display or rate controller with Automatic Section Control (ASC) capabilities, hydraulic control valve, electronic control unit, encoder or speed sensor, and wiring harness. The GPS receiver must be mounted on the equipment in order to keep the equipment on course to avoid any mistakes, and your rate controller can sometimes be used from other equipment on the farm you just have to be for sure they are compatible. The hydraulic control valve is used to turn the conveyor belt on/off,

as well as speeding up or down the process. The Electronic Control Unit is connected between the controller and hydraulic valve. Simply, the ECU is the communication between the controller (determining when a change is required) and the hydraulic valve (means of making the change). It also transfers other data between devices on the spreader to the controller such as conveyor speed from a sensor (System, 2018). Your Encoder is needed to monitor conveyor chain speed. This component is required as feedback to the controller for maintaining the target application rate when speeding up or slowing down, if variable-rate application (VRA) is desired, and for the ASC technology to work correctly (System, 2018). Wiring harnesses are important so that you are able to connect everything together so that the whole process will run smoothly and operate as designed.

Above is figure 3 (System, 2018)



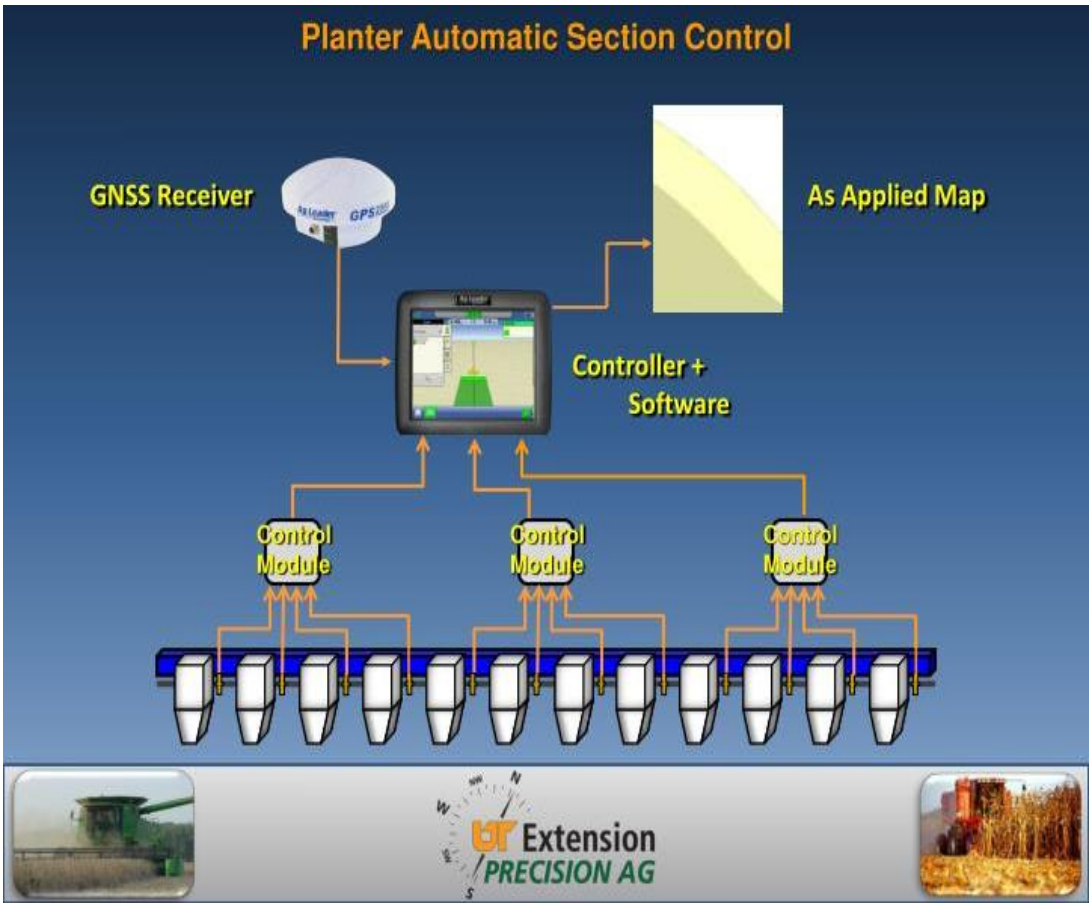


Figure 4 (System, 2018)

The other farming instruments that are used for the same kind of process just a different way are the Sprayers and Planters. These instruments all operate in the same way and perform similar tasks, as well as sharing the same benefits. According to (System,2018) improved application accuracy of inputs, reduced overlap areas and skips within fields, reduction of input costs by minimizing double-and-triple applied areas, improved environmental stewardship by eliminating application in sensitive areas within or around field and pastures, applied maps for application verification (time of application, amount applied, etc.) and use in future management analysis and decision making, and an existing capability of most rate control systems today is that the software required for ASC has already been installed but requires one to purchase a software unlock code and possibly a few additional hardware components are all benefits to

ASC/ Variable Rate Technologies. There were a few differences in the similarities for the different pieces of equipment. The planter has increased operator efficiency especially at night, and reduced operator fatigue because of the advanced equipment.

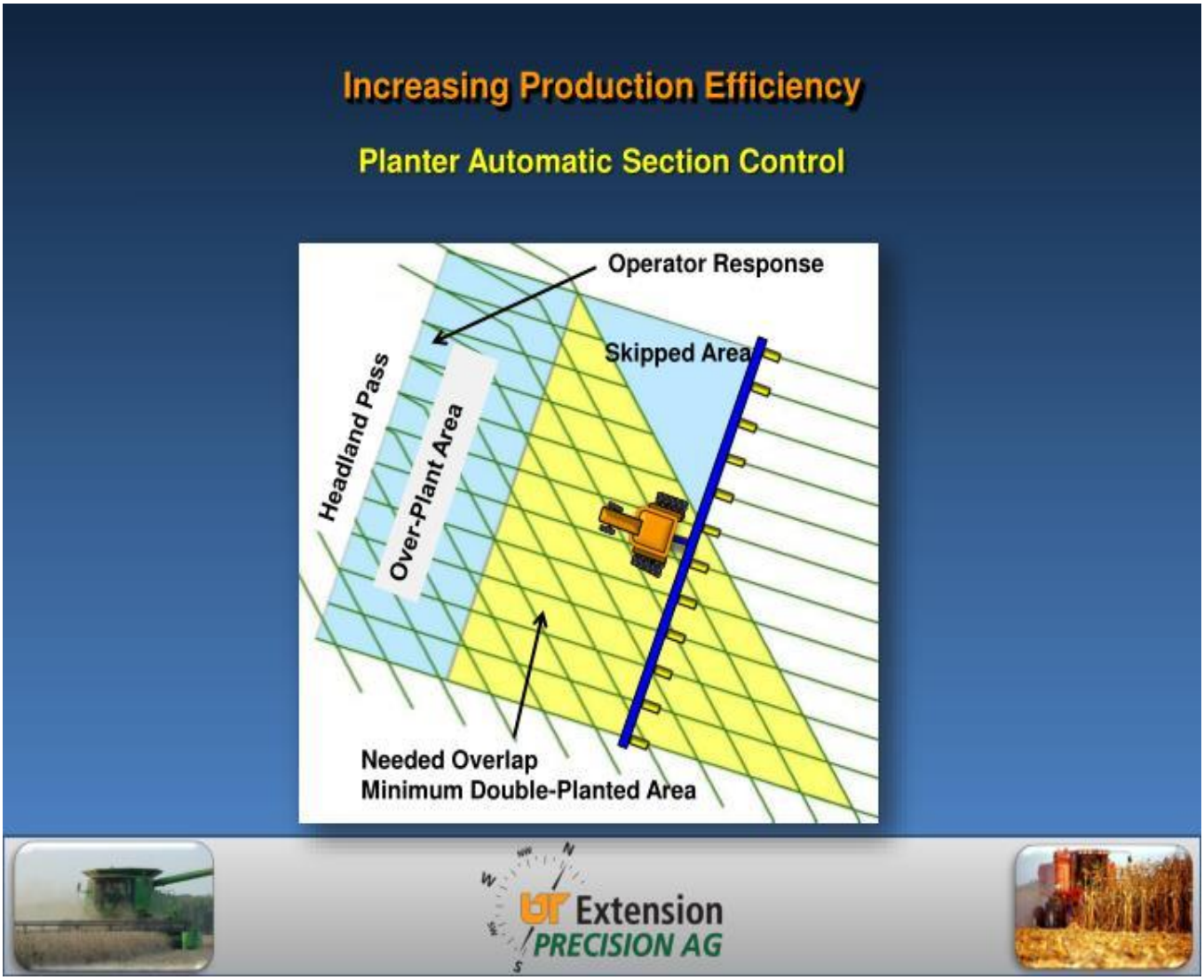


Figure 5 (System, 2018)

Lastly, the only other difference is with the sprayers, which is that they reduced crop damage from over-application of pesticides. With most technology, you must be knowledgeable with the equipment and the process of how it works. A disadvantage to this kind of farming is the knowledge that a majority of your older generation farmers lack in technology, so therefore it

can set them back when trying to adapt to this way of farming. You might face the disadvantage of price depending on how wealthy you are as a farmer or corporation. The equipment needed for this type of agriculture will range from $2,000 and up in order to make things run smoothly. The use of this equipment is revolutionary and will continue to prove its worth to the agriculture industry. Knowing that you are able to precisely spray, plant, or spread gives you a sense of peace because you are able to perform each of those processes without worrying. You will be able get things done more efficiently as well because you will not be wasting time going back over areas that do not need it to begin with or missing areas that needed the nutrients or pesticides. Having all of the capabilities to increase your production and increase your revenue from year to year, these techniques are very beneficial to agriculture.

A new farming technique that is an ongoing process are self-driven tractors. This is going to be a big asset to farming so that you will not have to have as much work force. In recent years, we have seen self-driven vehicles but they have not had as much luck with the vehicles as the agriculture community has with the tractors. The development of this tractor has provided a vision so that the farmers can have a unique approach to planting, harvesting, and the ability to maintain their crops in a less man powered approach. “Autonomous tractors use a lot of the same advanced sensors and systems that a true self-driving vehicle would. Most tractors sold in the U.S. already include auto-steering systems that give additional control even in low-visibility situations. By implementing these advanced features in everyday farming, growers can really put the power of tech to work (Ag, 2018).” This advancement is somewhat hard to believe but at the same time we have to realize the generation we are living in as well, so many advancements are made each day in other fields as well such as the medical field. The self-driven tractor has not hit the market yet but when it does, you will see either it be a booming product or it will not sale

quickly due to farmers being hesitant about trying something so advanced. This idea of self-driven tractors has been tossed around since precision agriculture became a reality in the 1980's and 90's, but now it is not just an idea it is an ongoing process to make these tractors hit the market. If and when they do hit the market, I believe that we will see a lot more farming take places at all times of the day, simply because you will not have to have someone in the tractor physically operating it.

Figure 6 (Robo-Tractor, 2016)

Just like any new product or active product being used in agriculture, you have the advantages and disadvantages it brings. "Self-driving tractors' automatic planting systems have exceptional accuracy, resulting in seed conservation and a substantially improved return on investment (ROI) for growers. The tractors' sensors can also collect information on soil conditions, offering improved maintenance of already-planted crops and generating increased data both before and after harvest time. Self-driving tractors can reduce the workload and stress on employees, providing assistance for driving and managing a wide range of tasks on the farm (Ag, 2018)." You will also see the advancements in the sensors and guidance systems, "sensors

can determine the moisture level of the ground, the progress of planting and harvesting operations, current yield, or the amount of fuel used on a given circuit or during a certain time period. As a result of the precise control that autonomous tractors and farm equipment can allow, growers can now continue working well into the evening. Even when it is too dark to see clearly, the sensors in place can deliver straight rows and accurate planting, which is especially important during the critical spring months. Growers can see a greater flexibility in managing time-sensitive growing tasks while reducing stress for workers. Not to mention, the guidance equipment used to navigate fields gives information that is more accurate during dense fog, dusty and windy weather and other conditions that can normally affect drivers' visibility. Autonomous tractors can also be set up to serve as mobile hotspots for collecting data from sensors located throughout the field. This can provide added help for precision agriculture applications and can deliver on-the-spot information regarding a wide range of factors that can affect growing operations, including: Current moisture levels in various fields, Expected and current yields, Fertilizer and pesticide application rates, Fuel consumption and other vehicular data. Growers can also review key data regarding price trends, commodities markets and other factors that could easily, and quickly, affect the price of their crops. Knowledge this powerful means you can make the most effective use of available funds and expect a bigger profit at the time of harvest and sale (Ag, 2018)." As you can clearly see this idea has many benefits that would significantly increase product and accuracy in and out of the field. The only disadvantages of the self-driven tractors would be the price and having to learn the operation components in order to make things run smoothly. Those two disadvantages alone will stop numerous farmers from purchasing one, once they are on the market for purchase. Overall, this idea could turn agriculture into a completely new ball game in ways that we cannot even think of, but the way technology is

making leap and bounds, this is where farming is going to end up. If you as a farmer have the financial status to make these purchases then you will be able to stay on top of the other farmers because the self-driven tractors will offer you the ability to have less labor to get things completed. I believe that this idea will sooner than later be available unless it is just too expensive and not feasible for farmers to purchase.

Technology has made so many advancements and it has benefited the advancement of agriculture as well. Technology is more involved with agriculture than most people tend to even think about. A drone is a device that has the capabilities to fly around in a certain radius from where the operator is located and video the area beneath it so that the operator can see. There are many different sizes of drones made for different jobs that they could use. Usually your biggest drones will be used for military purposes and the military usually only has access to these types of drones. That is not to say the military can only use these types of drones but also use smaller ones as well. Typically, your next size of drone only requires a small area to take off from and are used to cover large areas for agriculture purposes and surveying land. Next in size, you have a drone that can take off and fly around within a certain radius of the operator just like the others but the smaller the drone the less radius you have. It can hover over a certain area and land vertically wherever you please. The last size of drone is most likely the type of drones that you have seen more of, simply because they are easier to purchase. This particular drone can be easily carried around and it has the ability to be launched directly from the palm of your hand.

"Many of the latest drones have dual Global Navigation Satellite Systems (GNSS) such as GPS and GLONASS. Drones can fly in both GNSS and non-satellite modes. Highly accurate drone navigation is very important when flying and in drone applications such as to build 3D maps, surveying landscape and SAR (search & rescue) missions (Corrigan, 2018)." Though

drones have been around for a while, military were the only ones that used them because they were not available to citizens. Now drones are available to purchase and use for fun or even the business side of things and you are seeing this increase quickly in agriculture. There are many uses for drones in agriculture but the main ones are Soil and Field Analysis, Planting, Crop Spraying, Crop Monitoring, Irrigation, and Health Assessment (Mazur, 2016). Soil and Field Analysis is an important because you are able to fly over your crop and collect a 3D map of your field to analyze it and see what is needed to increase the production of that field or what product less of or does not need. This makes life much easier for the farmers because they do not have to go into the field by hand to gather this information.

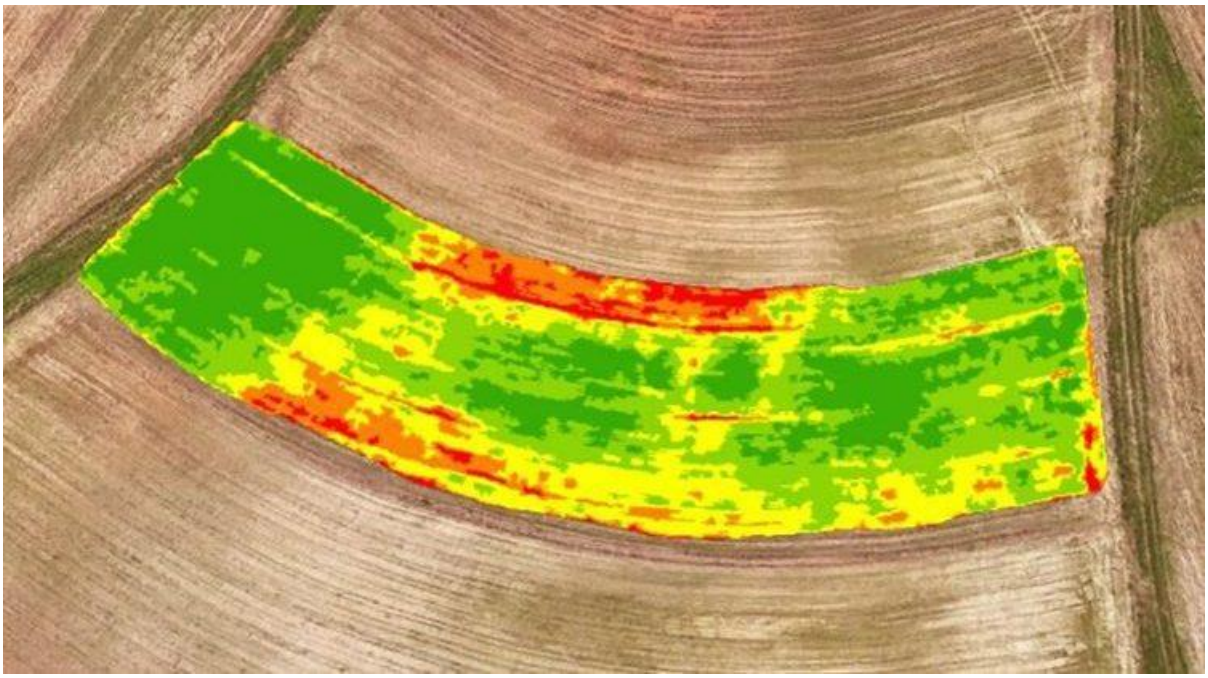


Figure 7 is a Picture of field mapping (DRONESPRO, 2018)

On the planting side of things, “Startups have created drone-planting systems that achieve an uptake rate of 75 percent and decrease planting costs by 85 percent. These systems shoot pods with seeds and plant nutrients into the soil, providing the plant all the nutrients necessary to

sustain life (Mazur, 2016).” This type of planting seems almost unimaginable because you are going from such a large piece of equipment that is pulled through the field to plant, to a drone that has the capability to take the seed and all the nutrients needed to a certain spot and plant it. “Distance-measuring equipment—ultrasonic echoing and lasers such as those used in the light-detection and ranging, or LiDAR, method—enables a drone to adjust altitude as the topography and geography vary, and thus avoid collisions. Consequently, drones can scan the ground and spray the correct amount of liquid, modulating distance from the ground and spraying in real time for even coverage. The result: increased efficiency with a reduction of the amount of chemicals penetrating into groundwater. In fact, experts estimate that aerial spraying can be completed up to five times faster with drones than with traditional machinery (Muzar, 2016).”

Figure 8 (DRONESPRO, 2018)

It is amazing to see the advancements we are making in agriculture to adapt to the growing population of the United States, if we have these capabilities then we will be able to keep up with production and still be able to produce enough for the population. Being able to use a drone to spray your fields instead of having to use your traditional sprayers is a huge downsize in equipment and increased time efficiency. Crop Monitoring also plays a key role in farming

because you must keep a check on your crops in order to be sure nothing major has gone wrong with it. This can be made difficult because of weather change and expenses as well, but with drones, you have the ability to check your crop even if the field is too wet for you to manual check it because the drop gives you that capability to fly. Being able to use this method also cuts down on the time it takes to monitor your crops. “Drones equipped with thermal, hyper-spectral, or thermal sensors can identify the parts of the field have become dry. This way the identified areas can be attended to promptly making irrigation precise and timely. Some drones are capable of scanning crops using visible and near infrared light. On-board light processing devices are then able to identify the amounts of green and near-infrared light reflected by the plants. This data is then used to develop multi-spectral images that depict the plant health. These images can be used to track crop health and to monitor remedied administered if any sickness is discovered (Kipkemoi, 2018).” Irrigation system can have a more precise location that it can be pinpointed where water is needed or not needed due to the drone identified the driest/wettest areas of the field. As a farmer, you would be able to save money on your irrigation, simply because you could focus on the areas that needed the most attention. Irrigation and Crop Health go hand-in-hand because without the water you have poor crop health.

Just like anything else, you have many positives to a product but you will also have your drawbacks and the use of drones has its pluses but it has its drawbacks as well. According to (Kipkemoi,2018) Flight time and range time, cost, federal laws, interference within airspace, connectivity, weather, and knowledge/skill are all drawbacks with drone usage in agriculture. Sometimes you see all the positives that are offered and you jump all in but then you come across the drawbacks and have to take a step back. Drones have a limit on how long they can be flown and they have a certain range that can be reached from the operator which all depending

on the type of drone being used. “Drones with the features that qualify them for use in the agricultural are quite costly. This is mostly so for fixed wing drones which could cost up to $25000 (PrecisionHawk’s Lancaster). For some drones, the heavy cost is inclusive of hardware, software, tools and imaging sensors (Kipkemoi, 2018).” With this device costing this much, there will be many farmers who stay away from this type of farming because they cannot afford to spend that much money on something like that. Spending around $25,000 on a drone is not a drop in the bucket for a lot of farmers and they cannot justify spending the money on it, whereas your larger farmers see no reason not to spend that money because they know that takes them one step closer to being able to produce even more than they are at the moment. Just like anything else in life if it is expensive and you cannot justify purchasing it then you will not make that investment. You will also run into federal laws that must be obeyed in order to use drones for agriculture. The use of a drone in agriculture is considered commercial usage and you must have a license in order to operate one, as well as only be flown at a certain elevation. For this very reason, you will not see as many farmers using drones because they do not want nor have the time to study and get a license to use them. If you were to hire someone to come to your fields and use a drone, you would then be out a pretty nice penny for that, so instead you see some farmers sticking to the traditional way of farming. “Agricultural drones share the same airspace with manually manned aircraft. Hence, they are prone to interference. It is, therefore, advisable the farmer files his/her flight plan with the local airport or the FAA before the flight. Most of the arable farmlands in the US have very little online coverage if any. This means that any farmer intending to use drones has to invest in connectivity or buy a drone capable of capturing and storing data locally in a format that can later be processed (Kipkemoi, 2018).” As you can see here there is more issues that farmers face with the use of drones that seem to be

more of a headache than an asset. Having to check with the local airport before flying is just another step in the way from getting the job at hand completed. With that being said comes along the next issue mentioned which is connectivity, due to most farmers being out in the country they do not have good connection so therefore they have to purchase some form of connection to use the drones. So you are faced with purchasing that or purchasing a higher quality drone that has the capabilities to reach a connection further away which in return costs more money as well. Just like any other aircraft, you have limitations as to when you are able to fly the drone depending on the weather. You would not make the decision to fly the device on a windy, rainy, or snowy day due to the risks you would be taking and you would not be getting as good of quality usage either. Lastly, you need knowledge and skill to operate and collect data from using drones. "The images require analysis by a skilled and knowledgeable personnel for them to translate to any useful information. This means an average farmer without these skills may need training or may be forced to hire skilled personnel conversant with the analysis software to help with the image processing. Drone technology keeps improving every day. With many manufacturers entering the industry, it is hoped that the cost of the drones and the accompanying equipment will reduce. Limitations like flight time and range are also expected to be solved by an improvement in technology. These improvements will ensure that farmers reap more from the use of drones (Kipkemoi, 2018)."

Figure 9 Shows a farmer navigating a drone to go and check their fields. (Ciaglo, 2016)

Comparing this to traditional techniques almost seems unimaginable because of the advancements agriculture has made in conducting certain tasks. Traditionally you would just go out into the fields to observe the weak areas, places not getting enough water, or over saturated areas and then take care of those places accordingly. Nothing is wrong with still doing things the traditional way because many people still do, but agriculture and how we operate has come a long way in the sense of technology. The use of drones seem to be a very useful and practical way of checking your crops or maintaining them, if you are able to support this financially.

Therefore, drones can come in many different sizes that have a wide variety/assortment of skills needed for each particular task that a farmer wishes to complete. Because the breadth of agriculture is very wide it is important to remember that selecting a drone that encompasses what fits your job the best is what you should buy. While beginning the first stages of purchasing a drone, one might write down things that they wish to accomplish with the device so that someone who is more experienced might educate and help with selectivity. As it has been highlighted, the main characteristic of drones is the ease of accessibility that farmers have/will have while using these devices. When working with large crops or a field of stock, having a drone will save a farmer time and money. He can hen allocate time and money to future projects as the need arises. While breadth seems to be a large characteristic of drones, it should be noted that the depth in which these devices have save thousands of dollars. For example, having a drone that eliminates a tractor and machine from planting and giving nutritional value to the fields not only saves money and time but also allows for better accuracy. When debating on whether to buy a drone or not, one should look at the characteristics the device holds and the ease of accessibility the device will provide in the future. For most, it has been a success and with time, it could be the case that many farmers rely on drones for the survival of their crops.

Moving forward, while living in the South we can all say that weather plays a detrimental role in the harvests and planting of crops year round. However, in Kentucky we also know that weather can be very much unpredictable. So, how have farmers been able to best accurately time out when their crops will be ready to plant or harvest? Most of the time, it comes with years of experience and heavy studying of the news and the farmer's almanac. Recent advancements in technology have led to developments that will forever change the way a farmer plans his crop yield. "Established growing regions have traditionally relied on static climate data sets collected by an existing fleet of government, city or airport weather stations. Now, with a global network of distributed weather stations in the field, Farmers Edge is providing real-time data from the field that can enable highly precise, predictive models that inform growers' decision making on: critical crop stages, the timing of field operations, pest and disease pressure, equipment deployment, soil needs and nutrient requirements. Through this collaboration, Farmers Edge continues to marry data science with agricultural science to provide the most accurate field-centric data in the industry." (Wong, 2016) To further elaborate, Farmers Edge is a global leader in precision agriculture who has recently announced collaboration with The Weather Company who we know as the world's largest private weather enterprise. Under the partnership of such businesses, Farmers Edge "integrated hyper-local forecasts from Weather's superior Forecasts on Demand (FoD) weather forecasting engine into its field-centric approach to predictive modeling." (Wong, 2016) With such enhancements in agriculture, technology allows farmers to take yet another step towards digitization of agriculture.

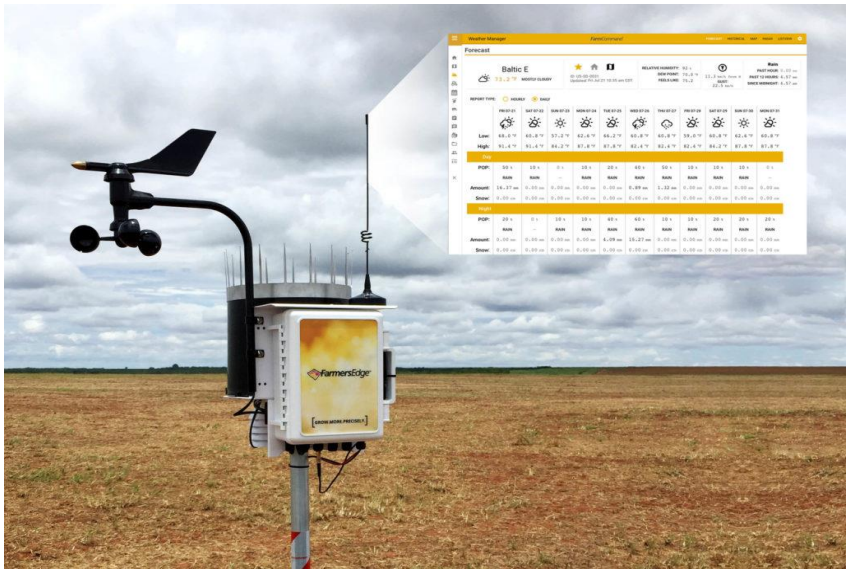


Figure 10 Depicts How Field-Centric Weather Data Improves Crop Staging Accuracy (FarmersEdge, 2017)

Remote Sensing Systems have played an important role in agriculture for many years, a lot longer than some would actually realize. Have you ever thought about what a remote sensing system is, what it does, and how long it has been around? Remoting Sensing in agriculture is usually just defined as viewing/observing a crop field without touching it, so it is viewed from the air by technology or by pictures taken from the air. "Although remote sensing can be as simple as a "windshield survey" of a field from a truck at 55 mph, the history of modern remote sensing began when black-and-white photographs of the landscape were first taken from the air. The first organized effort to acquire aerial photographs appeared in the late 1930s by the Department of the Army. Eventually the Agriculture Stabilization and Conservation Service adopted the technology and began collecting indexed photographs of the landscape for agricultural purposes. Many of these photographs are still available through the Farm Service Agency. Remote sensing, today, incorporates new technologies that provide increasingly efficient, complete, accurate, and timely information. These new technologies, together with

historical photographs, provide the informational basis for a practical management tool for site-specific management of crops (Casady, 2018).” It is amazing that you can date back to 1930’s for this type of agriculture and to see how things have evolved and progressed today. Being able to study fields without actually being in the field is such a key advantage. “In agricultural uses, remote sensing can produce meaningful measurements of factors like air and soil temperature, humidity, crop height, plant width and diameter, wind conditions and more (Farms.com,2018).” Many of these factors play important roles in how successful the crop will be or not be and the farmer must pay attention to these particular things closely. There are many types of remote sensing technologies used in agriculture but the main ones that are being used in agriculture are spatial, spectral, radiometric and temporal resolution.

Spatial resolution information is collected based on size and distance. For instance, we can think of spatial resolution as the distance from instrument to the object being observed. If a farmer wanted a precise and high-resolution image of his crop this particular type of information is what he should seek out. It also has the ability to capture low-resolution images that picture multiple and single fields. Radiometric resolutions is defined by its different levels of intensity. This type of resolution is useful for farmers because it provides better image quality to have a more accurate depiction of what their fields look like. Spectral resolution is important to farmers because it collects information through wavelengths that show color. For example, spectral resolution can depict which leaves on dying/healthy depending on the color that it portrays. This resolution can also use its technology for other chemicals and moisture that are detected in fields. Finally, temporal resolution is the given time in which an image is taken. When collecting information for short periods, the data that is gathered will be much less than if, you were to collect data for a longer duration. Longer durations would provide more data for the farmer.

However, it should be noted that technology sometimes has drawbacks since we are not under full control of the device. The biggest determinant of whether remote sensing technology will be accurate relies heavily on the weather. If it is storming, clouds can cause the device to misrepresent the images. This is also the case for other severities that our planet suffers from such as floods, snows, and fires.

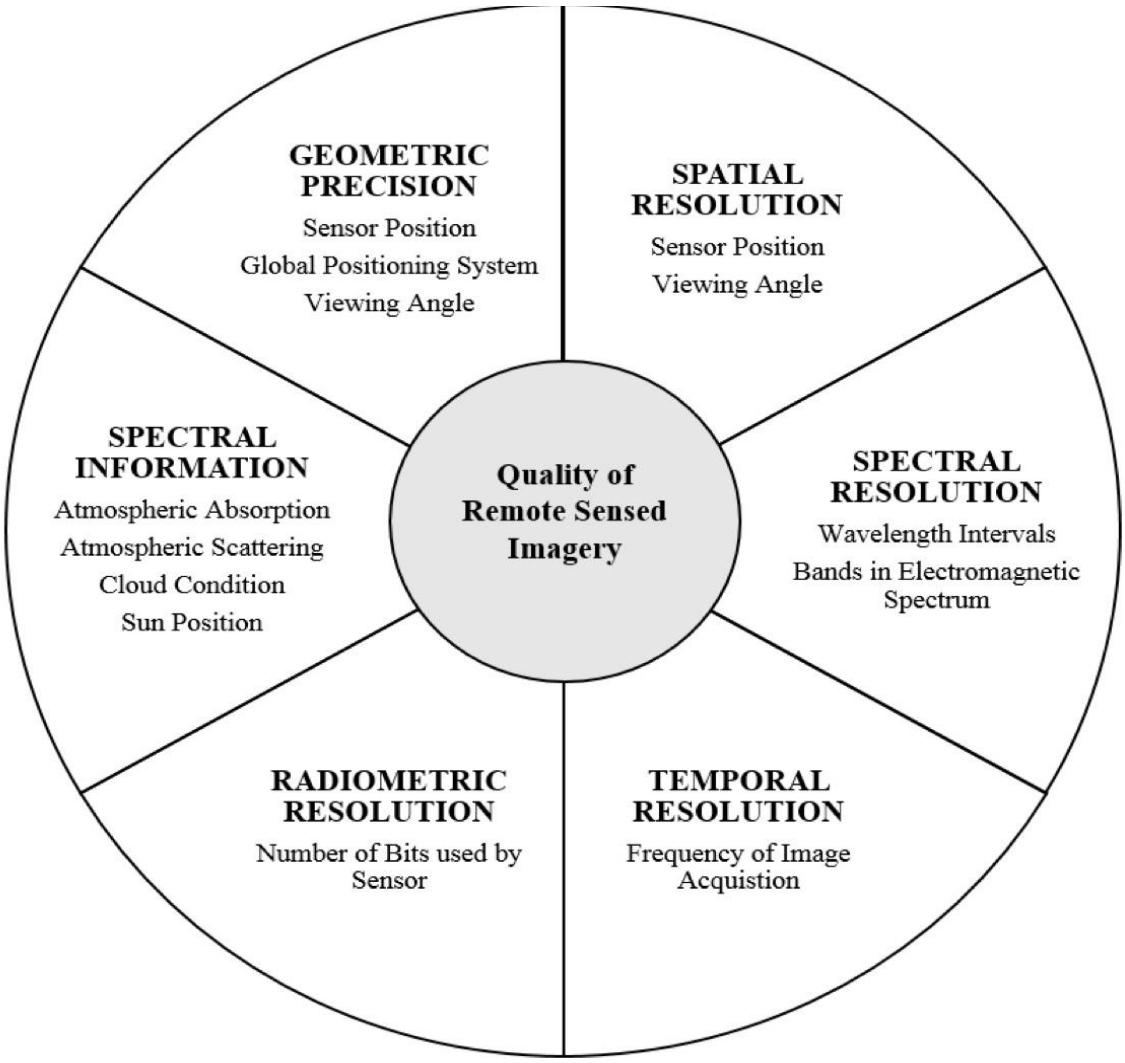


Figure 11 Factors influencing the quality of remote sensed images (Sami Khanal, 2017)

On the bright side, Remote Sensing provides farmers with multiple options depending on what suits their needs the best. However, the more technology and data required, the more

expensive it can be. That is why it is important for farmers to weigh the opportunity cost of increased yields. Some farmers have found that remote sensors become a paradox of choice. In other words, there seem to be too many options and choices for the job that is provided by the device. For all these reasons, remote sensing is a work in progress and will eventually evolve into a device that a farmer will need versus a device that farmers have wanted.

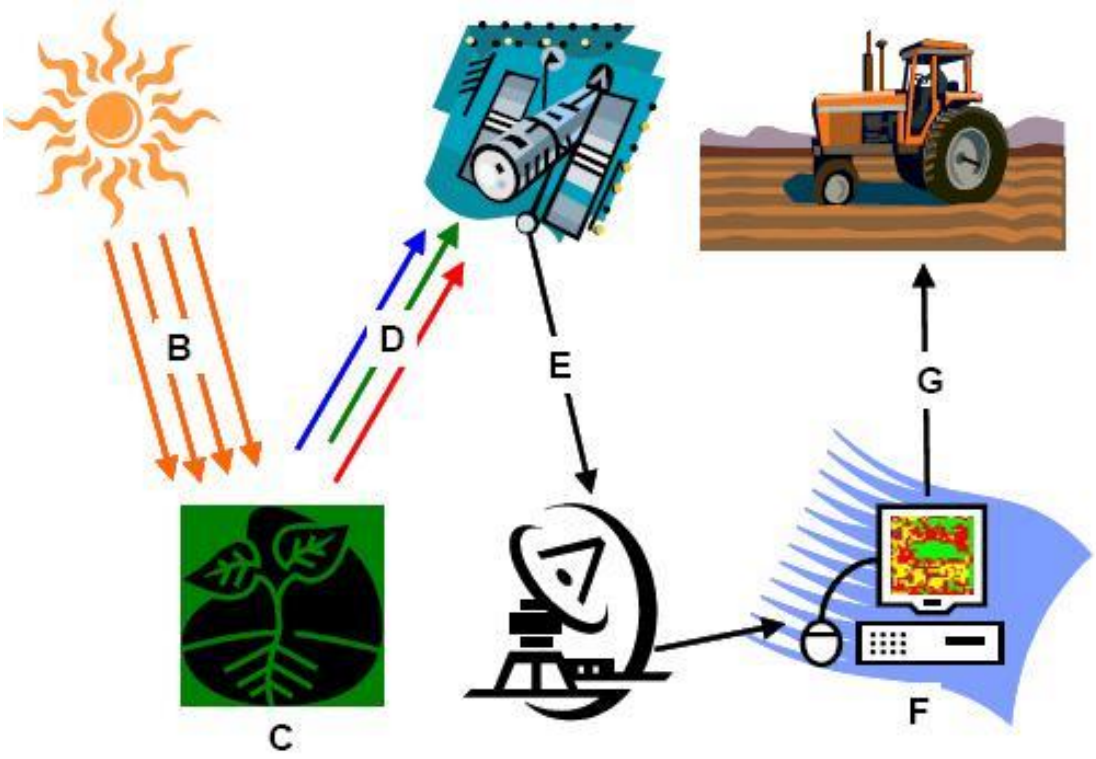


Figure 4. The remote sensing process.

Figure 12 Shows the process of Remote Sensing. (John Nowatzki, 2011)

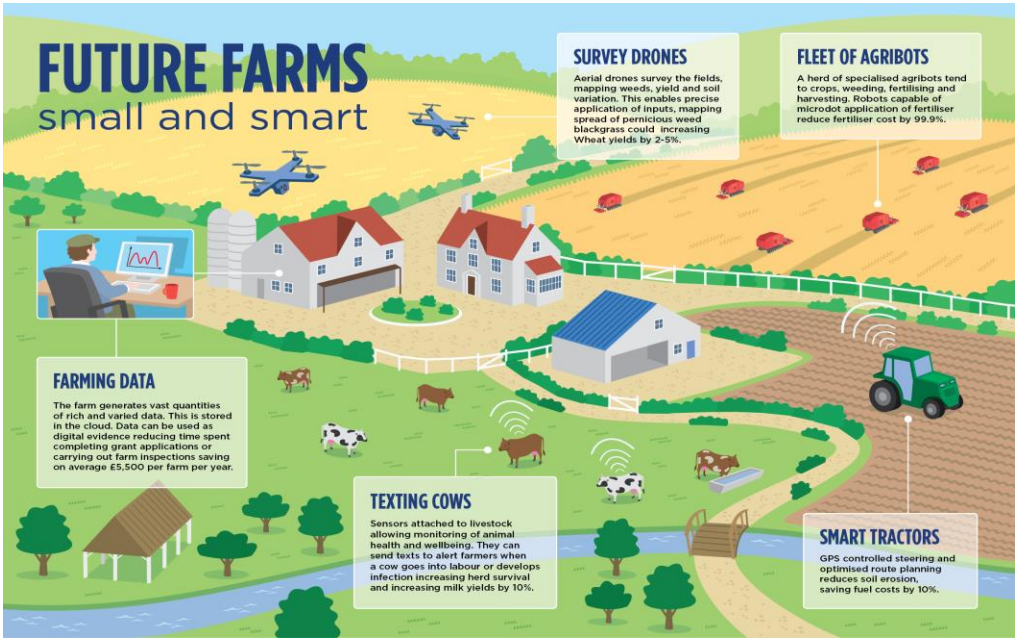


Figure 13 Encompasses a vast majority of what real world farmers are now experiencing on a day to day basis. This image shows many different forms of precision agriculture. (Nesta, 2015)

Because we have already discussed topics concerning farming data, survey drones, and smart tractors, the next essential topic in relation to precision agriculture deals heavily with agribots. These machines are "Small autonomous robots work in teams carrying out a range of tasks enabling the tailored cultivation of each individual seedling by precise application of resources. Some are capable of microdot application of fertilizer or water similar to an inkjet printer, reducing fertilizer costs by 99.9%.Others carry out laser weeding, dispensing with the costs and environmental impacts associated with herbicide use. (Nesta, 2015)" These crop robots can be specifically designed for better accuracy when dealing with particular crops. The "Broccoli Bot" has been engineered specifically for the broccoli plant which allows the bot to salvage as much of the crop as possible. In general, these bots allow farmers to maximize crop yields and minimize labor costs since broccoli is still primarily harvested by hand. However, broccoli is not the only crop that these bots can make more efficient. The problem lays in the

minds of innovators. Agribots are a newer generation of precision agriculture and therefore, they are still being revolutionized. Although we can understand what purpose they are meant to serve, technology must find a way to allow them to specialize in specific crop harvests before farmers will purchase. The biggest hope for these bots is to one day have them running 24/7 to allow for time efficiency results and quicker harvest turnarounds.

Figure 14 depicts what a modern agribot tends to encompass. Just as any other precision agriculture device, these will come in many sizes and bodies depending on their form of use. (Singh, n.d.)

Referring back to figure “” we now have texting cows. No, these mammals did not grow fingers overnight but innovators have figured out how to design technology so that cows can message their owners. “The equipment involves each cow wearing an intelligent collar that picks up on subtle movements with the same sensor used in Wii gaming and generates a continuous record of their activity patterns. Results will then be sent back using a range of wireless technologies like 3G, with a full update accessible via a hub or even through a mobile phone. Farmers can set up alerts for their phone to receive a text when a cow is in distress, coming in to

heat or entering labor. Wireless technology means that the signal from the cow's collar can be accessible from anywhere, so farmers can check on their cattle's status using their phone wherever they are." (Morrisons, 2018)

Figure 15 provides us with a metaphor for how these messages are sent from cow to farmer (Morrisons, 2018)

With this type of technology, farmers in the dairy industry particularly do not have to worry as much about their cattle because they will be alerted from the "text" sent from the very specific cow. This type of advancement in the farming industry is amazing and these farmers get alerts about anything involving their cattle, such as if a cow is hurting it will alert them, or if something in the "milking" system is broke it will notify them of the problem without them even being on site. In some cases the farmers have a very advanced milking system that is a robot and once the dairy cattle are on a schedule they will just show up to be milked and the farmer does not even have to be there to hook equipment up to milk. With this form of precision agriculture, a farmer is able to keep up with each individual cow and how it is performing, such as how much

milk it is producing each time a cow is milked. All of the advancements are increasing the efficiency of dairy farming and I believe that we will see these collars being used with other animals in agriculture as well. The "texting collars" seem to be a great addition to the industry because you are able to manage your farm more efficiently. I believe this form of technology in the farming industry will give great feedback, as well as crucial information to study on how to improve certain things. Farmers will have the ability to travel further distances from the farm without worrying about his herd or having to hire someone to watch the farm while they are away. This type of technology gives farmers a piece of mind in knowing that if anything goes wrong they will be notified immediately via text messages and can deal with the situation accordingly. This technology would and could be helpful in other farm related industries such as with pigs, equine, and chickens. The texting collars would be very beneficial when a female is expecting to birth because you would have the ability to monitor them closely without having to stay on the farm around the clock to do so.

As if Precision Agriculture could not be any more advanced than it already is, developers have created apps that allow farmers to check and measure data while also allowing farmers to track the performance of the machines that allow Precision Agriculture to thrive. The John Deere Connect Mobile app is used to help monitor, optimize, and better understand machine performance. The app connects to the machine through a WiFi network to document and display machine performance and agronomic data about the operation performed by the machine. It works in conjunction with either the GreenStar 3 2630 or Generation 4 4600 CommandCenter displays. The Connect Mobile app can also wirelessly send data to the John Deere Operations Center using either a WiFi network with Internet access or through cellular service using the grower's cellular data plan. The app can also be used for basic crop scouting activities through

the field review feature. Field review provides the grower access to every map layer documented by the Connect Mobile app and can be displayed on the iPad at any time. (Hopkins, 2017)

Figure 16 portrays a screenshot of the Connect Mobile App by John Deere. (Hopkins, 2017)

Aside from Connect Mobile, many other apps provide farmers with the information needed to access and monitor farm equipment. The ease with which farmers can download these apps only requires them to have a cellular device and the capability to download it onto their cell phones. Once they have it downloaded the simply must link their tractor information to the app through a Wi-Fi connection and the process of having information readily available on the farmers phone is complete. With this type of technology, farmers can better understand how their equipment is performing or whether it is lacking in a certain criteria that must be fixed. This will help farmers gain insight and help them save money.

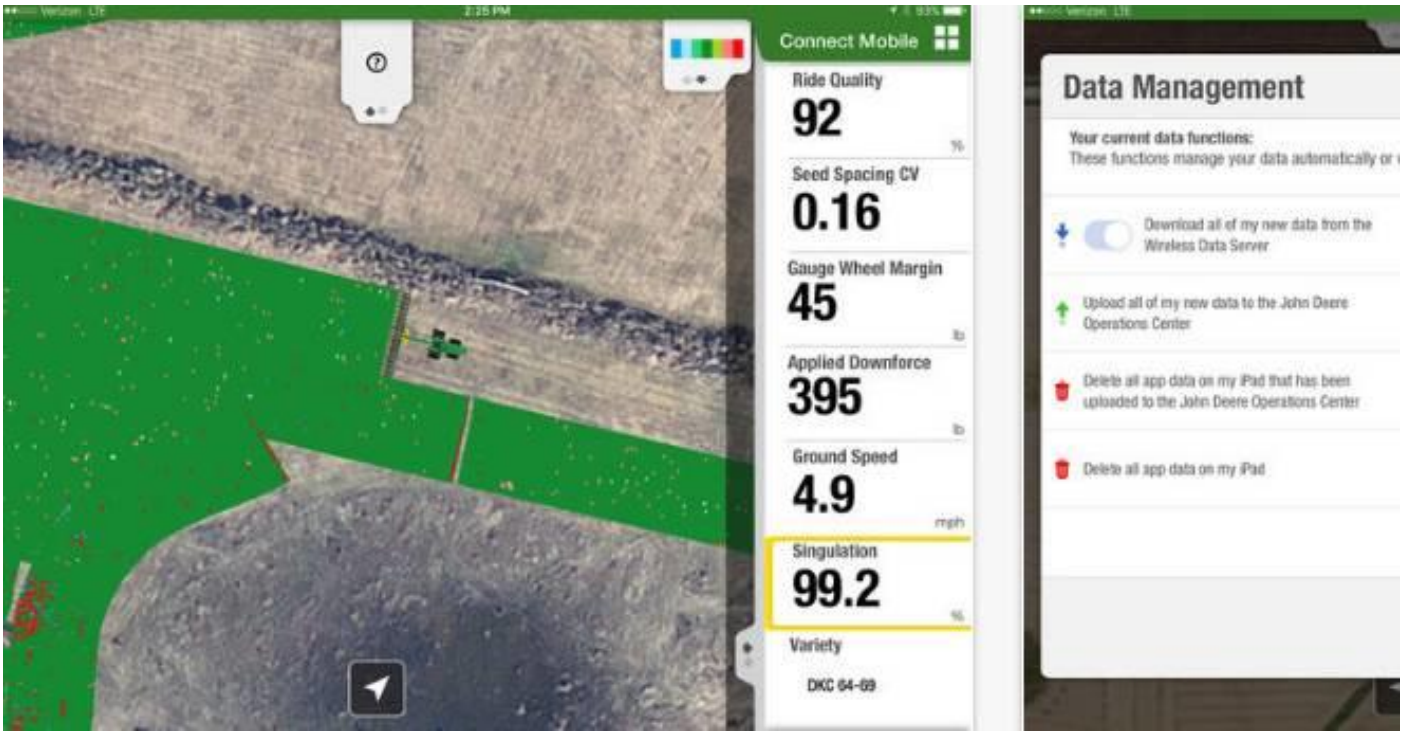


Figure 17 depicts a variety of different Precision Agriculture forms used by farmers.

Precision agriculture has become such a booming aspect in farming that and it has developed so many tactics for faster pace farming. Throughout this paper, you have seen everything from yield mapping to texting cows and how each style is used in precision agriculture. Global Positioning Systems are the main origin of all precision agriculture as you can tell; because so much of this is advanced technology, it requires the use of GPS to work correctly. Yield mapping is important so that farmers are able to see areas that need to be tended to more and they are able to focus on that area instead of the whole field. All of the sensors that go along with this part of precision agriculture must work correctly and together. Self-driven tractors have made their way into the industry but have not yet hit the market for purchase. Self-driven tractors could potentially make farming a lot less tiring because you will be able to

program the tractors to perform the task you need them to. Then we talked about drones and how they have made crept into being used in agriculture and how beneficial they are. Being able to check on your crop fields without having to be in them is a huge asset for farmers. The bad thing is the expense of the drones, which will keep many farmers from using them. With drones, you have drone planting systems, which can speed up farming and how quickly a crop is put in the ground. Remote sensing systems are great for farmers; they provide farmers with multiple options depending on what fits them best. A piece of precision agriculture that I find very interesting is the agribots, which goes along with the self-driven tractors too. The agribots allow farmers to salvage ever bit of the crop they are harvesting which in return allows them to have higher crop yields because these robots can do things that humans cannot. The technology that has been formed for cattle so that the farmers can closely monitor their health and production is a huge advancement in agriculture as well. Allowing farmers to be able to be away from the farm but still be able to keep check on the livestock is big. Overall precision agriculture has made agriculture better and more efficient. We will continue to see advancements to these precision techniques as well as new ones invented to keep improving agriculture. The population of the United States still rising plays a huge role in why we have to keep making advancements in agriculture because if we do not do so then we will not be able to feed everyone. Precision Agriculture will always be important and hopefully you have been able to see all of the advantages it brings to farming.

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