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Things to Know About Applying Precision Agriculture Technologies in Arizona

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Precision Agriculture (PA) technologies can enhance the productivity of irrigated agriculture in Arizona. This guide is intended to aid growers in selecting the right technology when considering the need to acquire new, or upgrade existing equipment. It is expected that growers will adopt new technology only when it solves a problem in an economical way, therefore consultation with your local machinery dealer is a key step in being informed on issues such as cost, service, infrastructure requirements, and compatibility between components, systems, brands, etc.

Use of Mechanized Technology and Farm Management

Technological innovation in U.S agriculture has been the basis for the outstanding gains in productivity that have been achieved (Fuglie et al., 2007). In the area of energy use, significant progress was made after the transition from animal drawn implements to mechanized operations. By 1945, the use of tractors was preferred due to its versatility (Culpin, 1992). Early in this transition power units used gasoline engines, but by now, tractors and self-propelled agricultural machines make use almost exclusively of diesel engines due to their extended durability and continuous power delivery characteristics. Seeking higher levels of field capacity, modern U.S. agriculture has experienced a process of using ever increasing farm equipment size. This trend has promoted management systems that rely on using production inputs in a uniform way across the field.

Uniform management has the advantage of being simple; however it disregards the spatial and temporal variability within the field that impacts crop yield. As the average farm size has increased due to land consolidation, there has been an unintended loss of efficiency in the use of energy-intensive production inputs. One way to visualize this is by walking through a field and recognize the change in plant sizes and soil types; some areas would benefit from extra amounts of fertilizer, or water, and other areas would not respond even if we use more of those inputs, still we treat the whole field in the same way. With this view in mind, we can realize that uniform management in order to be sustainable, needs to deal with the ever-increasing cost of energy inputs as well as its environmental footprint. These are only two constraints, among many others that we will face in the future. Once again, we need to bring technological innovation to keep our farming systems globally competitive and profitable and within the limits of environmental resiliency.

Precision Agriculture

Advances in agriculture technologies over the last 20 years point to a new paradigm in which two views are combined:

i) The use of energy-intensive inputs (i.e. chemical fertilizers and pesticides) based on the right amounts, at the right time, and in the right place. This type of management is commonly known as "Site-Specific Management".

ii) Technology used to perform the conventional pattern of mechanical operations but at higher levels of efficiency. This is the case of tractor auto-guidance.

This new paradigm defines the context of PA, a new production system with efficiency in mind. PA technologies are, to some extent, alternative ways to do the same operations while saving on resources such as time, labor, fuel, fertilizers, water, etc. Because resources can be utilized more efficiently, the use of PA technologies can also help in reducing the environmental footprint of agriculture. Figure one illustrates how information-intensive technologies in precision agriculture are an integral component of modern farming systems in Arizona.

Table 1. Typical operations and alternative PA upgrades.

Operation	PA technologies	Benefits	Observations
Chisel plow	Tractor steering control	Keep consistent spacing between runs Makes possible strip tillage in conservation systems and drip irrigated fields	Light-bar, steering assist, or hands-free options High levels of accuracy are generally not required
Leveling	RTK elevation monitoring	Yearly maintenance of field slopes without expensive laser leveling	Requires high level of accuracy
Disking	Tractor steering control	Avoid excessive overlap between runs (more land covered) Optimizes turning pattern	Light-bar, steering assist, or hands-free options High levels of accuracy are generally not required
Row listing	Tractor steering control	Repeatable row position year after year Avoid guess row Increase speed of operation Improve timeliness of operations prior to planting Optimizes turning pattern Reduce operator's fatigue	Makes possible day and night shifts Steering assist, or hands-free options Requires high level of accuracy Recommend using stabilizers to reduce implement drift
Bed shaping/ mulching	Tractor steering control	Improves bed uniformity, straight pattern, and spacing between runs	Steering assist, or hands-free options. Requires medium-high levels of accuracy Recommend using implement stabilizers to reduce drift
Planting	Tractor steering control Variable-rate seeding	Deliver more seed in germination-trouble areas Drills: avoid overlap between runs (saving seed) Row planters: straight seed line (for close cultivation). and spacing between runs	Steering assist, or hands-free options Requires high level of accuracy Variable application rates can be achieved through prescription map or manual adjustment

Operation	PA technologies	Benefits	Observations
Border disc	Tractor steering control	Straight berms to create uniform-width borders Repeatable position within season and year after year	Steering assist, or hands-free options. Requires medium-high levels of accuracy
Spraying (of chemical pesticides and liquid fertilizer)	Tractor/sprayer steering control Rate control with speed compensation and variable rate spraying Boom section control Boom height control	Directional control is particularly useful in flat ground applications Avoid excessive overlap between runs Reduce chemical drift Avoid spraying outside field boundaries	Steering assist, or hands-free options. Requires medium to high levels of accuracy Variable application rate through prescription map or manual adjustment Single/multiple chemicals
Side-dressing	Tractor steering control Rate control with speed compensation and variable rate application	Automatic dispensing of fertilizer according to prescription Tracking actual amounts of fertilizer used Increased speed of operation	Controller changes rates automatically according to zones and changes in speed Can be combined with other operations in the same pass (i.e. cultivation)
Cultivation	Tractor steering control Implement steering control	Allows cultivation close to the seed-line Increase speed of operation Optimizes turning pattern Reduce operator’s fatigue	Can be combined with other operations in the same pass (i.e. side-dressing)
Harvest	Harvester (hay swather, grain combine, cotton picker) steering control Yield monitors	Improves turning pattern to avoid incomplete swaths Records differences in yield with the field	Provides yield information that can be used to detect trouble areas, delineate management zones, evaluate variety performance, etc.

Figure 1. Use of modern technology in production agriculture in Arizona. In clockwise order we find satellite communications; global positioning systems (GPS) to enhance machine positioning in the field; variable-rate technologies for energy-intensive inputs; highly trained work force, and yield monitors.

Farming Operations Enhanced with PA Technologies

As seen in Table 1, virtually all operations in modern farming can be improved with the use of PA technologies. Also included are some of the benefits of adopting these technologies and important observations. It is worth noting that the most frequent PA technology adoption in Arizona is tractor auto-guidance, which has been commercially available for the last ten years. The high rates of adoption of tractor auto-guidance reported by Whipker and Akridge (2009) at the national level, demonstrate that this technology is perceived by growers as a significant improvement on mechanized operations. Table 1 also denotes one trend, which is the integrated use of technologies. We can see that steering control can be used in combination with rate controllers and other hardware (such as global positioning systems (GPS), hydraulic valves and pumps) to increase the functionality of the same power unit (tractor or sprayer) and allowing multiple operations to take place on the same pass through the field (i.e. cultivate and side-dress at the same time). As we will see in following sections, this is possible through the use of vehicle-mounted computer displays that have exceptional computing and electronic communication capabilities for monitoring and control functions.

Precision Agriculture Equipment and Software

GPS Receivers

Several kinds of GPS receivers are available for growers to use on the farm. The most basic type corresponds to hand-held receivers, sometime used for recreational purposes, but still these are quite useful for navigation and geo-referencing field samples. Generally, these receivers have low levels of accuracy (about 3-5 ft), but are inexpensive solution alternatives. Next are machine mounted GPS receivers with external antennae whose purpose is to provide positioning information that enables a variety of functions such as guidance, variable-rate application, yield monitoring, etc. These receivers range in accuracy from 12 inches to less than an inch depending on the correction source. Generally speaking, medium levels of accuracy can be obtained with free-of-charge correction sources available through satellite or ground stations. For high accuracy, GPS signal correction can only be attained from fee-based sources or by installing an on-site base station. Growers should keep in mind that cost and accuracy go hand-in-hand and the need for a specific accuracy level depends on the application.

Machine Steering Control

Early developments in machine guidance are the "light bar" systems. These are pieces of hardware mounted in the windshield of the tractor/sprayer/harvester cab in direct operator line of sight. With proper configuration, these units guide the operator who visually observes a series of green/red LED lights to indicate the machine's position relative to the desired direction. Light bars provide a good entry-level option for steering control, but limitations are evident when compared to the more sophisticated "hands-free" systems currently available.

"Steering assist" systems are devices that attach to the steering wheel—or steering column—to take over the directional machine control. One advantage of these systems is portability because the unit engaging the steering wheel can be easily moved from one machine to another. Steering assist systems provide an excellent option to auto-guidance but their accuracy is lower than the top-of-the-line autopilot systems that interface with the machine steering through the hydraulic system. These "hands-free" auto-pilot systems generally use the most precise GPS receivers that provide consistent signals of less than one inch accuracy. Directional control at this level requires extra navigation hardware and motion sensors such as gyroscopes and accelerometers.

In power demanding operations such as tillage, autopilot systems allow growers to save fuel and time by optimizing the number of passes into the field. Moreover, auto-pilot makes tractor operation easier, reducing operator fatigue and allowing the driver to pay more attention to the quality of the work done by the tractor/implement system. Proper use of auto-pilot results in more productivity that is seen in more acres covered during the operators' shift. As the growing season takes place, mechanized operations for planting, weed and pest control, fertilization, and harvest can be performed with high-efficiency by integrating a variety of PA technologies such as steering control, variable rate controllers, yield monitors, etc.

Multi-function Computer Displays

The integration of measurement and control systems on the machine is done through cab computer display. Computer displays installed in the cab can combine a variety of functions such as guidance, variable-rate application, land leveling, etc. These systems are very good options for farmers using the same tractor for a number of different applications. The display is a human-machine interface communicating with peripheral devices (i.e. servo-hydraulic valves, GPS receivers, rate controllers, speed sensors, etc.) to enable monitoring and provide control for a variety of functions. Multi-function computer displays (such as the Ag Leader Integra, John Deere GreenStar, and Trimble FMX) are available for tractor systems that are capable of a variety of functions such as automatic guidance, yield monitoring, variable-rate seeding, spraying, side-dressing, ground elevation monitoring, etc.

Rate Controllers

Rate controllers are devices designed to control the delivery rate of chemical inputs such as fertilizers and pesticides, either liquid or granular. These rate controllers monitor the speed of the tractor/sprayer traveling across the field, as well as the flow rate and pressure (if liquid) of the material, making delivery adjustments in real-time to apply a target rate. Rate controllers have been available for some time and are frequently used as stand-alone systems, but the newer computer displays installed in the machine cab usually are capable of communicating with these rate control devices to enable higher functionality such as memory storage for as-applied and prescription map based rate changes.

Soil and Plant Sensors

Sensor technology is an important component of PA technology and their use has been widely reported to provide information on soil properties and plant fertility/water status. Adamchuk et al. (2004) provided a comprehensive list of current sensors as well as desirable features for new sensors to be developed in the future. One of the most popular ways to characterize soil variability is surveying the field with soil apparent electrical conductivity (ECa) sensors that collect information continuously when pulled over the field surface. Because ECa is sensitive to changes in soil texture and salinity, these sensors provide an excellent baseline to implement site-specific management.

An area of intense study is the use of active-light canopy reflectance sensors to infer the crop nutritional status by estimates of plant size, biomass and photosynthetic activity and use this information to activate rate control systems to dispense fertilizers and/or plant growth regulators (PGR). There are published extension bulletins on the use of these spectral sensors for real-time nitrogen application in wheat (Berntsen et al., 2006), corn (Ferguson et al., 2007), and cotton (Taylor and Fulton, 2010). The operational principle of active-light spectral sensors is based on measuring the percent of light at certain wave-lengths that bounces back after modulated light is directed to the crop canopy. Vegetation indices are computed based on the amounts of reflected light from the green, red, and near-infrared portions of the electromagnetic spectrum. Sensor-based management is an emerging area with very high potential to improve fertility and PGR management through real-time variable rate applications.

Yield Monitors

Current technology for yield monitoring includes the mechanical harvest of grains and cotton. In the case of grains, yield is continuously recorded by measuring the force of the grain flow as it impacts a sensible plate in the clean grain elevator of the combine. Some cotton seed yield monitoring systems use optical sensors installed in the mechanical picker chutes to measure cotton flow rate as harvested cotton travels from the header to the basket. A recent development of a cotton mass flow sensor works on the principle of transmitting beams of microwave energy and measuring the portion of that energy that bounces back after hitting the stream of cotton flowing through the chutes. In all yield monitors, GPS receivers are used to record the location of yield data and create yield maps.

Other yield monitoring systems include devices used in forage crops to keep track of weight, moisture, and other information on a per-bale basis. There are few examples of yield monitors for specialty crops which are less developed at this time.

Precision Irrigation in Pressurized Systems

Recent developments are being released for commercial use in sprinkler irrigation by controlling the irrigation machines (i.e. pivots and linear-move) motion with GPS-based controllers. In addition to motion control, wireless communication and sensor technologies are being developed to monitor soil and ambient conditions, along with operation parameters of the irrigation machines (i.e. flow and pressure) to achieve higher water application efficiency and utilization by the crop. In west Texas, O'Shaughnessy and Evett (2010) have done extensive research looking closely into ways to increase the efficiency of these irrigation machines. These technologies show remarkable potential but further development is needed before they become commercially available.

Software

Applying precision agriculture technologies will frequently require the use of software to carry out diverse tasks such as display-controller interfacing, information layers mapping, on-the-go and post-processing data analysis and interpretation, farm accounting of inputs per field, and many others. Generally speaking, these software packages come at affordable prices, are user-friendly and easy to learn with some training. There are different options for acquiring software licenses depending on the intended use and the users' skill. These packages fall within three categories: generic GIS software, specialized farm management software, and proprietary software from machinery dealers. All are excellent options for PA farm management and record keeping to keep up with the needs of modern, information-intensive farming systems.

On-line resources for precision agriculture

There is a wealth of information available over the internet on new technology for farm production. Most manufacturers of farm equipment, GPS receivers, sensors, and other PA technologies use this media to inform growers on new products, technical specifications, trouble-shooting information, software upgrades, and a variety of services. The following contains a listing of some internet sites of U.S. companies where growers can find more information. Be aware that the University of Arizona does not endorse any products, services, or organizations that are included in this list.

Technology providers:

1. Ag Leader – **http://www.agleader.com**
2. AGCO ATS – **http://www.agcotechnologies.com/naen/solutions.htm**
3. AutoFarm – **http://www.gpsfarm.com**
4. CaseIH – **http://www.caseih.com/northamerica/products/precisionfarming**
5. Dickey-john Agricultural Electronics – **http://www.dickey-john.com**
6. Holland Scientific – **http://www.hollandscientific.com**
7. John Deere – **http://www.deere.com/greenstar/**
8. N-tech Industries – **http://www.ntechindustries.com**
9. OmniSTAR – **http://www.omnistar.com**
10. Outback – **http://www.outbackguidance.com/**
11. Raven Applied Technology Division – **http://www.ravenprecision.com**
12. Spectrum Technologies – **http://www.specmeters.com**
13. TeeJet Technologies – **http://www.mid-tech.com**
14. Topcon – **http://www.topconpa.com**
15. Trimble – **http://www.trimble.com**
16. Veris Technologies – **http://www.veristech.com**

Software solutions:

1. ESRI GIS – **http://www.esri.com/industries/agriculture/index.html**
2. Farmworks software – **http://www.farmworks.com/**
3. Manifold software – **http://www.manifold.net/index.shtml**
4. SMS software – **http://www.agleader.com/products/software/**
5. SST software – **http://www.sstsoftware.com**

News and updates:

1. Precision Ag – **http://www.precisionag.com/**
2. GNSS – **http://www.insidegnss.com/**
3. GPS – **http://gpsinformation.org/dale/nmea.htm**

Final Remarks

Tractor operations in agriculture is where the highest demand for mechanical power takes place, and precision agriculture technologies have the greatest potential to impact farm production. Integration of machine steering, input application, tractor performance, and communication systems can make significant contributions to the overall farm production efficiency in irrigated agriculture. Some of the benefits of adopting PA technologies include increased labor productivity, higher work quality, timeliness, savings in fertilizers and other chemicals.

Readers are encouraged to visit their local farm equipment distributors to learn of available PA technologies that will suit their needs. PA technology can be a sound investment but it is critically important to understand the technical aspects of PA in the economic context of the farm.

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