PRECISION AGRICULTURE FOR POTATOES--
WHERE DOES IT FIT?

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We hear so much these days about precision agriculture. Everyone seems to have their own definitions about what it is and what it isn't. It's all very confusing. What is it, really?

Precision agriculture is really nothing new. We've been doing it for centuries. When our ancestors farmed with horses--they were carefully managing small areas and practicing precision agriculture. When you use a backpack sprayer--it's precision agriculture. When you use a hoe to chop weeds or thin beets--it's also precision agriculture.

If it is not new, then why the big hype? What is it that has so many people excited? Many people refer to precision agriculture as only precision planting, precision herbicide sprayers, site-specific land application of fertilizers or yield monitors, but it is much more than that! This "new" precision agriculture is actually just a systematic way to look at the total farming operation. It is partly the equipment. It is partly the advances in communications and computer technologies. However, more than anything else, modern precision agriculture gives us the ability to again economically manage our fields on a foot by foot basis.

What makes this exciting is the ability to maintain detailed records on each area of your farm and the inherent flexibility that it gives you to make better management decisions. Modern precision agriculture is basically about information: its collection, its management and its interpretation. It has been made possible by advances in computer and communications technologies that allow us to use equipment and software to manage inputs in ways that account for the inherent yield variability across any field.

Cell phones, personal computers, fax machines, computers in tractors, satellite and phone modem communications were once considered exotic, but are now common farm tools.

This Presentation is part of the Proceedings of the 1997 Washington State Potato Conference and Trade Show.

Other "space age" technologies that will become common in the precision agriculturist's tool box might include:

1.) Geographic information systems (GIS) are computer software that provide ways to graphically present, analyze and assist in interpreting data. These data bases link management information and point data by: a.) creating map overlays (using various data "layers") to study relationships and examine patterns between yields and other mapped variables like topography, soil fertility, weed populations, drainage, compaction or any other factors we may be interested in studying; and, b.) providing a body of spatial data about discrete points that can be used for running computer models and evaluating historical trends.

2.) Global positioning systems (GPS) that use a communications network of 25 earth orbiting satellites to determine an exact location on the earth's surface. This "geo-referencing" of various field operations and measurements is critical to management and evaluation of precision farming.

3.) New computers and software that implement geo-referenced management maps to automatically change fertilizer rates and blends, adjust plant populations and varieties when seeding, vary herbicide rates on-the-go, and precisely apply water & nitrogen. Powerful hand held, pen based and voice activated computers with remote communications capabilities will soon be commonly available for multiple uses including yield monitoring, GPS, tractor engine and transmission diagnostics and reporting (even automatically ordering new parts) and transmitting these data to a base computer for storage and further analyses. The same computers could be used as portable electronic scouting tools with and without satellite or cell phone communications to specialists for on-site analysis of soil and crop nutrient/water status to aid in rapid identification of management problems as well as disease and pest diagnosis.

4.) Electronic communications systems for ready access to suppliers, advisers, and support services reducing down time at critical periods.

5.) On-the-go yield monitors using GIS and GPS allow the collection of site specific data (future models will be able to obtain site specific crop quality data too) that provide valuable information on yield trends and patterns.

In addition, improved techniques for remote sensing of soil and crop status, powerful computers, communications, "smart" sensors and other real time data collection systems that provide adequate feedback and control capabilities have made it possible to develop integrated, economically viable site-specific crop management (SSCM) systems. These data must be used with software to statistically evaluate, enhance and spatially combine with other GIS data layers to look at inter-relationships and causes of yield variability. Then integrated prescriptions can be developed with the grower that address short term and long term (if possible) solutions. Research is needed to give farmers confidence that the use of these technologies is practical and potentially valuable in improving irrigated potato production.

Most of the national attention has been on precision placement of fertilizers on grain and seed crops in rainfed areas where many of the benefits are lost because of inability to manage soil water. Because we must irrigate in the arid west and can control soil water, we have the capability to maximize the benefits of many precision agriculture technologies.

The concept of varying agrichemicals, fertilizer and water applications to meet the specific crop needs in unique zones within a single field has been a dream of many people for years, and we now have the technologies to accomplish this goal. Self-propelled (SP) irrigation systems like center pivots (CP) and linear moves (LM) are particularly amenable to site-specific approaches because of their automation and large area coverage with a single pipe lateral. Microprocessor controlled SP irrigation systems provide a unique platform with all the control capabilities for economical and effective precision irrigated crop management. The technologies discussed above have made it possible to vary agrichemicals, fertilizer and water applications to meet the specific needs of a crop in each unique zone within a field, particularly with center pivot irrigation systems.

Consequently, at Prosser, we have put together a large interdisciplinary team of university and USDA scientists, growers, service providers, equipment manufacturers and processors to provide an integrated approach to writing prescriptions for center pivot irrigated potato production in the PNW. Our research has focused on the areas of: 1.) development of basic field-scale SSCM data bases using GIS; 2.) geostatistical interpolation of sampling data; 3.) interfacing various plant growth and center pivot hydraulic models with the GIS; 4.) development of controls and communications to implement variable rate SSCM under center pivot irrigation systems; 5.) establishment of field monitoring; 6.) scheduling of non-uniform SSCM irrigations; 7.) evaluation of site-specific pesticide applications using center pivot systems; 8.) field evaluations of site-specific water and nutrient applications; 9.) yield monitoring; and, 10.) economic (farm budgeting) evaluation of SSCM.

More important than the technology, however, is the ability to properly utilize it at the right times. The development of site-specific, integrated real-time precision irrigation, fertigation and pesticide systems for SPs is under development. GPS, yield monitoring, GIS, various computer models, extensive field sampling programs, real-time monitoring of climate and field parameters makes it possible to optimize management for spatial and seasonal variability.

The next step is the integration of irrigation, fertilizer and pest management strategies into "systems" that optimize total management practices for temporal and spatial variability. The major research question is the determination of what a "prescription" should be and how it should be formulated. The identification and quantification of the major contributing factors and their interactions that influence a real-time prescription are difficult. A prescription must specify when, where, and how much of a specific input or cultural operation should be applied to optimize yield quality and quantity while protecting the environment in a management area, especially in the area of water quality. Prescription building requires collection and integration of detailed knowledge about magnitude and extent of variability of climatic parameters, soil characteristics, pests, diseases and other production inputs followed by the systematic processing of large amounts of data into coherent and rational decisions that optimize management on that site.

Prescriptions will always be a compromise, an optimized set of solutions subject to a lot of competing and often conflicting needs, that ultimately maximizes returns to the producer. There must also be the ability to implement decisions quickly and easily since climatic variations and pest outbreaks require timely prescriptions to apply water and chemical inputs on a daily basis.

Irrigation. Despite the inherent high frequency and fairly uniform applications of self propelled irrigation systems, considerable yield variations still exist which are largely assumed to be due to the spatial variability in water holding capacity (WHC) and nutrient availability. Yield variability is also increased by pest and pathogen effects on crop growth, which causes further variability in water and nutrient utilization.

Microprocessor controlled self-propelled center pivot (CP) systems linked to a central integrating computer provide a unique platform as well as control capabilities for precision crop management and are an effective and economical means to deliver site-specific crop management (SSCM) under irrigated conditions. With appropriate controls and decision making tools, these systems can be managed to account for spatial variations in water, fertilizer and pesticides requirements.

To date, our team has produced a working prototype of a system to implement site specific SP irrigation (and nitrogation). The computerized control system and valving to implement SSCM maps for water and fertilizer (N) applications have been field validated. A farm office computer talks to 30 addressable controllers along the center pivot pipe, position sensors, an on-site weather station (hourly) and soil water monitoring stations via radio modems. These data are input into the GIS and linked to computer simulation models, allowing for manipulation of large amounts of spatial data to generate optimum water and nitrogen application rate maps. Yield maps and remotely sensed data provide valuable information for assessing water and nitrogen variability. However, due to the random variability in water application distributions due to wind, start-stop operations of the SP machines, and sprinkler pattern variations combined with the low cost of water and nitrogen fertilizers, it is probably not economically feasible to site-specifically manage only for water and/or nitrogen at the current time.

Precision Pesticide Applications. Recent years have seen greatly increased pesticide costs for extra sprays required for late blight control on potatoes. "Pestigation" with self-propelled systems is especially amenable to SSCM approaches since herbicides, insecticides and fungicides can be applied after full cover to the entire circle or just to control "spotty" initial infestations. Utilization of early detection technologies (e.g., remote sensing) combined with the ability to "spot" spray and adjust rates depending on special conditions in discrete portions of an SP irrigated field, may potentially save PNW growers millions of dollars in reduced pesticide use and enhance integrated pest management programs.

Our team has <u>begun</u> development of hardware, software and economic analyses of site-specific fungicide and herbicide applications with SP systems. This work is in response to greatly increased pesticide costs for extra sprays required for late blight control, where the ability to quickly apply fungicides after full cover is critical.

Several agrichemical companies in the PNW have recognized the potential demand for this technology and are currently working on, or planning to implement, separate pesticide (primarily fungicides) application systems on SPs, but with very limited site-specific capabilities. Maintenance requirements of these systems, clean water and valves are practical problems that need to be addressed. Application booms will have to be raised and lowered, based on GIS maps, to specific heights above the crop to maximize canopy penetration and avoid drift. Portability and economics of these pesticide systems will be major considerations. Insect control could also utilize the same technology and application systems because insects are easily mapped and amenable to spot treatments. The same control system developed for site specific water application can be used for the pesticide treatments. However, the real challenge will be to develop ways to coordinate pesticide applications with water applications during peak water use periods so that there are minimal negative impacts on yield and quality.

Utilization of early detection technologies (e.g., remote sensing) combined with the ability to "spot" spray and adjust rates depending on special conditions in discrete portions of an SP irrigated field, can potentially save PNW potato growers millions of dollars in reduced pesticide use. In addition, site-specific pesticide applications could: 1) reduce pesticide costs to growers which makes them more competitive in global markets; 2) reduce the potential for resistant pest populations; 3) reduce total use and minimize negative impacts of pesticides on the environment and non-target organisms; and, 4) reduce potential for leaching of pesticides and increase chemical efficacy. We will focus on herbicides and fungicides because: 1) more herbicides are applied than any other group of pesticides; 2) both can be contaminants in ground water; and, 3) the current high level of grower interest in fungicide applications with SPs will facilitate total SSCM acceptance.

Site-specific pesticide applications could enhance IPM programs by reducing negative impacts of agrichemicals on non-target organisms and biocontrol agents in nonsprayed areas. IPM reduces costs as shown by Stevenson et al (1994) who estimated that Wisconsin potato growers that followed the IPM recommendations of the WISDOM model on 67,000 acres saved almost $6 million/yr. in reduced pesticide use and irrigations compared to prior input costs. If these values could be extrapolated to central Washington, where the average annual cost for agrichemicals (not including fumigants or fertilizers) on 125,000 acres of potatoes, is conservatively estimated at about $250/ac, the annual savings for pesticides alone would be about $11 million.

Yield Maps. Generally we currently manage fields uniformly trying to get maximum consistent yields from all parts of the field. However, we all implicitly know that we will never get uniform yields from all parts of our fields. Sometimes we are able to effect long term fixes to some problem areas but others may never achieve high yields. Yield reflects the plant's integrated response to all the factors influencing the crop over the growing season(s). A yield map indicates the variation of these combined effects. *This is valuable information only if the principal reasons for these variations can be established.* Is it the result of a site specific management practice(s) and/or which other factors?

We have been monitoring yields on wheat, potatoes, buckwheat, and sugar beets since 1994 because we know that yield maps can play an important role in characterizing spatial variability across a field. However, yield maps must be correlated with locations and magnitude of damage from pests and diseases as well as soil fertility, topography, soil texture and many other factors over several years to develop an integrated and useful assessment tool. It is important to remember the variation in yields is usually not due to the same factors in each area; different factors can and will affect yields in different parts of the field and they will vary from year to year.

Where does it fit?

Precision farming is one tool that production agriculture can profitably use to meet the agricultural challenges of the next century. Environmental issues, reduced water supplies, and reduced availability of chemicals/pesticides must be addressed and components of precision agriculture will be a part of the solution. We must develop the ability to systematically write environmentally sound "prescriptions" for each field. Precision agriculture can make us more competitive.

Precision agriculture is here to stay. It is based on sound science. No one expects every grower to adopt all the precision agriculture technologies. But you can expect to be using some of them each growing season, although they may not be the same ones every year. Will you be using precision pesticide applications? Absolutely (if for no other reason than record keeping)! Will you be using yield monitoring? Very likely. Will you be doing precision fertilizer applications? Probably. Will you be using precision water/nitrogen applications on your center pivots? Highly probable. However, the real benefits will be the record keeping and management flexibility that are made possible by these technologies.

Yield monitors, grid sampling and remotely sensed data are valuable tools that provide critical information on the variability in our fields as well as to evaluate the results of a site specific management program. We can adjust the amounts of water (nitrogen) applied by center pivot and drip irrigation systems to match the spatial variability in water holding capacity and related nutrient availability. But, yields and quality are affected by many, many factors. Variations in quality and quantity of yields are also increased by weeds, pests and pathogen effects on crop growth as well as microclimate changes across a field, which cause further variability in water and nutrient utilization. In addition, the implementation of a practice to correct one problem may often have unwanted side effects and even create new, and possibly more serious, problems that must be corrected in turn. In other words, the ability (*how*) to apply individual inputs precisely to match single needs does not mean that we know the *what, when, and where* to apply a "prescription" of precision agricultural practice or group of practices. We must learn how to write our day-by-day prescriptions for each field. We must take these *precision* technologies and apply them to *prescription* agriculture.

How Can Precision Agriculture Benefit You Today?

At this point, you are probably saying that these are "Gee Whiz" technologies and are not appropriate for farmers. However, I think you would be wrong. GIS and GPS are not pie in the sky. All of these technologies are in common usage in agriculture, but have had limited application to irrigation management, particularly in the PNW.

Hopefully, the above discussion does not imply that precision agriculture practices are not currently useful. I believe that they are most definitely beneficial and there are positive economic incentives for adopting certain aspects of precision agriculture now. The biggest current benefit is that they provide more and more information about the spatial variability that exists across a producers field plus variability due to P, K and other non-mobile nutrients as well as weed patterns that can be addressed and treated. Being able to write good prescriptions will require a detailed understanding of the field variability and what should be expected under "normal" conditions. We need to be building our GIS data bases now, and the current "precision" technologies in combination with good yield mapping and remote sensing are extremely valuable in this regard. It may take several years of building this background data base to make it truly useful. However, producers need to approach this with a long term attitude and begin the process so that they are ready when the consultants/field men are able to write a meaningful daily "prescriptions" for their fields.

It must be realized, however, that precision agriculture is basically the attempt to manage inputs that account for the inherent yield variability across any field. Consequently, computerized record keeping is the backbone of prescription agriculture. Data bases about cropping history, nutrient applications, soil tests with coordinates and the integration all available data bases are essential in making prescription farming a profitable part of crop production.

Precision agriculture can benefit you now, particularly with site-specific fertilizer mapping and applications. Yield mapping can provide valuable insight for future management decisions. It does not require large capital investments to get started. But, as growers, you need to get started now.

GPS, remote communications and many other "bells and whistles" will be required for full adoption of a prescription agriculture program, but these tools will have limited value until a basic data base has been compiled and initial analyses made to develop the first management maps. Now is the time for potential users to select appropriate GIS and record keeping software for a long term system. They should investigate various GIS software and work with a consultant, advisor, or extension agent to: 1) Properly structure management and collection of data needs, organize sampling based on variability. Data management systems must be flexible and capable of growing with you. The software must be able to interface with various other data bases to prevent dead end results and a lack of meaningful interpretations. 2) Begin to analyze your records and develop initial interpretations as availability of time and resources permit. These "initial" management plans will change as more information becomes available.

Each year will be different and comparisons will provide a systematic way to better understand the interactions and improve production. Yield maps are an excellent starting point to begin looking at responses to site specific management decisions.

A concerted effort needs to be made to gather satellite and aerial photos, soil classification maps, road maps, maps of electrical/utility lines, field drainage, topography and any other data that has been collected on your fields--especially if it has been geo-referenced. Develop record systems and management plans for each field referencing the site specific variability: soil yield potentials; previous yield histories; weed pressure mapping, and nutrient applications. Record yields, soil test results, and known soil properties into a GIS as close as possible. Make a commitment to keep accurate detailed records of production inputs, yields, etc. over the next several seasons. Geo-reference all soil and plant samples.

At first, the only benefit may be that your data base will help you know where to sample soil and plants. Continue to add information each year to refine management maps. As the technology improves, some data sets can be replaced with more accurate and/or more detailed data, and better interpretations can be made.

There is a tremendous need for support services. These will be a critical component, providing the link between raw and useful data to managing inputs according to variability in field. They will be needed to adequately process remotely sensed data, yields, pest scouting and other precision agriculture data; they will help the grower interpret, integrate and assign the information into the appropriate precision components (what, when and where). Manpower expertise in computers and software (e.g., expert systems/decision support systems) are needed to provide timely and useful data to growers.

Conclusions

Precision agriculture has the potential for reducing inputs, better utilization of existing resources, increased ecological benefits, and improved profitability. The various technologies such as differential fertilizer placement, precision planting and others that we collectively refer to as "precision farming" have been made possible by "tools" like GPS, GIS, computers, smart sensors, advances in communications and other emerging technologies. However, as is always the case with the advancement of any new innovations in agriculture, we have to learn how to collectively use them to their maximum potential in each area and crop. We must now learn to fit the various pieces of the precision agriculture puzzle into their proper places to: 1) optimize yields and quality from each area in a field; 2) reduce product variability; 3) protect the environment; 4) reduce inputs; and, 5) maximize the returns on investments.

We believe that precision technologies will be fundamental to farming in the future as is evidenced by the big efforts being made in developing various applications using these technologies by fertilizer companies and major farm equipment companies such as Ag Chem, John Deere, Case-IH, Heston and others. Companies like CENEX-Land 'O Lakes, Simplot

Soilbuilders and others are making very large investments in equipment and training for their employees to provide services in this area. Self propelled irrigation system manufacturers are also very interested and conducting research in this area. Software for evaluation and implementation is likewise becoming more available at low prices. Research and demonstrations are needed to give farmers confidence that the use of these technologies is practical and potentially valuable in improving SP irrigated production.

Higher yields and improved crop quality may result from optimal site specific water, nutrient applications, however, some of biggest immediate economic and cultural benefits will probably revolve around using precision technologies with SP systems for pesticide applications. If farmers adopt SSCM technology based primarily on economic self-interest, improved ground water quality will be an added benefit. Alternatively, farmers may adopt such technology to avoid the possibility of new regulations and penalties associated with potential negative impacts on ground water. However, due to the random variability in water application distributions due to wind, start-stop operations of the SP machines, and sprinkler pattern variations combined with the low cost of water and nitrogen fertilizers, it is probably not economically feasible to site-specifically manage only for water and/or nitrogen. Consequently, we are currently expanding the same technology, using the CP as a delivery platform, for site-specific pesticide applications that will attract grower interest and investment. Much work remains to enable consultants to write integrated ***prescriptions*** for precise applications that allow producers to fully realize the benefits of these technologies.

As we have seen, it is now possible to quickly and precisely implement decisions regarding the location and timing of nutrient, water, and pesticide inputs to meet the needs of the crop in discrete areas in a field throughout the season. But, the "preciseness" of an action does not necessarily make it right. Even though we now have the ability to precisely apply many inputs, it does not imply that we have the knowledge to correctly place these input(s) across the field. We are moving from "precision" towards "prescription" agriculture where the optimal benefits will ultimately be obtained.

These precision agriculture technologies and many of the necessary support services are available today. They will continue to be refined and will be available at ever lower costs. However, precision agriculture, or more properly, prescription agriculture will be useful only to those who make a *commitment* to begin building the detailed data bases, monitoring and record keeping system. It is more than high dollar equipment and software. The name of the game will be information management and its interpretation. What is the prescription for your field today?