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FROM THE GROUND UP
Agronomy News

INSIDE THIS ISSUE

Zoning In On Precision Ag

New technologies help growers pinpoint management zones to improve the bottom line

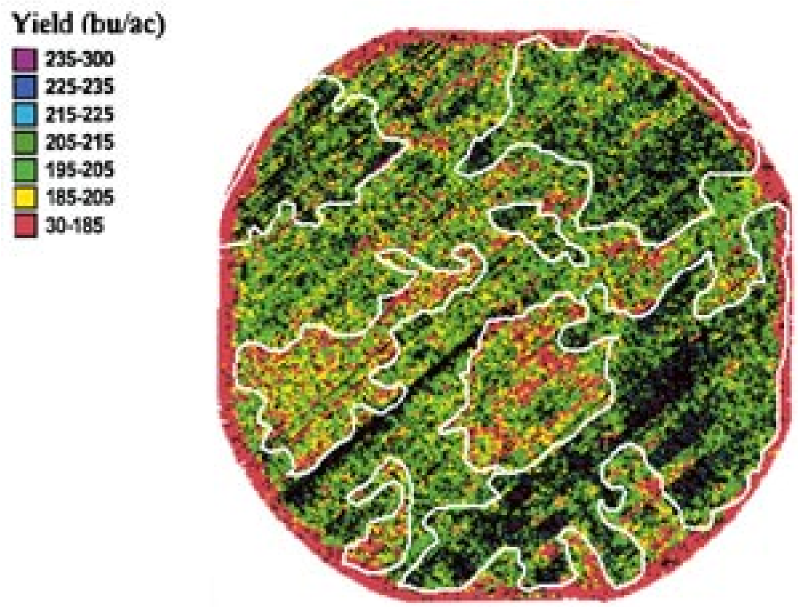

Figure 1. Grain yield variability in a center pivot field.

Precision farming is an art and science of utilizing advanced technologies to enhance grain yields in an economic and environmentally sensible manner.

Our goal is to maximize ag-input use efficiency, or in other words maximize net dollar return per acre from the fields, increase grain yields, protect environment, and enhance farm profitability.

We have been practicing crop production for centuries. And during this time period we all have realized that when we harvest our crops year after year, the grain yields harvested from different areas of a field are not uniform (Figure 1). For example, you have a 160-acre cornfield or a quarter section center pivot cornfield, there are areas within the same field that produces different levels of grain yield. The grain yield variability

Knowledge to Go Places

Zoning In On Precision Ag (continued)

in one field can range from to 300 bushels/acre. Well we all have observed that for a long time. The question is, what can we do about it?

Is there something we can do to enhance our production and bottom line?

Figure 2. Yield Monitor for locating, measuring, and recording yield data.

In the past, we did not have the technology to quantify these differences in grain yield. Thanks to precision farming technology we can now locate, measure and record such areas in the field that produce below or above the average grain yield of the whole field (Figures 2 & 3). Not only that but precision farming provides us the tools and the opportunity to manage the grain yield variability that exist in our fields.

The big question is: "How do we manage this grain yield variability that exists in our farm fields to maximize our net $$ return?"

Managing grain yield variability

The first approach that we all started practicing and evaluating as researchers and consultants was Grid Soil Sampling (Figure 4). However, very soon we realized that grid soil sampling is time-, labor- and cost-intensive. Besides, it needs to be performed on each field and almost every year or so and therefore becomes cost prohibitive.

There has been a need for a method of managing variability in our farm fields that is stable, less cost- and labor-intensive that can be used for several years and can still manage grain yield variability in a profitable manner.

In the last few years, ongoing research conducted by scientists from CSU, USDA-ARS, Colorado has created a system to divide farm fields into different sections or areas that are referred to as productivity level management zones.

This was accomplished based on:

1. Farmer's personal experience and grain yield history,
2. Aerial imagery of bare soil and other stable soil properties, such as organic matter content, and
3. Topography of the land.

Using this method we can divide our fields into at least three different management zones based on the productivity potential of each area.

They are:
Management Zone 1--high yielding

Management Zone 2--medium yielding

Management Zone 3--low yielding

Our ongoing research has shown that these management zones are real and there are significant differences in the grain yield across management zones.

Figure 3. Combine equipped with yield monitor

Zoning In On Precision Ag (continued)

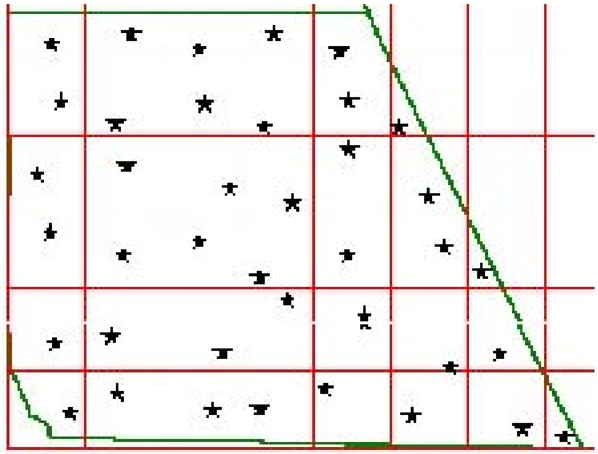

Figure 4. Grid Soil Sampling Performed on Experimental Area

Concept of Management Zones

I think the concept of management zone is easy to understand. If we look at the fingers of our hand, they all belong to the same hand, but their sizes are different. The three management zones can exist in the same field, but their production potentials are different (see Figure 5.) No matter how much water and nutrients we may add, the grain yield in each region is limited to the productivity potential of that zone. You can estimate the maximum yield potential of each zone through years of farming experience and yield monitoring. Going back to the "fingers of our hand example" above, no matter how much we may stretch our fingers they are not going to increase in size. I am not suggesting that there is no further potential for our crop yields to increase, I am suggesting that the three management zones "Low, Medium, and High" are based on the productivity potential of the soil.

The question then becomes: Should we be applying the same amount of nutrients across the field? For example, if

Zone 1 has the potential to produce 200 bushels, Zone 2 has the potential to produce 175 bushels and Zone 3 has the potential to produce 150 bushels or more.

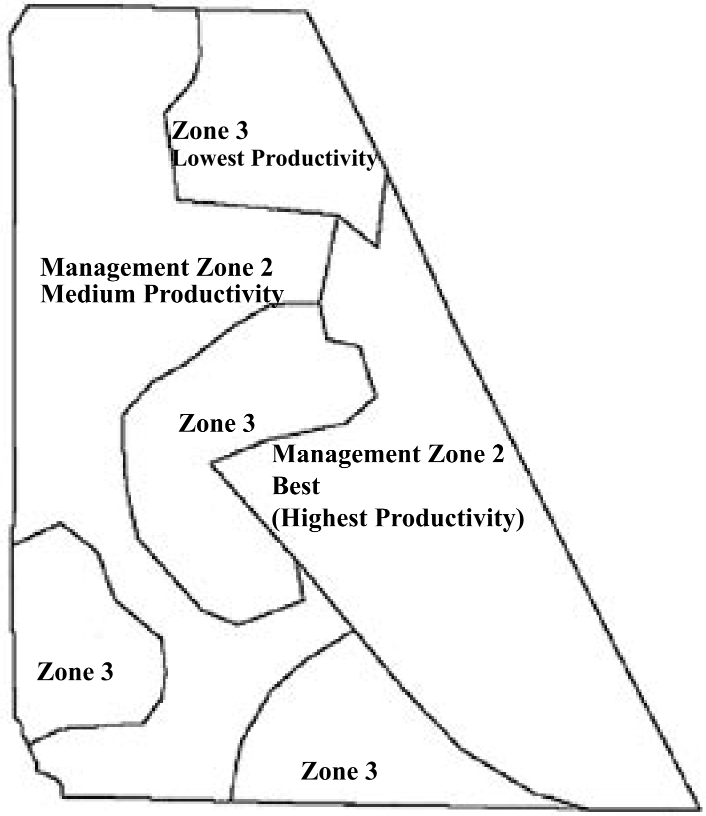

Figure 5. Three Management Zones in the Experimental Field at South Platte Farm

It is quite logical that we do not need to apply the same amount of nutrients across the field when we know that the nutrient needs are different for different areas of the field. If your inputs are based on the highest yield goal, you know you are over applying in Zone 2 & 3. If you target your input application based on the average yield goal, you know you are under-applying for Zone 1 and over-applying in Zone 3.

Managing nutrients within zones

It is a general feeling among folks I have talked to that if they apply more inputs (water and nutrients) to low yield management zones they will be able to bring the grain yield level up to the level of the most productive management zone.

This is similar to saying there are three people, "Big & Strong", "Medium-built" and "Short & Puny" and that if we feed a lot (a huge meal) to the "Short and Puny" person, we will be able to get the same amount of work done out of the "Short and Puny" person as compared to the "Big & Strong". We all know that's not going to happen. There may be some

Zoning In On Precision Ag (continue

exceptions, but generally speaking, if we feed the “Short & Puny” guy the same huge meal as the “Big & Strong” person, the “short guy” most likely will be running back and forth to the bathroom.

The point I am trying to make is that different areas of the field have different productivity levels, and merely applying more inputs to low productivity areas are not going to translate into more grain yields. Instead we may lose or leach that extra water and nutrients out of the soil below the root zone and increase the potential for leaching of nutrients to ground water slowly over time. Instead of applying the same amount over the field, the nutrients should be tailored to fit the potential of the management zone, just as you would tailor a coat to fit the size of the person’s body.

The key to managing variability that exists in our farm fields is to optimize the application of our agricultural inputs to different regions or “management zones” of the field based on their inherent productivity potential.

Big & Strong Medium-built Short & Puny

Figure 6. Management zones within a field have different nutrient needs, just as humans might.

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Figure 7. Tailor the nutrients to the management zone, like you tailor a coat to fit.

FROM THE GROUND UP

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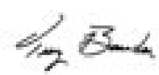

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Pest Management Uses New Tools

Global Information Systems data are critical for diagnosing and tracking infestations.

A GPS receiver.

When I obtained my PhD degree 25 years ago, a plant pathologist was advised to always pack a few basic tools which included a good quality hand lens and a sharp pocket knife when venturing out to tackle crop production problems and diagnostic calls in the field. Today, that same plant pathologist (or to be more politically correct - Integrated Pest Management Specialist) must pack those standard items, in addition to the omnipresent cellular telephone /pager, palm top or notebook computer, and GPS (Global Positioning System) receiver with GIS (Geographic Information System) files!

Since 1997, Colorado State University plant pathology personnel have utilized GPS/GIS technology to describe more than 1000 vegetable production fields (bean, onion, potato) and foliar disease outbreaks in eastern Colorado (26,000 km2), with emphasis upon bean rust (Uromyces appendiculatus), onion purple blotch (Alternaria porri), and potato late blight (Phytophthora infestans) and early blight (Alternaria solani). Annual pest surveys were conducted periodically throughout major crop production regions to verify field reports provided to CSU by cooperators and record cropping patterns and priority disease sightings including some soil-borne problems such as Fusarium Wilt (Yellows) of bean, onion and sugar beet.

These GIS records have been valuable for followup pest surveys during each spring as pest management personnel returned to previously diseased crop sites to monitor for evidence of successful overwintering of plant pathogens within infested debris and/or infected volunteer plants that emerged and survived within the canopies of rotational crops (e.g., field corn, winter wheat, sugar beets, alfalfa). During favorable environmental periods, pathogen spores could then be disseminated downwind by wind, equipment and water to near and distant fields of susceptible varieties of host crops that were planted on the same farm or other farms throughout the county and production region.

The GIS records and GPS receiver allow specialists to return to last year's field problems with no hesitation or confusion. Since 1997, we have utilized GPS/GIS technology to improve our pest survey efficiency and verify the successful overwintering of bean rust, onion purple blotch, and potato early blight. This information on pest biology and sightings was then related to environmental events obtained on a daily basis from a network of remote electronic weather monitoring stations maintained by CSU, USDA/ARS, and NCWCD (Northern Colorado Water

Pest Management Uses New Tools (continued)

Conservancy District) personnel throughout Colorado. These data are incorporated within disease models to help pest management specialists improve the timing and accuracy of disease forecasts in relation to local weather forecasts for the next 7 - 10 days, and enhance the effectiveness of integrated pest management strategies which will be implemented by crop consultants and growers in the affected region.

Timely pest alerts on outbreaks and management of bean rust, late blight and early blight of potato, and purple blotch of onion have been distributed weekly via newsletter (CSU Pest Alert), educational satellite (Data Transmission Network), and Internet (VegNet @ http://www.CSUag.com) to regional growers, scouts and IPM personnel throughout the growing season from May to September. The impact of this program has been widespread as timely IPM information and alerts helped growers and commodity groups prevent widespread and devastating outbreaks and multi-million dollar losses from these types of foliar pathogens.

Future research and adaptation of GPS/GIS technology for pest management programs at Colorado State University will continue to backstop our growers and supportive commodity groups such as dry beans, onions and potatoes, and various research and extension programs including Colorado Integrated Pest Management and the USDA/ARS that are also involved with sugar beets.

Volunteer beans in corn

A recent article by M. R. Nelson et al. ("Applications of Geographic Information Systems and Geostatistics in Plant Disease Epidemiology and Management", Phytopathology 83:308-319, 1999) provided some interesting insights from their GPS/GIS and pest management experiences in Arizona that are very applicable to Colorado and the surrounding region:

Research is needed on cost/benefit analyses of GIS applications in agriculture. The current most successful applications of this technology involve teamwork; that includes ann experienced field person, an experienced computer user with some background in statistics, and a patient data entry person. Larger farms, younger farmers, and better-funded extension programs are more likely to apply these tools. It will illustrate the association of environmental factors, landscape features, and cropping patterns with the recurrence of disease or other problems. This technology will aid practitioners in the design of disease management in IPM programs, particularly on a regional scale.

by Howard Schwartz
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Corn Insect Management

Site specific management techniques help growers pinpoint zones needing treatment.

Arthropod pests are rarely distributed uniformly throughout a corn crop or a corn producing region. For example, Banks grass mites are more common along the edges and in drought-stressed portions of corn fields. European corn borer adults tend to select earlier-planted fields during the first generation flight and later-planted fields during the second generation flight. Within a field, larger plants will be preferred during the first flight and less mature plants during the second. Western corn rootworm larvae are generally more abundant in those parts of the fields with heavier soils and higher organic matter levels.

Management of corn insect and mite pests is generally accomplished by

(1) estimating the average population density or amount of damage of an infestation in a given field;
(2) comparing this estimate to an economic threshold; and
(3) application of an approved insecticide or miticide to the entire field if the economic threshold is exceeded (see the Western High Plains Integrated Pest Management Guide for Colorado, Western Nebraska, Montana and Wyoming for economic thresholds and registered pesticide products).

Given that pest distributions are variable within a field and that treatment decisions are made on a whole-field basis, it is likely that some portions of the field will not be infested or damaged at a level above the economic threshold. Site-specific scouting and application methods would allow producers to avoid the unnecessary expense of treating these areas.

Sampling for corn insects generally involves counting insects, usually eggs or larvae, or damaged plants on a set number of plants at each of several locations per field. These counts can then be converted to percent infested or damaged plants or to insects or damage per plant for economic threshold comparisons. The amount of effort involved will depend on pest species and plant growth stage, but treatment decisions are usually based on information gathered in one hour or less per week per field. Determining the treatment need for small field subsections using this approach would be exceedingly expensive. Two possible, more cost-effective, alternatives are

(1) more efficient scouting methods or
(2) a management zone approach.

We have investigated the use of pheromone traps for more intensive sampling of Western bean cutworm and European corn borer, as part of the precision farming project. Pheromones are chemicals produced by one sex (the female in both of our target species) of an insect species to attract the opposite sex. Pheromone sampling is accurate in that the only insects attracted to the trap are of the target species. This can save time in training and in scouting. Also, pheromone sampling is relatively cheap. The trap we use (Figure 1) is modified from a one gallon plastic milk jug and the pheromone lures usually cost $2 - 3 each if purchased in quantity. We collected moths from about one trap per acre in each of two corn fields for two years and were able to map spatial variability for both species (Figures 2 - 3). We were also able to use our data to calculate that 25 traps per field would be adequate for our study site. This works out to about $1.00 per acre to sample both Western bean cutworm and the European corn borer flights, excluding labor (trap-to-trap travel time and time to sieve and count moths) and assuming bulk purchases.

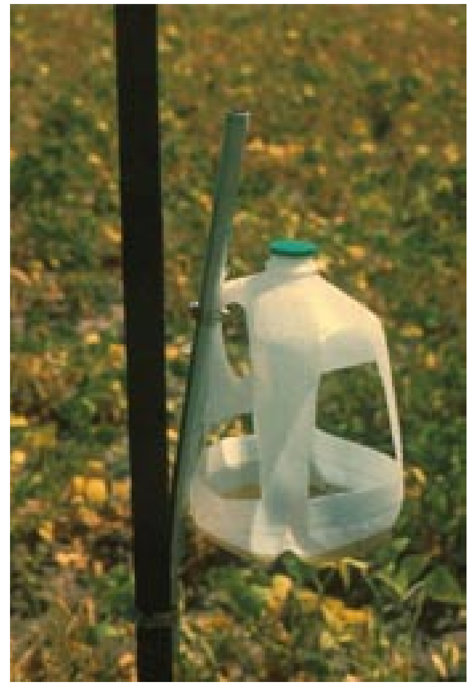

Figure 1. Pheromone trap.

Corn Insect Management (continued)

We now have an efficient method of sampling the adult stage of these two important corn pests. However, corn is damaged by the larval stage of these insects. The relationship between pheromone trap catches and egg-laying or larval activity is not well known under our growing conditions. We currently are trying to measure this relationship. If there is a close relationship, then pheromone trapping could be a viable tool for site-specific corn pest management decisions.

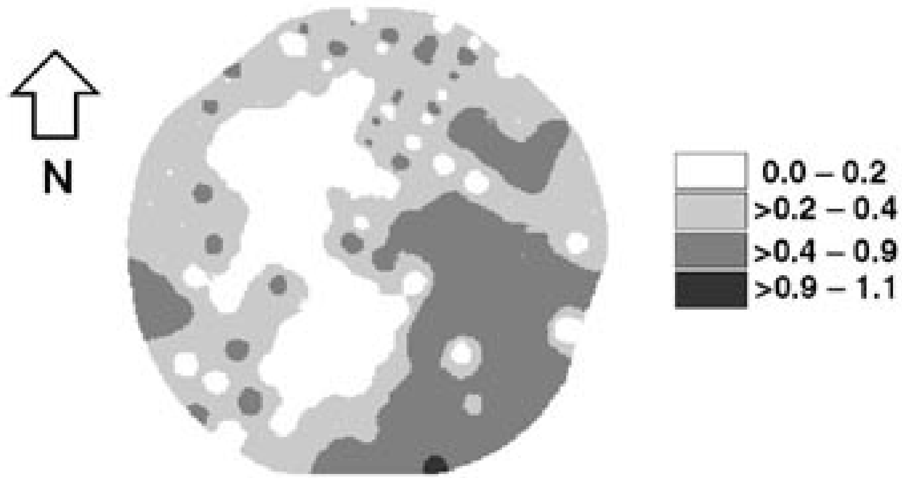

Figure 2. Daily European corn borer per trap. Field 1, 1998.

A compromise between whole-field decisions and those made for acre or smaller units is the management zone approach. This strategy recognizes that, while sampling for small units can be prohibitively expensive, the fact remains that most fields are sufficiently variable to justify management as several subsections. Fields are broken up into several smaller units (management zones), based on a few simple criteria such as bare soil color and texture, that are managed individually. It might be possible to make pest management decisions at the management zone level rather than the field level and realize some cost savings. Pest management benefits relative to whole-field decisions might include (1) identification of zones in need of treatment, contrary to the whole-field decision; and (2) detecting zones that don't need treatment, contrary to the whole-field decision. The downside risk, of course, is having similar outcomes at both levels, meaning the extra pest scouting effort required by the management zone approach was not a good investment.

Regardless of their size, once the treatment need has been determined for field subsections we then need the technology to treat some subsections and leave others untreated. There is substantial concern about the accelerated development of insecticide and miticide resistance by the use of reduced rates. Therefore, site-specific management will likely involve either treatment with a full rate or no treatment.

Treatment difficulty will vary with the pest and crop growth stage. Western corn rootworm larvae are commonly treated with granules applied with planter or cultivator-mounted equipment. Site-specific application

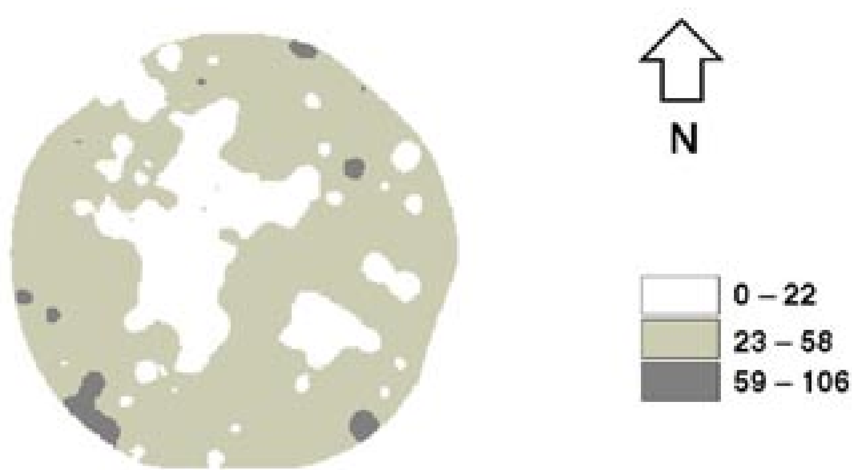

Figure 3. Total Western corn rootworm per trap. Field 1, 1998

Corn Insect Management (continued)

software and hardware to control the granule meters should be easy to adapt or develop. First generation European corn borer larvae are best controlled with granules applied with aerial or ground equipment, or with chemigated liquids. Site-specific granule application technology is not readily available for aircraft. Chemigation of field subsections (sectors) is currently feasible. Treating smaller sections will be possible as span-by-span and nozzle-by-nozzle chemigation controls are commercialized. Western bean cutworm, second generation European corn borer, Western corn rootworm adults and Banks grass mite are controlled by treating fully-grown corn with liquid insecticides applied with aircraft, high clearance ground sprayers, or chemigation. Additional site-specific application software and hardware may have to be developed for these situations as well.

Site-specific management of corn insects has the potential to make corn production more efficient through more targeted insecticide and miticide applications. Improvements in pest sampling methods and application technology will be necessary to realize this potential.

by Frank Peairs
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Meet...Raj Khosla

Dr. Khosla is an Assistant Professor and Extension Specialist in the Department of Soil & Crop Sciences at Colorado State University. He is responsible for Research, Extension and Teaching Program in the area of Precision Farming and Irrigated Cropping Systems. He teaches an undergraduate course "GIS in Agriculture" every fall semester in the department of Soil & Crop Sciences and Bio-Ag Resources and Chemical Engineering.

Dr. Khosla's current area of research and extension is focused on evaluating various techniques of delineating "in-field production level management zones". He uses GPS and GIS technologies to manage spatial variability of soils by precise crop input management in an environmentally sensible manner. His work also includes evaluating remote sensing techniques to quantify crop stress conditions for nitrogen in irrigated corn, ground truthing with tissue samples and chlorophyll meter measurement, and making site-specific N-recommendations.

The overall goal of Dr. Khosla's research and technology transfer efforts are to enhance farm profitability while enhancing environmental protection by developing precision agriculture strategies that are compatible with farming practices in irrigated western Great Plains region.

Dr. Khosla has traveled extensively around the world including, Asia, Europe, North and Central America. In his spare time he likes reading, playing tennis, and traveling.

Precision Irrigation

Researchers focus on ways to improve irrigation efficiency.

Irrigation is by far the biggest consumer of water in Colorado, and irrigated agriculture has been identified as a potential non-point source of pollutants to our State's water supplies. Virtually every irrigator is aware of this potential problem, and most are keen to do the best job they can to maintain quality as well as quantity of our water supplies. USDA-ARS in Fort Collins has worked with farmers for many years to provide best irrigation management practices to minimize the adverse impact of irrigated agriculture on public waters. To us, precision irrigation means two things: precision with respect to area and precision with respect to time. Because crop nutrients, such as nitrogen (and many pesticides) are very readily dissolved in water, thus move through the soil if excess water moves through the soil, precision irrigation in either context means less opportunity for contaminating our water supply because more ag chemicals are kept in or on the soil where they belong. The time aspect of precision irrigation is called "irrigation scheduling," and many farmers as well as farm advisors are aware of this terminology. Irrigation scheduling can mean using field devices, such as gypsum blocks or expensive instruments to measure when the soil can hold more water, or it can mean computation of how much water is required by the crop at its current stage and by weather conditions, to meet crop needs in the near future. Either approach can provide guidance as to when to irrigate and how much water to apply, and may provide the opportunity to reduce irrigation application significantly — thus reducing costs of pumping, nitrogen fertilizer, and other chemicals, as well as protecting water quality. Today, the Colorado Climate Center (CCC) at Colorado State University CSU, in cooperation with CSU Cooperative Extension, CSU Ag Experiment Station, USDA, and several commodity groups, maintains a network of 36 weather stations across the state. These stations report their weather to CCC daily, and these data are used to compute the water used by a variety of crops. The weather data as well as crop water use (evapotranspiration or ET) are posted on the Internet.

In years past, the concept of irrigation scheduling has been promoted on the basis that we can calculate the ET quite accurately if we know the appropriate weather data from the past few days, and that we can determine how much irrigation water is applied if we assume that the irrigation system applies the same amount of water

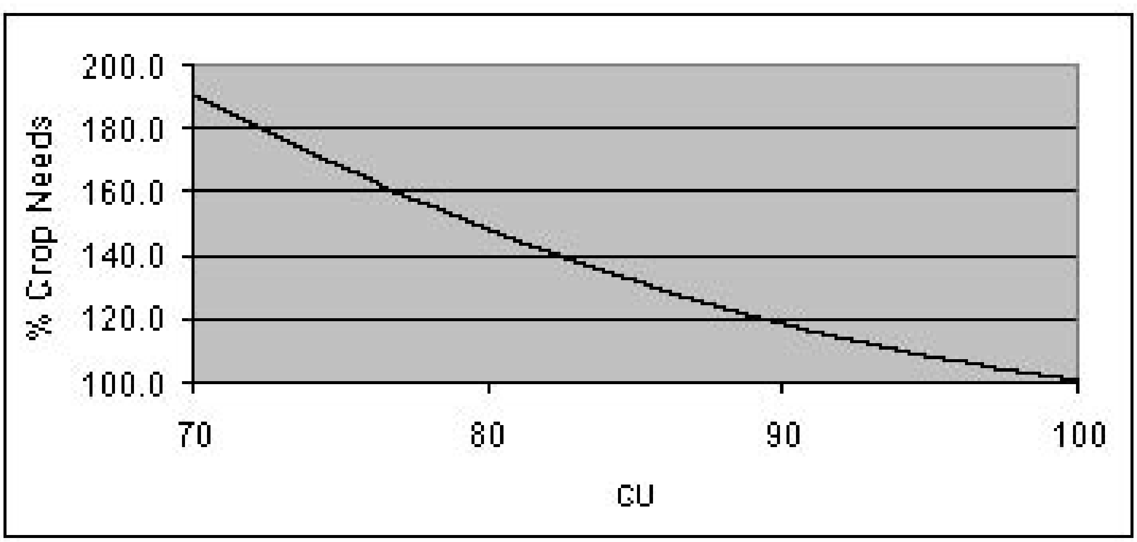

Figure 1. Water needed, as a percentage of crop needs, to maintain different values of uniformity in a field kept 85-90% well irrigated.

Precision Irrigation (continued)

everywhere in the field. The concept of precision farming now allows us to take a different approach to the concept of precision irrigation — one of applying just the right amount of water needed in each area of the field. Seldom do we have enough information to say that the crop in one square foot of a field requires more water than that in another area. However, we do know how differences in soils affect how much of the water applied is held for later crop use. We also know that irrigation does not result in the same amount of water being stored in the soil in one part of the field as in another. With gravity irrigation systems, changes in slope, soil type, tillage, wheel traffic, irrigation stream, set time, and distance from the head ditch all effect the amount of water stored in the soil. Even with center pivots, irrigation is not the same from one point of the field to another, but depends on topography, sprinkler package, and end gun operation.

What is appropriate irrigation management and the outcome of that management, also depends on the climate. For example, in the eastern US, where irrigation may account for 6 to 8 inches of water annually to supplement rain, it may be feasible to irrigate sandy spots only, hoping that heavier soils will hold enough water to last until a rain in the near future refills the soil profile. In these cases, we may well find that some soils have a lower ability to produce a crop, and that precision farming best dictates that inputs be reduced in those areas that have lower production potential. Thus, a system with the ability to put different amounts of water in different areas may be worthwhile.

In Colorado, where corn requires 24 to 27 inches of well-timed water to produce at its potential, rainfall is not as large a factor (typically providing 7 to 10 inches during the growing season). In this case, we have the potential to control the total water picture much better than irrigators in areas with more rainfall. Where water is the controlling factor of production, and particularly where nutrients can be applied with the water, there is little reason to believe that one soil has a lower potential production than another soil. We see evidence in the fact that many of the very sandy soils, considered not irrigable prior to center pivots, produce as much or more than the "good" or heavier soils of the major river valleys.

We believe that precision irrigation implies that we need to design the irrigation system to apply water as uniformly as practical, then to operate the system to apply just the amount of water the crop needs. We are presently conducting studies on the same center pivot irrigated fields as our colleagues at Colorado State, and I will use information from those studies to illustrate the importance of uniformity. In the past, irrigation engineers believed that a system capable of applying water with a "coefficient of uniformity" (CU) equal to 80 was a good system. However, we now know that we pay dearly in terms of water required, and consequently in terms of both energy and lost chemicals, if we have an irrigation system with low uniformity and we try to keep most of the field "well irrigated." Figure 1. shows how much water

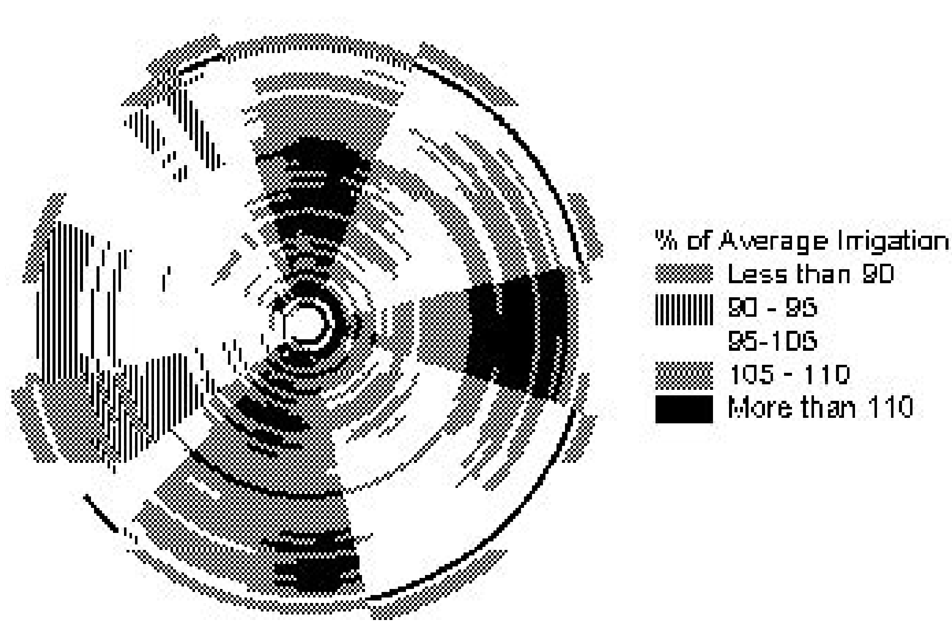

Figure 2. Water application variations on an experimental field in 1999.

Precision Irrigation (continued)

we must pump, as a percentage of what the crop requires, for different values of uniformity if we keep 85-90% of the field "well irrigated".

Thus, if we increase uniformity from 85 (132%) to 95 (108%) we can reduce the total water required by 24%! There are several reasons that uniformity of a center pivot may not be up to par — nozzles worn from pumping sand, improper nozzles installed (either poor design, or nozzles not installed where they were intended), large changes in elevation on systems without pressure regulators (or regulators that no longer work). One of the big factors in nonuniformity of irrigation is use of an end gun. When the field is planted to near the limit of end gun reach, it is obvious from plant growth that water is not applied uniformly. Less obvious is the variation of water application along the pipeline as pressure changes when the end gun turns on or off. The range of total seasonal irrigation application over one of our study fields (CU = 86) in 1999 is shown in Figure 2. As a result of topographic changes, incorrect nozzle sizing along the pipeline, turning the end gun on and off, and stopping the system when it rained, then moving back to the pivot road before starting the next irrigation, the water application is less than uniform, even on this "well designed" system. Less than half the field receives within 5% of the average irrigation application, and significant areas receive either a deficit or a surplus exceeding 10 percent. Overall, if the irrigator manages to keep 85-90% of the field well watered, he will need to pump 28 percent more water than the crop requires. The concept of precision timing is equally important, as studies in several areas show that the average irrigation is frequently on the order of 30 percent more than the crop actually needs.

Our current work is concentrated on determining the effect of this "imprecise irrigation," combined with fertigation, soil differences, and estimated leaching, on the availability of nitrogen fertilizer to the crop, and ultimately on crop yield.

by Harold Duke
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Fertilizer Application By Management Zone

Soil color, landscape position, and past management experience are keys to developing management zones for fertilizer application.

Developing accurate variable rate technology (VRT) fertilizer application maps is critical in implementing precision farming technology. Intensive grid soil sampling has traditionally been used to develop application maps. However, the cost and labor associated with grid sampling has led us to conclude that another approach, such as production level management zones may be more feasible. A production level management zone is a region of a field that has similar yield limiting factors. Therefore, a specific rate of fertilizer, or other input, may be appropriate for this management zone.

The question is how do we identify these different production level management zones in a field?

We have known that soil color in bare soil photographs can be used to identify different soil organic matter (SOM) levels. We also know that topography affects production with higher yield generally being obtained in lower positions in the landscape, with lower yields on eroded side slopes and hills. One of the best estimates of yield differences in a field is obtained from the producer. Producers know which areas of a field produce good yield and which areas are low in production. It is logical that nutrient needs are different among these areas.

Based on these relationships, we have developed a research and extension program to determine if management zone technology could be used to develop accurate VRT application maps based on aerial photographs showing soil color, landscape position, and past management experience.

Aerial photographs were taken and used as an initial template in developing production level management zones. In this procedure, a gray scale image of a bare soil photograph was enhanced using Adobe Photoshop® to contrast color differences. The farmer drew vector lines using commercially available software (Agri Trak Professional®) to establish the individual management zones (high, medium, and low productivity areas) based on soil color, topography and his/her management experience with the field (figure 1). Management zone maps were developed for two center pivot irrigated corn fields in northeast Colorado. The fields were sampled using a 1.4 acre grid. Samples were analyzed for nitrate, organic matter, phosphorus, potassium, zinc, pH, and texture. Electrical conductivity and yield were also mapped on both fields.

Evaluation

Using the soil and yield data we have begun to evaluate if the farmer-developed management zones represent areas of high, medium and low productivity and have the potential for developing Variable Rate Application maps. We found that soil nutrients and grain yield followed the trends indicated by management zones. Levels of soil organic matter, potassium and grain yield were significantly different in all management zones.

Soil texture data show similar trends. Clay and silt levels were significantly higher in high productivity zone, intermediate in the medium zones, and lowest in the low productivity zones. Sand followed the opposite trend. These soils are sandy and higher productivity in areas of lower sand and higher clay levels would be expected due to the higher water holding and cation exchange capacity of the more clayey soils.

Electrical conductivity values also followed trends indicated by the management zones and were significantly different across all management zones. In these soils, texture probably has the greatest influence on conductivity values with clay having the highest conductivity values and sand the lowest.

Results from field No. 2 indicated that the soil and crop parameters were significantly different across the management zones, however, they did not always follow trends indicated by the zones. This indicates that our method of delineating management zones is consistent. However, the zones need to be ground truthed to classify them into various productivity levels. Electrical

Fertilizer Application By Management Zone (continued)

conductivity data collection appears to be a cost-effective alternative to soil sampling to ground truth management zones.

Practical implications

Grid soil sampling to the intensity required to generate accurate Variable Rate Application maps may not be feasible because of the time and expense required. Management zone technology may be a more economical method of developing Variable Rate Application maps.

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Colorado State University
D. W. Wiens
CenTrak L.L.C.

Figure 1. Fertilizer map.

Variable Rate Fertilizer Applicator

Websites

Global Positioning Systems

http://www.aero.org/publications/GPSPRIMER/index.html
Provide you with complete details of the GPS system, navigation, GPS elements, satellite in space, how it works, and the use of GPS in everyday life.

http://www.trimble.com/gps/index.htm
Provide you with a tutorial explaining the GPS technology, what is differential GPS, how it works, where to buy, its applications and accuracy of the system.

Geographic Information Systems

http://www.gisdatadepot.com/
The GIS Data Depot provides FREE GIS data downloads and creates custom spatial data CD-ROMs for geographic information systems and cartographic, digital mapping and spatial analysis applications.

http://www.esri.com/
ESRI is the world leader in GIS (geographic information system) software and technology. This site features free GIS software, online mapping and GIS training, demos, data, product and service info.

Precision Agriculture

http://www.precisionfarming.com/
Provides you with information and explanation on some of the technologies involved with site-specific farm management, such as GPS, and examine the current state and future of these new agricultural practices.

http://www.pioneer.com/usa/technology/precision.htm
This site cover areas including Mapping Soil Properties or Grid-Sampling, Yield monitoring, remote sensing, Electrical conductivity measurements, and Farm profits as related to precision agriculture.

http://www.veristech.com
This site provides information on application of Veris system. Using a Veris EC map to direct sampling by soil zone, develop a variable-rate lime application recipe based on the samples from those zones and more.

http://terraserver.com/
You can search your favorite spots on the planet earth. The site provides high resolution topographic images and more of the planet.

http://www.deere.com/deerecom/Farmers+and+Ranchers/harvestlink.htm
Harvest Link is a comprehensive source of custom harvesting information. You'll find timely crop and weather information and productive ways to enhance your equipment to maximize performance.