Site Specific Farming

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Overview

Nutrient management is a major component of a soil and crop management system. Knowing the required nutrients for all stages of growth and understanding the soil's ability to supply those needed nutrients are critical to profitable crop production. Site-specific nutrient management is applying those concepts to areas within a field that are known to require different management from the field average.

Site-specific nutrient management is a concept that can be applied to any field and any crop. While most often thought of in relation to use of computer and satellite technology, the site-specific nutrient management does not require special equipment, and does not require a large farming operation. The technology tools certainly expand the capabilities for using site-specific management.

Site-specific crop and soil management is really a "repackaging" of management concepts that have been promoted for many years. It is basically taking a systematic approach to applying sound agronomic management to small areas of a field that can be identified as needing special treatment.

The components of site-specific management may not be new, but we have the capability with new technology to use them more effectively. Site-specific management includes practices that have been previously associated with Maximum Economic Yield (MEY) management, best management practices (BMPs), as well as general agronomic principles. The systematic implementation of these practices into site-specific systems is probably our best opportunity to develop a truly sustainable agriculture system.

Objectives

Site-specific management systems are designed to meet the following objectives:

Identify and quantify variability within fields

Variability within fields comes from a variety of sources. Most of them are related to the soil, resulting from either natural or man-made factors. Natural variability is largely due to variation in physical properties of the soil. Topography is a major factor. It affects the movement of water over and within the soil, impacts soil temperature, and is a major influence on erosion potential. Soil texture and structure also vary across the field, sometimes dramatically. Texture (relative sand, silt and clay content) varies in both the surface and subsoil and influences holding capacity and movement of nutrients and water, effectiveness of herbicides, and root growth. Structure relates to the arrangement and density of the soil particles and has similar influences. Structure, however, can be affected by both natural and man-made forces. Water holding capacity of the soil is a critical characteristic that is affected by all of these factors, and has a major influence on nutrient management, plant growth and potential yield.

Man's activity influences soil tilth---affected by cropping system and tillage operations as well as physical, chemical and biological activity in the soil. Compaction results from a combination of natural and man-made factors and is a major influence on yield variability within a field. Crop rotation, pasturing of livestock, fences, tile drainage, fertilizer and manure application are among the man-made influences of soil variability. The man-made factors often are more important than the natural factors in accounting for within-field variability.

Variability is measured by soil sampling, field scouting, physical measurements, soil survey and yield monitoring.

Understand the impact of variability

Yield ultimately integrates all variability factors and gives us a composite measurement of their impact. Yield variability provides a compilation of the variability of all of the physical, biological, and management factors. By carefully analyzing yield data along with the site-specific data from the other layers of information, the components of yield variability may eventually be determined and used as a guide to improve management.

Manage variability to increase profits

Once variability is identified and measured, action can be taken to manage that variability to increase profits through increased yield, reduced expenses, or both. The best way to improve profits is to increase yields. Spreading fixed costs over more bushels, for example, reduced the total cost per bushel and increases net profits.

Equipment

There is no special equipment requirement for site-specific management. The concept can be applied with conventional dealer- and farmer-owned equipment. Identification of areas requiring special management can be done with conventional soil testing and scouting techniques. Different fertilizer rates can be applied to different areas by staking or flagging them and spreading the

different areas separately. Estimates of within-field distances to identify these areas can be documented by measuring, counting rows, pacing or other relative means. These are inexact measurements, but may be adequate for many situations.

GPS

Global Positioning Systems (GPS) is a worldwide navigation and positioning system based upon a constellation of 24 satellites launched by the U.S. Department of Defense. It is designed to provide an accurate, dependable means of determining 3-dimensional position, velocity and time. It provides a continuous, world wide radio-navigation service for military and civilian use. Orbiting at 11,000 miles above the Earth on a 12-hour orbital period, these satellites transmit radio signals that can be picked up by receivers on the ground. With 3 satellite signals, accurate latitude and longitude can be determined through triangulation; four satellite signals allow for measurement of elevation.

For security reasons, the government sometimes intentionally degrades the GPS signal from the satellites through a process called selective availability, so that the accuracy is limited to about 100 meters. This is not a major problem for most navigation uses, but is not acceptable for many mapping applications, such as site-specific crop management systems. To compensate for this degradation, and to generally improve positioning accuracy, agricultural users need to provide for a fixed- point reference system, or differential GPS.

The accuracy of GPS depends upon the type of receiver. The system generally provides accuracy within a range of 100 meters. That is not accurate enough for most agricultural applications, so differential GPS must be used to get accuracy of less than a meter. Differential GPS can be provided by a variety of sources. A fixed-point ground transmitter can serve the purpose, but most users find it more convenient and less expensive to subscribe to a service that provides the differential signal. Commercial FM radio signals can provide the differential reference signal for short distances (30 to 50 miles) and are usually not affected by weather conditions, but are sometimes limited by terrain. These require a special receiver and a subscription fee.

The U.S. Coast Guard provides a differential AM radio signal from beacons positioned throughout much of the U.S., with a range of 100 to 250 miles. (Full coverage is expected by 1998 or 1999 as a new train tracking system is implemented.) This signal has a longer range, but is more susceptible to interference and weather conditions. The advantage is that the receiver is less expensive ($1,000 to $3,000) and there is no subscription fee.

A series of low-orbit, fixed-position (geo-stationary) satellites offers another alternative. These are somewhat more expensive ($4,500 to $6,500 initial investment, plus annual renewal fee of around $900), but are unaffected by terrain, have little atmospheric interference and cover most major areas of the world, including all of the U.S. Several suppliers are available. Most GPS receivers are now built with the antenna elements for both GPS and the satellite differential signal already installed, so the system can be easily activated, simply by telephoning the supplier if the user chooses to subscribe to the geo-stationary satellite differential system.

With high-end technology, accuracy of less than one-centimeter error is possible, but the added cost of these receivers is not justified for most agricultural needs. Cost of the differential receivers is usually directly related to the accuracy. Receivers for the most accurate GPS signal cost over $30,000; for the sub-meter differentially corrected signals, costs of $3,000 to $10,000 are common, depending on the system selected.

Geographic Information Systems (GIS)

Geographic Information Systems (GIS) consist of data and software designed for spatial analysis of geographically-referenced data. Various data bases in an agricultural GIS system might include soil survey data, soil test information, pest infestations, yield data, remote sensing imagery and other types of observations and records that can be collected and referenced with their geographic position (by GPS). These data sets can then be converted to maps to illustrate their spatial variability within the field.

GIS is more than mapping. Most people think of GIS as a tool for creating maps to illustrate spatial variability of production factors, but the capability of GIS goes much further. The real power of GIS software lies in calculations and analysis of the geo-referenced data sets to correlate their effects on yields and interactions with other factors of production. By using models integrating the different spatially-variable data sets, responses to inputs can be predicted, or interactions affecting yield can be identified. Accumulated over time, the GIS data sets become increasingly useful as record-keeping and prediction tools.

Yield Monitors

Probably the most critical tool for site-specific management is the yield monitor. Yield is the ultimate integrator of all of the inputs, physical factors, biological systems and management. It is also the factor that results in the income for the system. Measuring yield variability is an essential component of the site-specific management system. Yield monitors on combines for grain harvesting were the first to be adopted on a wide scale. By 1997, four years after the first yield monitors were installed, over 22,000 were in place, with about 50% of them being used with GPS to provide a geo-referenced yield data base.

As yield monitors are developed for other crops, such as cotton, sugar beets, potatoes and forage crops, site-specific management is expanding geographically. The value of geo-referenced yield data as a management tool is so great that it is likely that most harvesting systems will eventually include yield monitors as standard equipment.

Digital Soil Survey

Soil surveys, available from the USDA Natural Resources Conservation Service (NRCS) for most crop producing areas, provide a cataloging of soil types within a given field. Digital soil surveys (on CD-ROM) are being developed which are geographically-referenced and provide all of the supporting interpretive information published with the soil survey. This information can provide valuable help in interpreting site-specific data and relating physical and chemical characteristics of the soil to changes observed in crop yield or other factors.

Intensive Soil Sampling

Site-specific production systems will usually require more intensive soil sampling. The most common system is a 2 ½ to 3 ½ acre grid, preferably taken on a systematic, unaligned grid basis. (See soil sampling chapter.) Research has shown an advantage to shifting to a 1-acre grid, or even smaller where the field is known to be highly variable.

Variable-Rate Application Systems

As early as 1929, University of Illinois agronomists recommended grid sampling and variable-rate application of lime on acid soils. This same concept has been expanded to include more nutrients and incorporate satellite-guided, computer-controlled variable-rate application of nutrients, seed and pesticides. These systems allow for site-specific management to be implemented on a larger scale with on-the-go variable-rate application.

To effectively utilize the GIS data bases, the farmer and his input suppliers need to have the capability to apply inputs (seed, fertilizer, lime, pesticides, etc.) at variable rates. This can be done in a variety of ways, but the use of variable-rate controllers makes the task easier. Controllers of many types are available to adjust application rates on-the-go. Some handle individual inputs, while others can adjust rates of multiple products simultaneously. Usually an on-board computer is programmed with the data (maps) indicating the variability in the rate to be applied. This computer controls electronic and/or hydraulic systems to adjust the rates as the applicator travels across the field, guided by a GPS system. For best results, the system should record the actual rates applied in a GPS-referenced data set. This applied rate data set can then be compared to the intended application data set to be sure the proper rates were used throughout the field.

In-Field Sensors

A variety of electronic tools are available or under development to be used in the field as measurement or monitoring tools for farmers or their consultants. Examples include:

- nutrient electrodes for use in electronic soil and plant analysis (pH, K, Ca, etc).
- organic matter sensors to help determine proper herbicide rates.
- chlorophyll meters to estimate photosynthetic activity and relative plant health.
- ion-specific nutrient electrodes for measuring nutrients on-the-go and developing a nutrient data base and map for the field (under development).
- electro-magnetic induction systems for estimating compaction, depth of topsoil, and other physical feature.
- ground-penetrating radar
- electrical conductivity measurements to measure physical characteristics and help improve soil survey information.

Remote Sensing

Another developing technology for site-specific farming is remote sensing systems, using multi-spectral scanners on aircraft or satellites to monitor changes in the reflectance of various wavelengths of light from fields and growing crops. Satellite imagery is also useful in more precise mapping of field boundaries, location of tile drainage lines, and other physical conditions. The data collected can be processed, geo-referenced, mapped and analyzed with the help of GIS tools, to provide additional data layers for GIS analysis and management decisions.

Several different companies around the world are developing and evaluating remote sensing services and related interpretation support. Satellite imagery provides an opportunity to help identify problems developing in the field, and especially monitor changes in the area affected.

Satellite imagery is most effective when used in conjunction with field scouting ("ground truth observations") to help identify the reasons for variability or changes in the spectral image collected by the scanner.

Data Management

Perhaps the greatest challenge in site-specific management is the handling of large amounts of data. It is essential that a systematic storage system be developed early in the process. Raw data should be archived for possible later use with improved software systems. Backup copies of all data should be maintained at a different location to avoid losses in event of a fire or other disaster.

A well-thought-out file naming system for data files can prevent headaches and lost information as the data base grows. Keep it simple, but thorough. Wherever possible use standardized notations such as the USDA's "Farm-Tract-Field" designation. It may also be helpful to include the NRCS watershed "zip code" number. Of course anytime GPS coordinates can be attached to data points, they provide the most precise means of identifying where the data were collected. A GPS-referenced data set will greatly facilitate many of the interpretation processes available now and in the future.

Building a Database

The data collected in site-specific systems can very soon become overwhelming. It is important to develop good data management habits from the beginning. Save all raw data, including yield monitor data, spreader application data, both planned and actual, and any other records collected. The raw data are essential in the likely possibility that data will need to be reanalyzed in a few years as new software becomes available. Most relationships among production factors and their effects on yield can only be determined after several years of data are available. The data base must be carefully organized to be of use.

Backup copies of everything should be made and stored in a different physical location. The data sets are valuable production resources that are impossible to replace in the event of a fire, a hard disk crash, or some other catastrophic event.

Record Keeping

Good records are essential for tracking what has happened in a field, and become a guide for future management. Gradually shifting from the pocket calendar though the show-box and the ledger book to the computer, record systems have undergone a lot of evolution to become important management tools for modern farmers. Records on seed planted, tillage systems used, nutrients and pesticides applied, and yields harvested are all part of a complete record system. Financial information such as input costs, grain sales prices, etc., should be tracked for each field as well, so that complete economic analysis can be performed.

Interpretation

New tools for analysis and interpretation are available and provide an opportunity to utilize much more extensive information in the decision process. This is an area of rapid development of software and hardware for data management. But there is still a major role for the expertise and experience of the farmer, his input suppliers and his advisers---the management team for the field. The

computers and the software are tools to help in the process, but the human element will be critical for interpretation for the foreseeable future.

Nutrient Management Plan Development

The value of GPS, GIS and Remote Sensing technologies cannot be realized until the data are incorporated into the management decision process. These tools are valuable in preparation of comprehensive crop and soil nutrient management plans that can help improve production efficiency, increase yields and reduce potential environmental problems associated with crop production. The GIS system provides a means to monitor and evaluate nutrient needs, crop removal, and losses to the environment.

Taking Advantage of the Information

Sites-specific management systems can show an advantage over field-average systems only if management is intensified to take advantage of the increased information available. Collecting data is only the first step. There must be a commitment to utilize the information in a more aggressive management program.

Information Integration

Site-specific management and the technology tools available for its implementation depend upon the integration of many sources of information. Without the use of computers and GIS software, it is impractical to try to analyze all of the information available. Site-specific systems----including yield monitor data----generate large amounts of data, which can be used to better understand the field and the interactions of various production factors. Integrating these data through GIS and using it to interpret yield variability are key steps in moving to a higher level of production, input efficiency and profitability. They also are our best chance to reduce potential negative effects on environmental quality.

Team Effort

A comprehensive nutrient management plan should involve the assistance of the farmer, the fertilizer dealer, crop consultants or other advisers who help interpret the data, develop recommendations and eventually implement the plan. Each member of this management team brings his own expertise, experience and ideas to the decision process. They may have different levels of involvement, but the team effort will result in the most successful implementation. The complexity of production systems and the level of investment in putting a cropping system together justify careful attention to ensuring the best team available is used to formulate the plan and evaluate its results.

Stepwise Implementation

For many farmers, the switch to site-specific management and investment in the new technology tools is a formidable challenge for both the learning process and the financial commitment. It does not have to be a complete transition. A stepwise implementation plan may be a better fit. Starting with a good soil testing program and a yield monitor, a farmer can begin developing the data bases and the experience needed to fully implement a site-specific management system. It takes four or five years of yield data to begin to identify true variability within the field and some of the

cause/effect relationships involved. Stepwise implementation may make the whole process more acceptable to the farmer and his advisers as they gain confidence in the new system.

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Regulatory Requirements and Environmental Concerns

Nutrient Management Plans are required for some cost-sharing programs at the federal and state level. This is stimulating more interest in developing such plans. Despite the actual or threatened regulatory requirement for nutrient management plans, they are a good management practice and should be encouraged for every field on every farm. Site-specific nutrient management plans help ensure that the proper levels of nutrients are available for all parts of a field, that all nutrient sources are considered, and that excess applications are avoided. Ultimately, nutrient management plans for every field will help ensure that crop production systems have minimal contribution to environmental degradation.

LINKS TO OTHER EFU CHAPTERS			
• Appendices • Authors • Environment • Fertigation • Fluid Dry Fertilizers	• History of Fertilizer • MEY – Maximum Economic Yields • Micronutrients • Nitrogen • pH	• Phosphorus • Potassium • Soil Sampling • Secondary Nutrients • Site Specific Farming	• Soil Defined • Soil Testing • Tillage Systems