AUTOMATION AND REMOTE SENSING - EQUIPMENT AND APPLICATION BENEFITS

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INTRODUCTION

Economic and environmental pressures are major concerns for nearly all agricultural producers. Irrigated agriculture is a big contributor to non-point pollution and water quality problems in the United States. Numerous studies have documented the high vulnerability of irrigated sandy soils to leaching of nitrates and emphasized the need for sound water and nitrogen management practices to reduce nitrate leaching and the potential groundwater degradation. To survive these ongoing pressures, producers must improve their crop production management practices to efficiently and affordably apply water and fertilizer to reduce environmental degradation while maintaining or increasing profitability.

Improving crop production practices requires a higher level of management to make decisions based on more extensive information about the crop's status as well as technologies and equipment to implement the decisions with less labor and at a lower cost. Precision (site specific) farming involves management of inputs based on agronomic, economic, and environmental factors with insight gained from yield results and geo-referenced field characteristics and features. Many agronomic inputs can be rapidly measured and their spatial variability easily assessed using remote sensing. Automation is required for efficient and effective spatially variable application of chemicals, fertilizer, water, and other agricultural materials.

Crop production is dynamic throughout a growing season because of normal weather variations and the complex interactions of water, nutrients, and climatic factors. Real-time management based on data collected throughout the growing season offers significant economic opportunities for reducing the use of water and fertilizers without reducing yields.

APPROACH

As with most industries in the current 'Information Age', agricultural producers stay competitive by making decisions based on greater and more complex amounts of information. However, more information by itself is insufficient. Producers need an entire system to collect, process, and interpret the data to make a decision, as well as an efficient way to implement their decision. The major components of a system that aids the producer include:(1) data collection, (2) data analysis, (3) interpretation and decision making, and (4) implementation.

For the data collection component, remote sensing and Global Positioning System (GPS) are two technologies that can be used to rapidly collect field data necessary for making real time decisions. The Global Positioning System (GPS) quickly and accurately determines the location on the earth's surface where data is acquired. For the data analysis component, a Geographic Information System (GIS) can be used to handle and analyze the voluminous, spatially related data that describes the crop status throughout a field or a farm. For the decision making component, a computer model such as an irrigation scheduling program using crop coefficients or a comprehensive Decision Support System (DSS) with decision making criteria for various agricultural management objectives, can be used. For the implementation component, automation is a general topic for discussing how to efficiently and affordably implement irrigation decisions.

The objective of this paper is to discuss: (1) remote sensing as a means to efficiently collect large amounts of spatially related data and (2) automation as an efficient way to implement management decisions to apply different amounts of water and fertilizer throughout a field. Details about GPS, GIS, and DSS are discussed in another report and will not be addressed here.

REMOTE SENSING

Background

Prior to 1960, aerial photography was the sole remote sensing system used. However, with the advent of the space program in the early 1960's, the pace of the technological development for remote sensing accelerated. The first satellite designed specifically to collect data of the earths' surface and resources was the Earth Resources Technology Satellite (ERTS-1), later named Landsat 1, which was launched on July 23, 1972. Since then, several Landsat satellites have been launched to add additional satellites to obtain more frequent coverage, to replace ailing satellites, and to update sensors on the satellites. Landsat multispectral data have been used in agriculture, forestry, geology, land use planning, and other areas.

Remote sensing generally involves data collection from satellite, airborne, or ground-based platforms, processing and analyzing the data, and converting the data to information. The aim of remote sensing is to learn more or to learn more efficiently and to produce information which can be applied in decision-making or problem-solving. Two questions may need to be addressed before delving two deeply into the application of remote sensing to a given problem: 1) Is there justification for applying remote sensing or any new method to the problem? and 2) Is there any chance that remote sensing can provide information that will assist in solving the problem?

Crop Coefficient Estimation

Crop coefficients are normally determined experimentally from lysimeter measured crop evapotranspiration (ET) and expressed as a ratio of crop ET to reference ET. Reference ET is usually alfalfa or grass ET calculated using calibrated ET equations and measured weather data. Crop coefficients have a minimum value following planting which represents bare soil conditions, approach 1 or become greater than 1 at effective cover depending on whether the reference is alfalfa or grass, respectively, and then decrease in magnitude as the crop matures. Published crop coefficients for specific crops represent average plant growth conditions for the specific growing seasons used in their development. Thus the crop coefficient curve can be construed as an "ideal" growth curve. Due to various factors (weather anomalies, nutrient deficiencies, insect damage, disease, etc.) plant growth can and does deviate from this "ideal". Consequently, crop ET may be different than estimated by using published crop coefficients.

Monitoring crop growth in the field via remote sensing can provide essential information to keep the crop coefficient curve tracking actual plant growth. Research using hand-held radiometers that measure reflected radiation in wave bands similar to the sensors onboard the Landsat satellites has shown the usefulness of remotely sensed canopy reflectance data measured in the red and near-infrared to represent a reflectance-based crop coefficient for corn. Advantages of this crop coefficient over traditional crop coefficients are: 1) they are independent of the time base variable, 2) they are sensitive to periods of slow and fast plant growth induced by weather conditions and 3) they respond to leaf loss caused by hail and various forms of plant stress induced by water deficit, insects, and disease. The crop coefficient curve derived from the reflectance-based crop coefficient for corn is a direct representation of actual crop growth conditions in the field. Thus, spectral inputs to irrigation scheduling models or other agrometeorological models allow quantification of various crop responses to its environment that would otherwise be difficult to include. Consequently, irrigation scheduling for corn could be improved by using canopy reflectance data to determine crop coefficients.

Plant Nitrogen Status Estimation

Water quality issues concerning excessive nitrates in ground and surface water supplies are impacting N fertilizer management schemes in many agricultural areas. Nitrogen fertilizer applied in small amounts as needed by the crop, i.e., N management based on a spoon-feeding strategy during the growing season for irrigated corn, could reduce N application rates and nitrate leaching. Knowing when and how much fertilizer N to apply during the growing season is essential to successfully implement this N management strategy.

Soil and plant tissue sampling for N availability are well documented. However, these methods require considerable effort for sample collection and processing. Repeated sampling throughout the growing season is very laborious and time consuming. In addition, a time delay exists from sampling until the laboratory results are obtained. A relatively new procedure using a chlorophyll meter to assess the plant nitrogen status has been developed within the past five years. This technique provides instantaneous results and has been demonstrated as a tool to schedule fertigation for corn on an "as-needed" basis. Unfortunately, data obtained with the chlorophyll meter represent a point measurement on a single leaf from a single plant. Consequently, many plants must be sampled to obtain a representative average value for the particular sampling date. Furthermore, considerable time is required to assess spatial variability. Remote sensing of canopy reflectance has the capability of sampling a plant community rather than a single or small number of plants and rapidly assessing the spatial variability in a field.

Recent research has resulted in the development of a N reflectance index using canopy reflectance data measured in the green and near-infrared wave bands. Comparison of the N reflectance index to the N sufficiency index (chlorophyll meter) produced a near 1:1 relationship for corn growth stages V11 to early dent. Relationships between the N reflectance index versus plant total N concentration and the N sufficiency index versus plant total N concentration were similar. This result also indicates that the N reflectance index is a good representation of the N sufficiency index; consequently, the N reflectance index can be used to monitor plant nitrogen status. In fact, the N reflectance index is probably a better indicator of plant nitrogen status since more of the plant is measured.

The above two examples for use of remotely sensed data for water and nitrogen management schemes represent a small portion of remote sensing applications in agriculture. Remote sensing technology and its applications in agriculture are still in its infancy; the potential of remote sensing has only begun to be tapped.

AUTOMATION

The major goal of automation is to significantly reduce the labor required to achieve an efficient irrigation and to reduce the detrimental effects of overirrigation. Time is a very precious commodity to producers who are very busy with a variety of decisions to make and tasks to do during the irrigation season. When water is inexpensive and/or the producer is not concerned about the environmental consequences of poor irrigation practices, there is little economic incentive to invest in automation equipment. However, as the economic stakes increase, interest in automation also increases. As the level of management increases, irrigation decisions become more complex and may include differential application of water and fertilizer within a field.

Automation equipment must be reliable, flexible, and affordable to be accepted by the producer. Since the primary reason for automation is to free the user from time-consuming and sometimes monotonous tasks, the equipment must be easy to use and perform reliably under a variety of conditions.

Since automation is a broad topic, any detailed discussion depends on the specific irrigation type. Although considerable research has been done to automate surface irrigation systems, widespread adoption has not occurred because successful implementation usually requires a site-specific design and installation. Commercial companies are reluctant to develop and promote products which require a lot of individualized design for each field.

Center pivot sprinkler irrigation has become more automated with the advent of computerized control panels. These panels contain a microprocessor which enables logical programming of the sprinkler as well as data storage to record the operational history. These programming capabilities allow the user to make operational and speed changes at any angle, so water and chemicals can be differentially applied on any sector of a field. Electronic sensors which measure wind speed or rainfall amounts can also be connected to input ports on the control panel. A logical condition such as wind speed or rainfall amount exceeding a user specified threshold, as well as a logical consequence such as turning off or changing the speed of the pivot, can be programmed. The microprocessor continuously compares the input port value with the threshold value and executes the consequence when the specified condition becomes true.

Multiple operational programs can be entered and stored in the control panel for future use. To initiate a previously stored program, the user selects the desired program from the list of available programs. The operational history of a pivot can be reviewed by recalling the recorded operational changes to the control panel screen, but this process can be time consuming if there are a lot of pivots to review.

One option that is useful for farms having multiple pivots, is a communication link (e.g. radio, telephone) between a central base station having a microcomputer and each of the computerized pivot control panels. Base station software automatically monitors each of the pivots at user specified intervals to verify correct pivot operation as well as record the operational history on disk for review, summarization, and future analysis. Alarms can be set to alert the irrigator when a pivot malfunctions. Programming of individual pivots can also be done from the base station enabling the irrigator to quickly and efficiently implement irrigation decisions from a single location.

EXPECTED BENEFITS

The expected benefit of a comprehensive system for collecting and analyzing data to make and implement decisions, is more precise application of water and chemicals which reduces irrigation costs and the risk of environmental damage from overirrigation. Remote sensing can potentially provide an integrated assessment of various aspects of the crop status at a reasonable cost which can then be efficiently analyzed. Simulations of irrigation schedules using real data from three corn growing seasons indicated that estimated crop water use using the reflectance-based crop coefficient was about 15 % less on average than when traditional crop coefficients were used. Total number of irrigations (on average) for the growing season were reduced by approximately 16 %. This indicates that over irrigation as well as under irrigation may be minimized due to better estimates of crop water use and appropriate timing of the irrigations.

Use of the N reflectance index is expected to reduce the total N application to corn during a particular growing season. The main advantage is the capability to identify areas within a field where plants have adequate or inadequate nitrogen fertilizer and apply N fertilizer only where needed and when needed by the plant.

Automation enables the irrigator to quickly and reliably implement the management decisions that are based on data collected on a real-time basis. Spatial estimates of crop water use within a field are possible with remote sensing which would allow differential applications of water to a field that would further minimize over or under irrigation.