VARIABLE-RATE IRRIGATION: CONCEPT TO COMMERCIALIZATION

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INTRODUCTION

Water conservation has become a critical issue in the southeast U.S. for many reasons including cyclical drought periods (some for extended periods), depleting aquifers, salt water intrusion near the coasts, and the "water wars" between Georgia, Florida and Alabama. Also, the changing population demographics of more people moving into the urban areas is shifting the political balance in favor of these more affluent areas of the states at the expense of the rural, agricultural regions. The increasing urban demands are particularly hard hitting for Georgia farms, where there are over 11,000 center pivot irrigation systems accounting for nearly 1.5 million acres of irrigation farm land (Harrison, 2005). Georgia's agricultural use of freshwater (irrigation) accounts for 18% of total use (Hutson et al., 2004), with 37% from surface water sources and 63% from groundwater (Harrison, 2005).

Most center pivot irrigation systems currently in use apply a constant rate of water, yet very few fields are uniform. A field's inherently variable nature stems from factors such as soil type, topography, multiple crops, drainage ditches and waterways, and other non-cropped areas (Fig 1). To complicate matters, most fields are irregularly shaped and some even have structures that may be in the pivot path, such as a house or barn. Thus, to optimize crop production and increase water use efficiency, a method is needed for delivering irrigation water in optimal, precise amounts over an entire field.

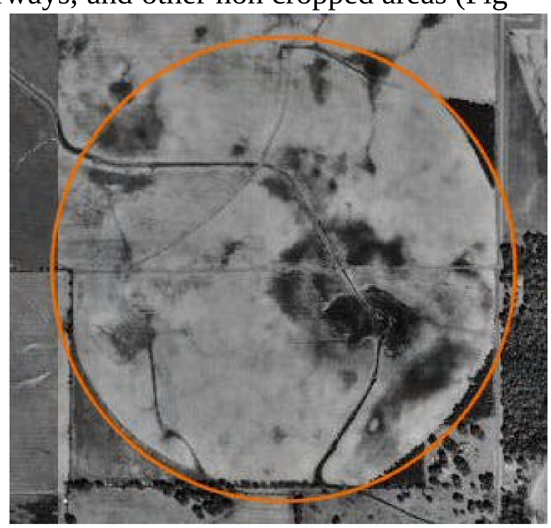

Figure 1. Bare soil image of typical South Georgia center pivot field.

Over the past decade, many research groups in the U.S., including the University of Georgia-Tifton Campus, USDA/ARS in Florence, SC, and Ft. Collins, CO, University of Idaho, and Washington State University, have all developed different research systems for applying irrigation water in more precise amounts. Evans et al. (2000) and Sadler et al. (2000) provide excellent literature reviews of ongoing precision irrigation projects around the country, indicating a substantial interest in spatially-variable irrigation by researchers.

MATERIALS AND METHODS

Variable-Rate Irrigation System

Beginning in 1999, the University of Georgia (UGA) Precision Ag team partnered with an Australian company, Farmscan (Computronics Corp. Ltd., Bentley, Western Australia), to develop a user-friendly and reliable/robust Variable-Rate Irrigation (VRI) control system for center pivot irrigation. The VRI system varies application amounts by cycling sprinklers ON/OFF (based on percent of 1 minute), controlling the end gun and by varying the system's travel speed. Application rates are based on percent of "normal" application as selected by the center pivot operator by his/her choice of system travel speed. To reduce application in relation to "normal", the VRI system will increase system travel speed and/or cycle sprinklers. To increase application in relation to "normal", the system will decrease travel speed. For example, to achieve a 50% application rate, the VRI system either increases speed or signals a sprinkler control zone such that the sprinkler valves in that zone open for 30 sec and then close for 30 sec, repeating continuously. A rate of 80% would correspond to 48 sec ON and 12 sec OFF. A rate of 100% (the "normal" amount) is, again, set by travel speed of the pivot. Any rate over 100% would require slowing of the travel speed accordingly.

The UGA/Farmscan VRI system (Fig 2) controls each sprinkler ON/OFF by a normally-open, pneumatically-actuated, flow-control valve. System sprinklers are typically grouped into control zones with multiple sprinklers each. An electronically-actuated air solenoid valve provides control actuation to the sprinkler valves in a control zone via 8 mm diameter air tubing. A 120 VAC air compressor mounted on the mainline near the pivot point supplies compressed air for valve actuation. Travel speed and end gun are controlled by interrupting the normal center pivot "walk" signal line and end gun signal line and injecting the VRI system's own signals. The VRI system retrofits on existing center pivot systems and integrates GPS positioning to continuously determine location/angle of the mainline. The system is designed with several "fail-safes" to insure the center pivot operator can apply water if there is an error or failure in the VRI system. Perry et al. (2002) describes the development of the UGA/Farmscan system in greater detail.

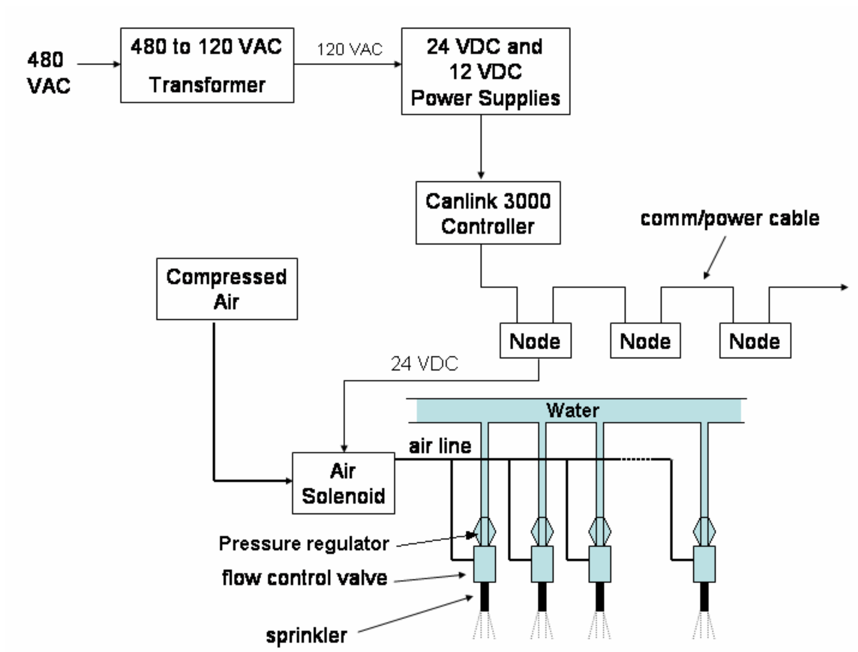

Figure 2. Diagram of UGA/Farmscan VRI control system.

The Farmscan Irrigation Manager PC software (Fig 3) provides for development of application maps. The software allows multiple pivots to be defined and allows each pivot to have multiple application maps defined. The software allows a pivot to be divided into wedges from 2 to 10 degrees “wide” (either full or partial circle) with up to 48 control zones radially along the pivot mainline. The number and size of the control zones are determined by features/anomalies in the field to be managed and by the installation of valve control hardware. Once a pivot and its irrigation control zones have been defined, a pie-shaped grid is displayed (divided into sections corresponding to the defined control zones). Using a legend of application rates (0 to 200%) the user selects a rate from the legend with the mouse and then “paints” each control zone of the map with an application rate. The resultant map is then digitally stored and copied to a PCMCIA SD memory card and uploaded to the master controller at the center pivot. At the present time, the water application map is a static map created with the aid of the farmer’s knowledge of the field, aerial images of soil and/or crops, soil maps, yield maps, etc.

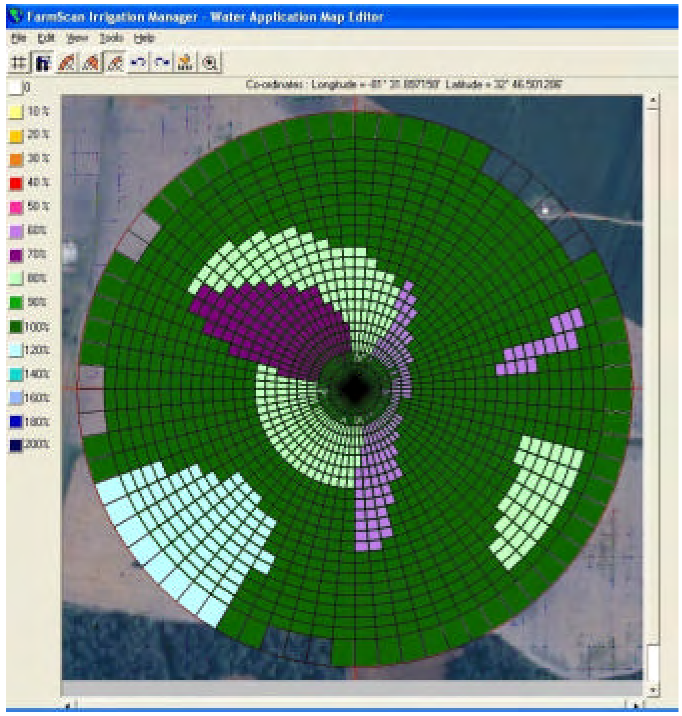

Figure 3. Farmscan software used to generate irrigation application maps.

The process for using the UGA/Farmscan VRI system is as follows:

1. Pivot information is entered into PC software;
2. Desired application rates are defined in the desktop software;
3. A control map is generated by the software;
4. Control map is transferred from PC to controller via SD data card;
4. The controller determines pivot angle via GPS;
5. Based on the control map, the controller optimizes pivot speed and/or cycles sprinklers (and/or end gun) to set application rate.

System Evaluation

Researchers have evaluated the UGA/Farmscan VRI system in various ways. Perry et al. (2003b) reported on the effectiveness of the VRI system to achieve targeted application rates in various sprinkler zones. The VRI system was able to achieve target application amounts fairly well, especially at higher rates. However, these tests measured variations in application only along the pivot mainline. Perry et al. (2003b) and Dukes and Perry (2006) evaluated water application uniformity while under VRI control and found the VRI system’s cycling of sprinklers ON/OFF to vary application rate did not alter the uniformity.

To evaluate the VRI system in the “real world”, the UGA Precision Ag team installed prototype VRI systems on 5 farmer-owned center pivot systems in Georgia. Each of these systems presented a unique combination of crops, soils, and irrigation system hardware. In each case, the farmer took the lead in developing a water application map for the VRI controller. The farmers used yield maps, aerial photos, soil survey maps, and, of course, first-hand knowledge of the fields to aid in development of the application maps. The prototype systems were used by the farmers for 2-4 years and performed quite well. One common aspect of each installation was the potential for water conservation with VRI. It became apparent that a method for varying irrigation across a field could also lead to substantial water savings, as many fields have areas that require less water or no water at all.

To verify water savings resulting from use of VRI, Perry et al. (2003a) evaluated three methods for calculating water savings and compared them to actual water savings. The calculation methods used included a) calculating gallons/min delivered in each sprinkler zone; b) calculating acre-inches delivered to each sprinkler zone; and c) calculating savings using summary data provided in the Farmscan PC software. The actual savings were determined by mounting a flow meter onto the system mainline. The group looked at three center pivot systems fitted with VRI controls that were operated with and without VRI engaged. Each calculation method produced a reasonable estimate of water savings, with the method using the software summary data being the easiest to calculate. Each of the three methods underestimated water savings or additional water usage. The application map shown in Figure 3 would produce a calculated water savings of 7%.

Commercialization

During the summer of 2004, several interested groups partnered to move the VRI technology beyond the prototype stage and into commercialization. The Flint River Soil and Water Conservation District of Georgia, the Georgia office of the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), The Nature Conservancy, and UGA jointly developed a plan to utilize federal NRCS Environmental Quality Incentives Program (EQIP) funding to provide a 75/25 cost-share opportunity for growers in the Flint River basin of Georgia to install VRI on suitable pivots/fields. UGA helped NRCS develop a ranking system and narrowed an original sign-up list down to 23 systems. Additionally, the Conservation District, NRCS and The Nature Conservancy jointly funded a position in the Flint River basin in southwest Georgia tasked with promoting water conservation, in particular VRI, to area farmers.

Also, in late 2004, a research/extension team from UGA and Clemson University in South Carolina was awarded over $500,000 through the NRCS Conservation Innovation Grant (CIG) program to install VRI controls on additional suitable center pivot systems, primarily in Georgia and South Carolina, by providing a 75/25 cost-share. The CIG grant also provided funds to demonstrate the use, benefits, and effectiveness of VRI for irrigation management, water conservation, and optimal application efficiency through a series of workshops/field days.

Hobbs and Holder, LLC. (Ashburn, GA) (www.betterpivots.com) was selected as the vendor to provide the VRI hardware, installation, training, and support via a licensing agreement with Farmscan. This start-up company was created by the partnering of two experienced crop consultants with a keen interest in precision agriculture and technology.

RESULTS AND DISCUSSION

Hobbs and Holder began commercial VRI installations in December 2004 and continued through late winter 2005 and had all original 23 NRCS EQIP-funded systems operational for the 2005 crop season.

Also in 2005, Hobbs and Holder began installing CIG funded VRI systems in Georgia and South Carolina. Currently, 10 CIG grant-funded VRI systems have been installed in Georgia and 5 have been installed in South Carolina. With approval of NRCS, the CIG grant has also funded one VRI installation in Arkansas and one in Alabama in 2006. Several more installations in Georgia and South Carolina are in the planning phase.

The Georgia NRCS received additional EQIP funds in late 2005 to install more VRI systems during Winter/Spring 2006 at the same 75/25 cost-share. Similarly, NRCS in Mississippi and South Carolina developed cost-share programs to cover VRI installations in their respective states.

The total number of VRI installations has now reached 44 (Table 1). This number includes a variety of center pivot manufacturers, system sizes (length and capacity), ages, nozzle configurations, etc. Most VRI systems have been installed on irrigation systems on row-crop farms. However, four VRI systems have been installed on turf farms. For the 44 systems installed currently, the water savings averages 12% (using the summary data calculation method). Table 1 lists the VRI installations completed to date.

Table 1. VRI installations completed by state and funding source.

State	CIG Installs	EQIP Installs	Other Installs	Total
Georgia	10	22	1	33
South Carolina	5	1	0	6
Alabama	1	0	0	1
Florida	0	0	1	1
Mississippi	0	0	1	1
Arkansas	1	0	0	1
North Dakota	0	0	1	1
TOTAL	17	23	4	44

During the 2005 and 2006 growing seasons, the UGA/Farmscan VRI systems performed well. As with any first generation product, there were occasional problems that Hobbs and Holder had to resolve. Problem resolution often involved the in-field replacement of a controller, circuit board, or GPS unit. These components were returned to Farmscan for repair or replacement.

CONCLUSIONS

The UGA/Farmscan VRI system has been shown to be capable of optimizing crop production and increasing water use efficiency by delivering irrigation water in optimal, precise amounts over an entire field. With VRI, the soil moisture needs of crops on varying soil types can be met while limiting over-applying or under-applying irrigation water. Similarly, the system can reduce or eliminate water application to non-cropped areas.

Commercialization of the UGA/Farmscan VRI system has progressed well. With cost-share funding from NRCS EQIP and from a NRCS CIG grant, 40 systems have been installed. Four systems have been purchased without cost-share assistance.

Reasons that farmers have expressed an interest in having a VRI system have ranged from environmental stewardship, conservation, economics, and enhanced productivity. Current VRI systems are installed on farms that grow some of the more traditional crops (peanuts, cotton, and corn) to the less conventional crops (i.e., turf).

Future Directions

UGA researchers have been working on wireless communication to/from soil moisture smart sensor arrays. The smart sensor arrays were developed to measure soil moisture and temperature using off-the-shelf components to keep costs down. The next challenge is to integrate the smart sensor array with the VRI controller.

Once this is achieved, growers will have the ability to control variable rate irrigation in real time using data collected with the smart sensor array. An example of what this technology will enable is the following: As the pivot travels around the field, the amount of water applied to the predetermined irrigation management zones will be a function of current soil water status as measured by the smart sensor array rather than a predetermined amount based on a static prescription map.

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