

PRECISION PIVOT IRRIGATION CONTROLS TO OPTIMIZE WATER APPLICATION

Calvin Perry

Research & Extension Engineer
Biological & Agricultural Engineering and NESPAL
The University of Georgia, Tifton GA
perrycd@tifton.uga.edu

Stuart Pocknee

Program Coordinator
NESPAL
The University of Georgia, Tifton GA
stu@agrisurf.com

ABSTRACT

A precision control system that enables a center pivot irrigation system (CP) to precisely supply water in optimal rates relative to the needs of individual areas within fields was developed through a collaboration between the Farmscan group (Perth, Western Australia) and the University of Georgia Precision Farming team at the National Environmentally Sound Production Agriculture Laboratory (NESPAL) in Tifton, GA. The control system, referred to as Variable-Rate Irrigation (VRI), varies application rate by cycling sprinklers on and off and by varying the CP travel speed. Desktop PC software is used to define application maps which are loaded into the VRI controller. The VRI system uses GPS to determine pivot position/angle of the CP mainline. Results from VRI system performance testing indicate good correlation between target and actual application rates and also shows that sprinkler cycling on/off does not alter the CP uniformity. By applying irrigation water in this precise manner, water application to the field is optimized. In many cases, substantial water savings can be realized.

INTRODUCTION

Agricultural water use is a major portion of total water consumed in many critical regions of Georgia. Georgia has over 9500 center pivot systems, watering about 1.1 million acres (Harrison and Tyson, 2001). Many fields irrigated by these systems have highly variable soils as well as non-cropped areas. Current irrigation systems are not capable of varying the water application rate to meet the needs of plants on different soil types nor capable of stopping application in non-cropped inclusions. This limitation results in over-applying or under-applying irrigation water. In addition, five years of drought and a lawsuit over Georgia water use by Florida and Alabama have prompted a renewed interest in water conservation methods by the general public, which is becoming increasingly insistent that agriculture do its part to conserve water.

The NESPAL Precision Ag Team has developed a prototype method for differentially applying irrigation water to match the precise needs of individual sub-field zones. Research projects dealing with spatially-variable irrigation water application have been ongoing for a number of years (Sadler et al., 2000; Heerman et al., 1999; Jordan et al., 1999; King and Kincaid, 1996; Evans and Harting, 1999). In each case, the research team used a different method for accomplishing the variable water application. However, most of these systems remain in the research phase.

Recognizing that water is the major yield determiner in nearly all agricultural settings, the authors' original interest lay in varying application rates from a precision crop production viewpoint. However, it readily became apparent that a method for varying irrigation across a field could also lead to substantial water savings.

The method is referred to as Variable-Rate Irrigation (VRI). This system easily retrofits onto existing center pivot irrigation systems.

The major components of the NESPAL VRI system are shown in Figure 1. The process for using the VRI system is as follows:

1. Pivot information is entered into the desktop software;
2. Desired application rates are defined in the desktop software;
3. A control map is transferred from desktop PC to the Canlink3000 controller via 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.

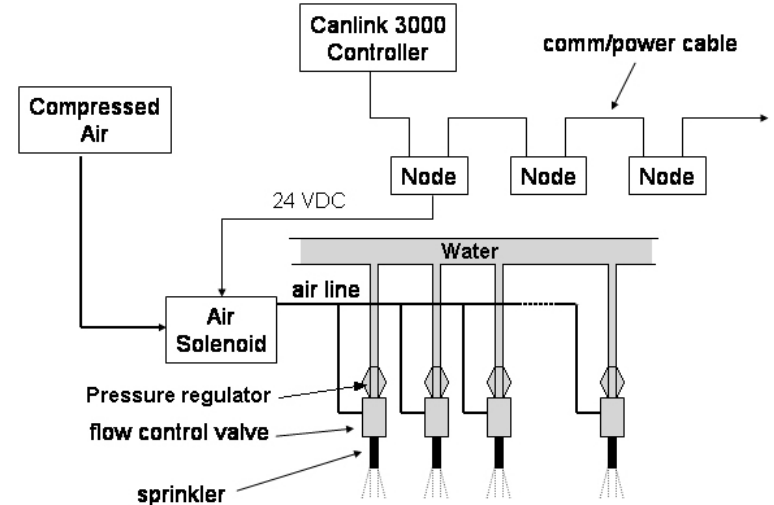


Figure 1. Layout of variable rate control system.

MATERIALS AND METHODS

The Farmscan Irrigation Manager™ software (Figure 2) 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” with up to 48 control zones radially along the wedge/pivot. 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 “marks” each control zone of the map with an application rate. The resultant map (Figure 2) is then copied to a memory card and uploaded to the master controller.

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. The user must account for the control map possibly having higher resolution than can be practically accomplished with the actual sprinkler arrangement on the pivot.

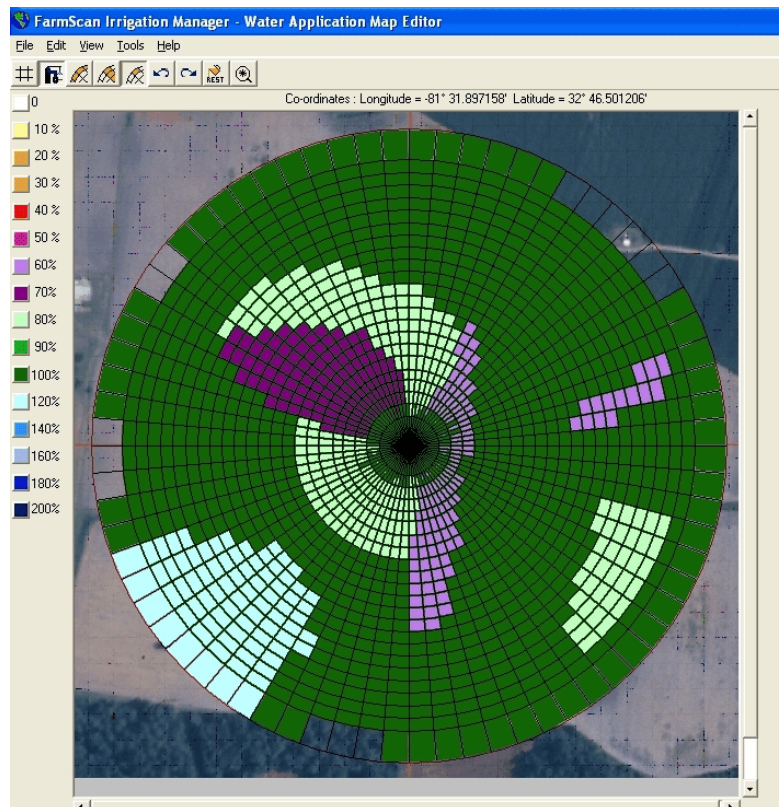


Figure 2. Software for creating application maps.

The VRI control system was installed on a NESPAL research pivot during February, 2001. Fifteen sprinkler banks or groups were configured to contain 2, 3, or 4 sprinklers so as to provide approximately 50 ft zones, each controlled by an addressable “node.” The node circuitry was placed in four weather-proof enclosures located on two of the wheeled support structures for the pivot. Flow uniformity was maintained by installing 15 psi pressure regulators at each sprinkler. The sprinkler banks were configured in small segments to provide fine control resolution. The banks could be combined if coarser control was desired. The relatively small banks also allowed for system testing with multiple control zones and associated hardware (air lines, solenoids, nodes, etc.).

To verify the variable-rate functionality and that the pivot’s sprinkler uniformity was not adversely impacted by the addition of VRI controls, a series of application tests, each repeated three times, were performed on the NESPAL pivot. The first test involved operating the pivot with VRI engaged but all sprinklers at 100% cycle time for 100% application rate. In effect, this test produced a baseline uniformity of the pivot. The second test instructed the VRI control system to operate all sprinklers at 50% cycle time to produce 50% application rate. The third test consisted of setting various target application cycle times and rates along the pivot.

Catch cups (3.58 in diameter plastic drinking cups) were attached to wooden dowel rods via a plastic ring. The cup/rod assemblies were placed at 5 ft intervals radially along the mainline, beginning 30 ft from the pivot’s center point (Figure 3). The cups rested on the rods approximately 18 in above the soil surface. The catch cups were deep enough to prevent most water drops from splashing out of the container. The pivot was operated at 11% speed timer setting, corresponding to an end tower travel speed of approximately 22 in/min. During the three repetitions, the pivot was operated twice in the “forward” direction and once on the “reverse” direction. During the uniformity testing, speed control was not engaged to keep the pivot travel speed constant. As the system passed completely over catch cups, the collected water was measured in a graduated cylinder. This test is similar but does not fully conform to the ASAE Standard S436.1 (ASAE, 1998) for testing uniformity of center pivot irrigation systems.



Figure 3. Catch cups underneath center pivot.

The VRI control system has since been installed on four farmer-owned CP systems in Georgia (Table 1). To determine actual water use (and potential water savings), a test was conducted on two of these CP systems (TS and LP). An application control map was developed for each system which was used to estimate water use for one complete pass of the irrigation system. The two systems were operated with VRI engaged for one complete pass (circle) while actual water use was being monitored by a Polysonic DCT-7088 ultrasonic flow meter mounted on the mainline (Figure 4). The water used while irrigating without VRI engaged was determined by measuring the normal flow rate with the Polysonic meter and then multiplying that rate by the time the CP would normally take to complete one pass.

RESULTS AND DISCUSSION

The results of the 100% and 50% application rate tests are shown in Figure 5. The 100% data provided a “normal” or baseline application amount to which other application rates could be compared. The amount of irrigation water collected in each cup was used to determine coefficients of uniformity (CU) by the Christiansen Method and the Heermann and Hein Method (ASAE, 1998). For the 100% test, the Christiansen CU was 89% and the Heerman and Hein CU was 87%. The 50% test produced a Christiansen CU of 89% and a Heerman and Hein CU of 88%. These CU’s indicate a uniform application for both rates.

The mean application for the 100% test was 61.2 ml with standard deviation (SD) of 5.9 and a coefficient of variation (CV) of 0.096. The 61.2 ml value became the baseline for further comparisons. The mean application for the 50% test was 28.4 ml with SD of 4.2 and CV of 0.148. This mean differed from the expected mean (30.6) by 7.1%. A single sample t-test was used to compare the 50% data to the assumed expected/known rate of 30.6 (50% of 61.2), and indicated a significant difference between the 50% mean and the known rate. This could be attributed to application losses that often occur in center pivot irrigation systems and which have a greater effect at lower irrigation rates.



Figure 4. Ultrasonic flow meter.

Table 1. Farmer-owned center pivot systems with VRI controls installed.

Pivot	Towers	Mainline Length (ft)	End Gun	Total Acres	Flow Rate (gpm)	Pressure (psi)	Sprinkler Type	Control Zones
LP	3	569	Yes	32	275	25	Spray on drop	13
TS	3	609	Yes	37	750	55	Impact	16
JB	5	995	Yes	88	1000	43	Spray on top	23
DS	7	1408	Yes	162	1200	40	Impact	8*

* Only the last span, overhang, and end gun were controlled by VRI system.

The results of the variable rate testing are shown in Figure 6. All of sub-section 1 and most of sub-section 2 were located within the first span of the pivot. The uniformity of application from sprinklers in this span is usually poor and unavoidable due to nozzle size limitations. By design, irrigation sprinklers are sized and spaced to overlap adjacent sprinklers to improve uniformity. Sections 3, 4 and 5 were large enough to allow calculation of CU values and were each quite uniform (86%, 94%, 95%).

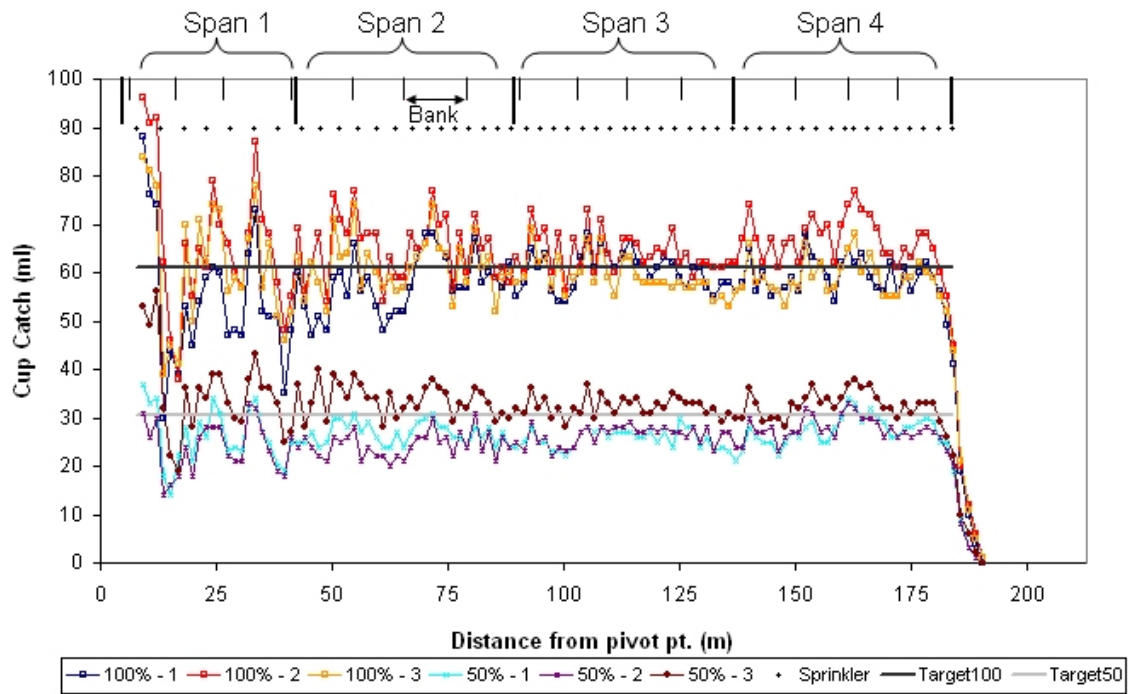


Figure 5. Results of the NESPAL pivot 100% and 50% tests.

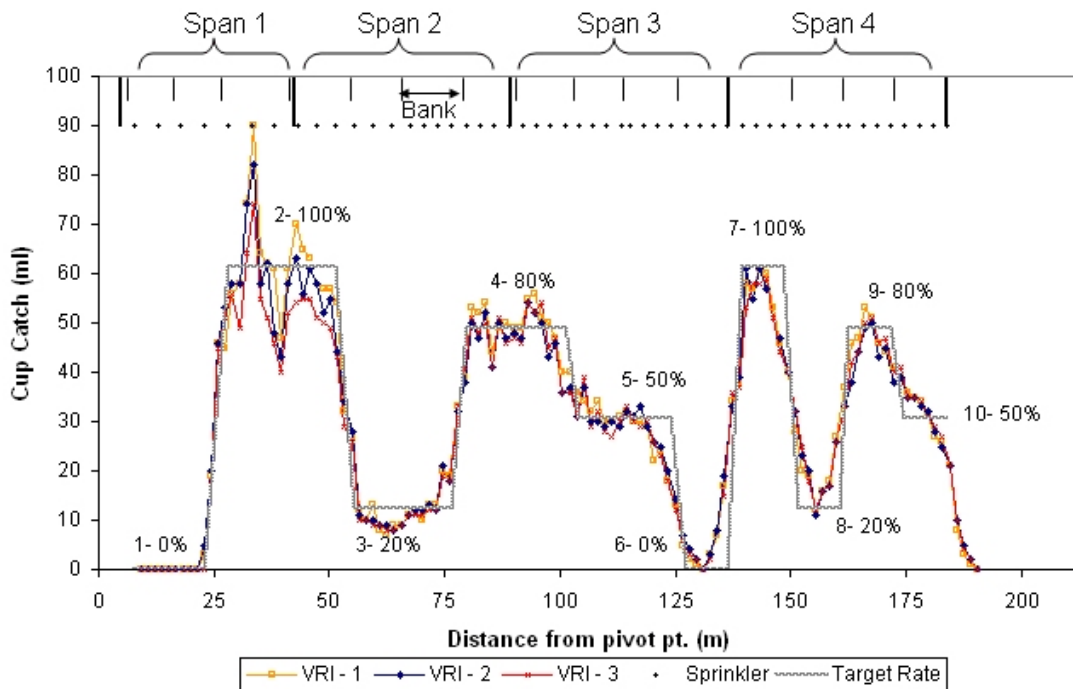


Figure 6. Results of the NESPAL pivot variable rate tests.

Results from the actual water use study with the two farmer-owned CP systems are shown in Table 2. The two pivots were operated at higher than normal travel speeds to reduce the time personnel had to remain on site during the testing. With VRI controls, the LP pivot used considerably less water in one pass. However, the TS pivot used slightly more water under VRI controls.

Table 2. Results of actual water use testing.

Pivot	Measured non-VRI water use	Measured VRI water use	Calculated VRI water use	Percent Timer Setting	Time for one pass
TS	188,800 gal	195,300 gal	197,600 gal	90 %	4.4 hours
LP	68,400 gal	43,800 gal	52,900 gal	100 %	4 hours

SUMMARY AND CONCLUSIONS

The results of the application tests indicated that the NESPAL pivot's application was uniform in non-VRI mode. Similarly, when all sprinklers were set to 50%, the application was again uniform, showing that the VRI system's cycling of sprinklers on/off to vary application rate did not alter the uniformity. Normal irrigation losses likely prevented the system from more closely matching the target application (50% of normal). The third series of tests mimicked a variable-rate scenario and 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.

The results from the actual water use study indicated substantial water savings in one field while no change in water use in the other field. This is common with many precision agriculture tools. Each field is a unique situation that has its own variability to be addressed.

The installed VRI systems will be tested further for circumferential variations, reliability and usability. The authors plan to continue to document actual water savings and crop yields realized from use of VRI controls. New sensors that could interface with the VRI controller and provide real-time soil water information will also be investigated.

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