Update on Variable Rate Irrigation Performance

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Abstract *The paper will discuss the processes, data and results in the work being conducted to validate the performance of variable rate zone control irrigation. Information from two years of data collection and analysis will be presented. A brief review of the status of commercially available variable rate products in the USA will begin the paper. Information on the processes used to validate performance will be presented. Then the discussion will move to specific information on fields' characteristics and VRI irrigation equipment. The data will be presented that has been collected through the 2010 and 2011 growing seasons in the USA. The data will include but not be limited to catch can, soil moisture, aerial imagery and crop performance. The paper will close with the conclusions and recommendations for future work in evaluating VRI performance.*

Keywords Irrigation, variable rate irrigation, center pivot, precision irrigation

Introduction

Since the introduction of the center pivot in the mid-1950s, the mechanical move industry has continued to improve and develop products to better meet the needs of production agriculture. The overall goal has been to provide cost-effective, uniform irrigation across the field with a specific application depth.

With the introduction and acceptance of precision agriculture, suddenly more information has become available for a particular field and areas in the field, including yield, EC maps, soil and grid sampled fertility maps. Farmers now have data indicating the variability across the field, which was already suspected but not proven. The challenge then becomes how to use this data and how to make changes that would impact different areas of the field.

Research into variable rate, or "site specific," irrigation has been conducted at a number of locations across the United States by both Universities and USDA-ARS. These include, but are not limited to Universities of Georgia, Idaho, Nebraska and Texas A&M, and the USDA-ARS at Florence, SC, Ft. Collins, CO and Sidney, MT (King 2005, Marek 2004). The first commercial, marketed variable rate irrigation package in the USA was jointly developed by the University of Georgia, FarmScan and Hobbs and Holder (Hobbs & Holder 2006). This package 'broke' the center pivot into sections and had the ability to apply different depths in different areas along the pivot and in the direction of travel. These units have primarily been installed in the southeastern United States. AgSense (AgSense 2011) introduced a commercial add-on unit for center pivots in 2009 that would change the speed at various locations around the field based on a specific field prescription in six degree increments. Valmont Industries introduced the Valley VRI Zone Control in 2010 and in 2011 the Valley VRI Speed Control packages.

Objective

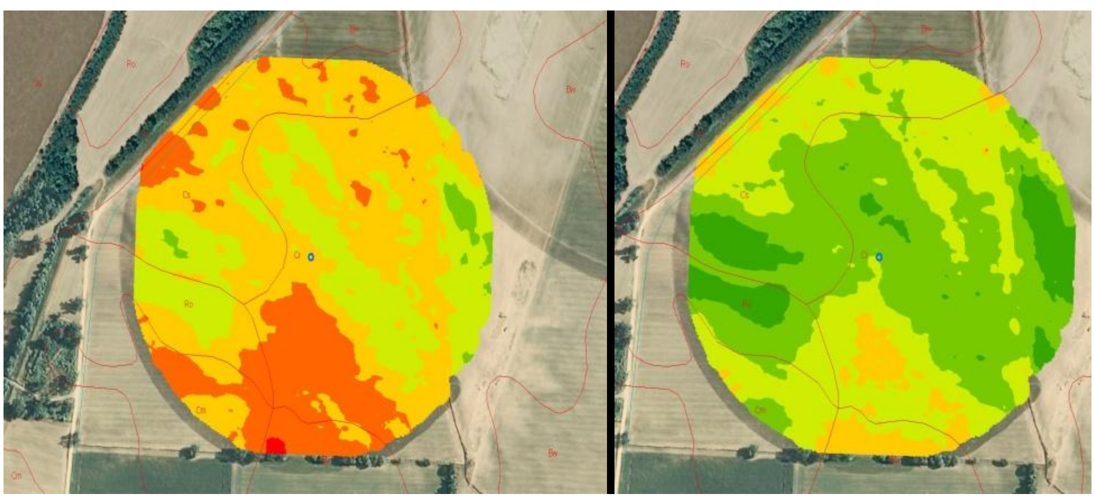
The goal of this project was to collect and analysis field data on commercial center pivots using zone control packages to characterize the performance of variable rate irrigation.

Discussion

The zone control packages reviewed were all Valley VRI Zone Control consisting of a Valley Pro2 control panel, VRI tower boxes, sprinkler control valves and sprinkler package. Below is a conceptual drawing of the Valley VRI Zone Control package components.

A prescription that is specific for the field is created with the Valley VRI Prescription Software or CropMetrics Virtual Agronomist. The prescription is then loaded into the Pro2 control panel. The VRI Prescription Software allows prescriptions to have up to 30 zones and 180 sectors around the field, each sector as small as two degrees.

In the spring of 2010, Valmont Irrigation began to validate the lab and field testing that had been done with the Valley VRI Zone Control package on a field near Dyersburg, Tennessee. The machine's configuration was a total length of 350m (1,148 ft) and six drive units. The flow rate was 51lps (800gpm) with fixed-pad sprinklers with a medium groove pad and regulator. The field challenge was parts of the field were either being overwatered or under watered, and uniform crop production was not being achieved across the field. In conversations with Dr. Earl Vories of USDA-ARS about VRI and how to determine the layout of Management Zones, it was suggested by Dr. Vories that apparent electrical conductivity (EC_a) of the soil profile be used (Vories 2008). EC_a is a sensor-based measurement that provides an indirect indicator of important soil physical and chemical properties.



Deep EC_a Figure 2 Shallow EC_a

Results

In 2010 the problem of characterizing performance was approached in three ways:

- Visual observation management zones – particularly those with the lightest textured soils receiving the full depth and those with the heaviest soils receiving a reduced depth.

- Soil moisture monitoring in one of the areas with the light textured soils where the prescription always called for 100% of the base application depth, and in heavy soils area where the base depth was reduced by 40%.
- Aerial imagery– infrared to compare ground cover and growth of the crop and visually look for areas where the crop appeared to be under stress.

One of the first observations was the cycle time was too long when a Pivot Zone was operating in an area where there was to be a reduction in the application depth. It was observed the drive unit was moving too far during a pulse and sufficient overlap of the sprinkler package in the direction of travel was not being achieved. To correct this, the cycle time was changed in the constants at the control panel.

The soil moisture data was tracked remotely; it looked for drying trends in the area where the prescription called for a reduced application depth. Below is an example of the soil moisture data sets for a sample time period (Figure 4a and 4b).

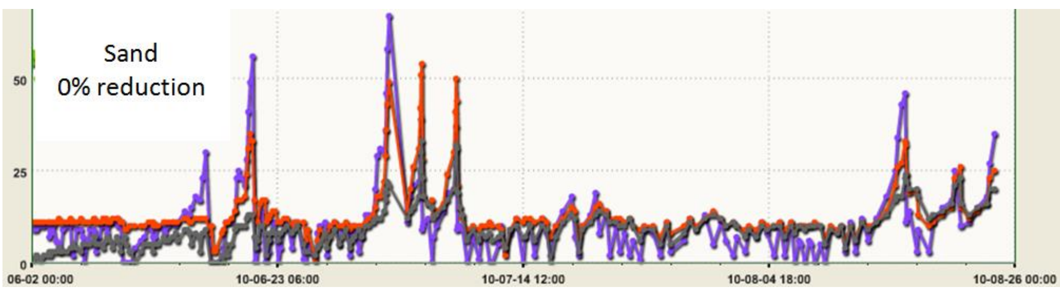


Figure 4a

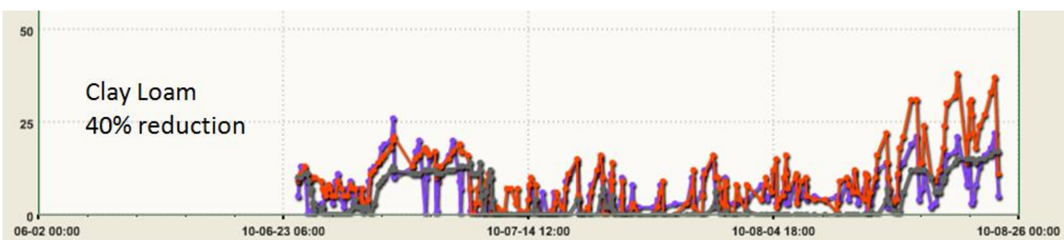
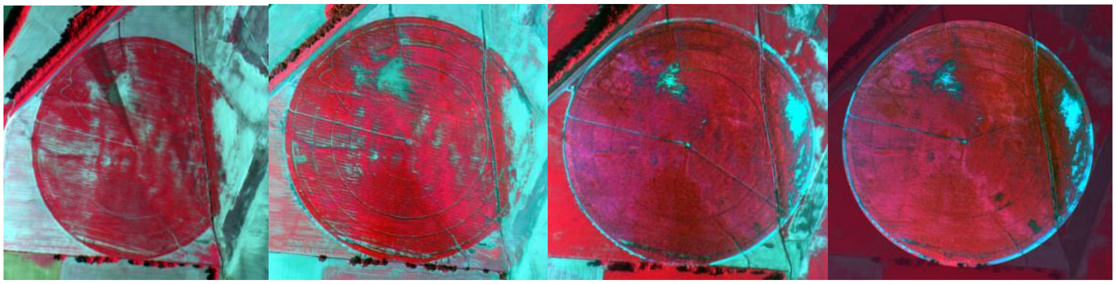


Figure 4b

Figure 4a is an area with clay loam soil that received 60% (40% reduction) of the base application depth. Figure 4b is an area of fine sand that always received 100% of the base depth. Each area received the same number of irrigations. Most important from this data is that over time, the clay loam with the reduced application depth did not show a drying trend; for most of the crop season it paralleled the soil moisture status of the area that received 100% of the base application depth.

The following were a series of infrared images taken during the growing season



June 16th June 30th July 23rd August 6th

Figure 5

In the images above, there was gradual improvement in the ground cover and, in general, the crop appeared "good" across the field with no particular weak areas except for the areas where the crop was blown out by wind in the early season.

For the 2011 crop season several VRI zone control packages were followed to characterize performance in southwest Kansas, western Nebraska, eastern Nebraska and central Illinois. Plans to continue work with the Tennessee pivot were discontinued due to flooding along the Mississippi and no crop was planted. The plans to characterize these VRI zone control packages included:

- Sprinkler uniformity by catch can testing
  - Along the center pivot – 3m (10ft) spacing
  - In the direction of travel – in a grid of three lines (3 x 30) under a particular zone (usually the next to the last) in a 3m (10ft) spacing
- Soil moisture grid sampling
  - Watermark sensors were spaced roughly 10m (30ft) apart at 15cm (6in) deep in an array of six in two areas – one group of six where full application depth was applied and another group where the application was reduced
- Aerial imagery
  - Used combination of chlorophyll, ground cover and NDVI at 5m resolution

Unfortunately due to resource constraints, weather and other situations not all of the center pivots had all of the characterizations done.

Southwest Kansas

Figure 6

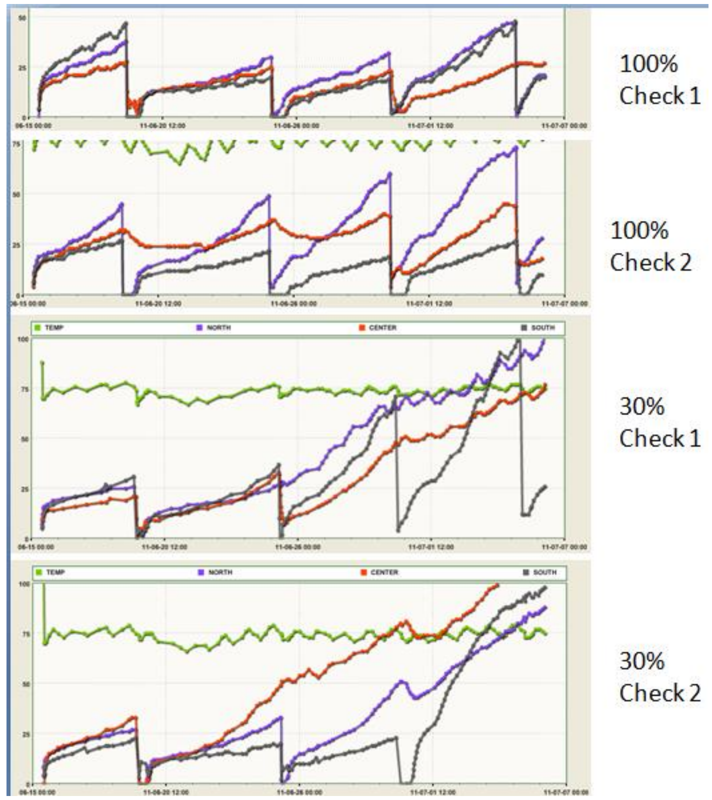


Figure 7

Figure 6 is an aerial shot of the center pivot and figure 7 presents the soil moisture grid data. All sensors were positioned 15 cm (6in) deep in a grid pattern. The 100% shows irrigations and the soil profile being refilled. The 30% gradually shows a drying and after irrigation and the soil profile not being refilled. No other data was collected from this center pivot

Western Nebraska

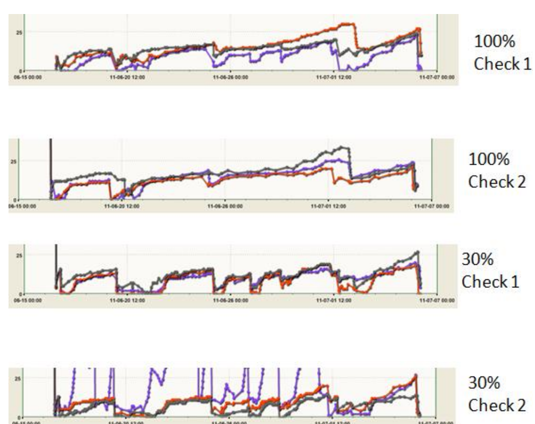


Figure 9

Figure 9 shows the soil moisture grid the same layout as for figure 7. However rainfall ‘masked’ any signs of soil moisture differences.

Figure 10 shows a catch can layout during a test. The cans are in three lines in an arc under a specific zone. The center pivot is operated ahead of the catch can arc to ensure everything is operating okay and then started into the catch can area. After the center pivot moves across 1/3 to ½ of the catch cans then the prescription is changed and then later changed back.

Figure 10

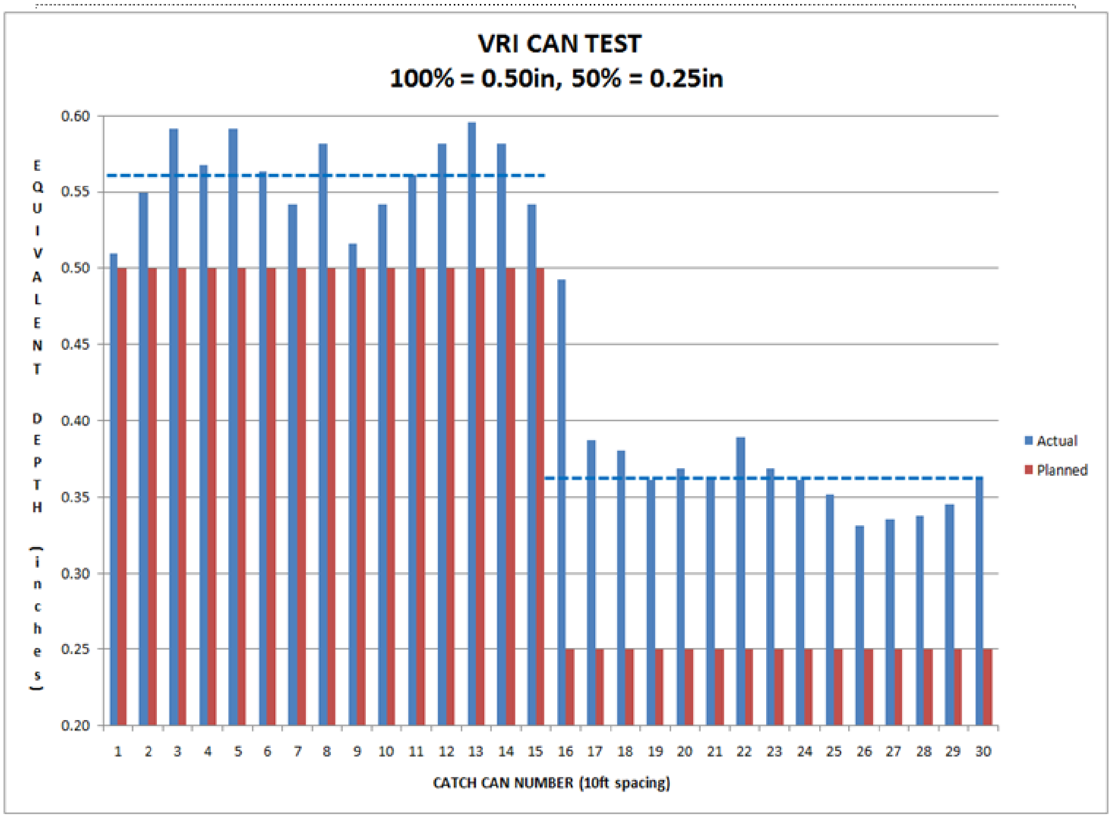


Figure 12

Figure 12 represents one of the passes and the data of the catch can test. The red bars represent the application depth that was planned to be applied and the blue bars the actual average of the three catch cans that are side by side. This center pivot had a rotating sprinkler package mounted on drops about 2.5m (8ft) off of the ground.

Figure 13 shows the Christiansen Coefficient for each segment of the arc. The blue bars are each arc for the area of 12mm (0.50in) application depth. The red bars represent the lines when applying 6mm (0.25in).

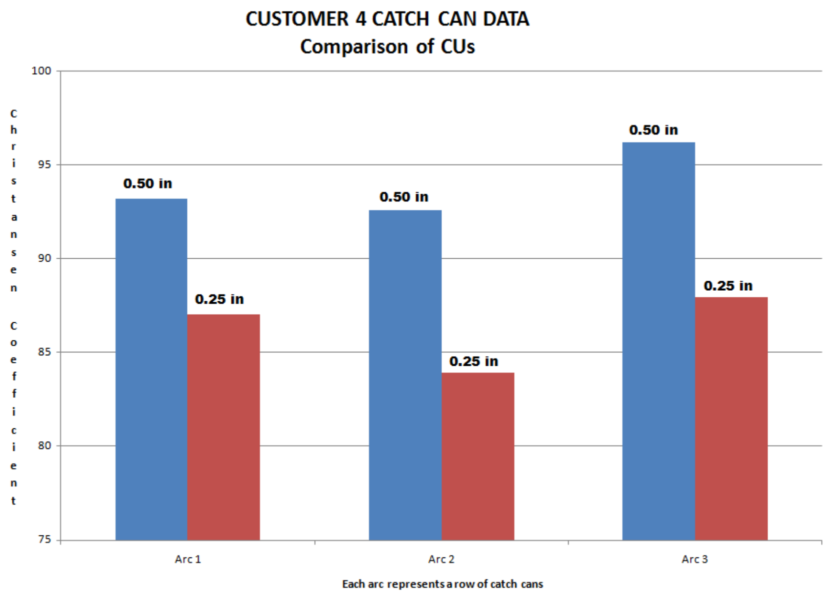


Figure 13

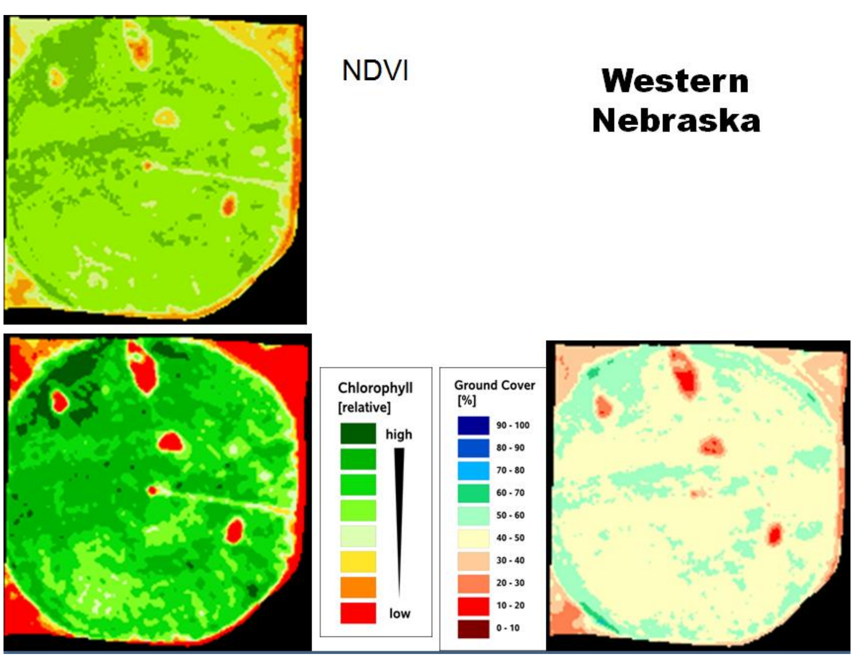


Figure 14 shows three examples of aerial imagery that was collected on July 12th.

Again due to the rainfall no trends were observed during the growing season when comparing one image to the next taken three to four weeks later.

Figure 14

Eastern Nebraska

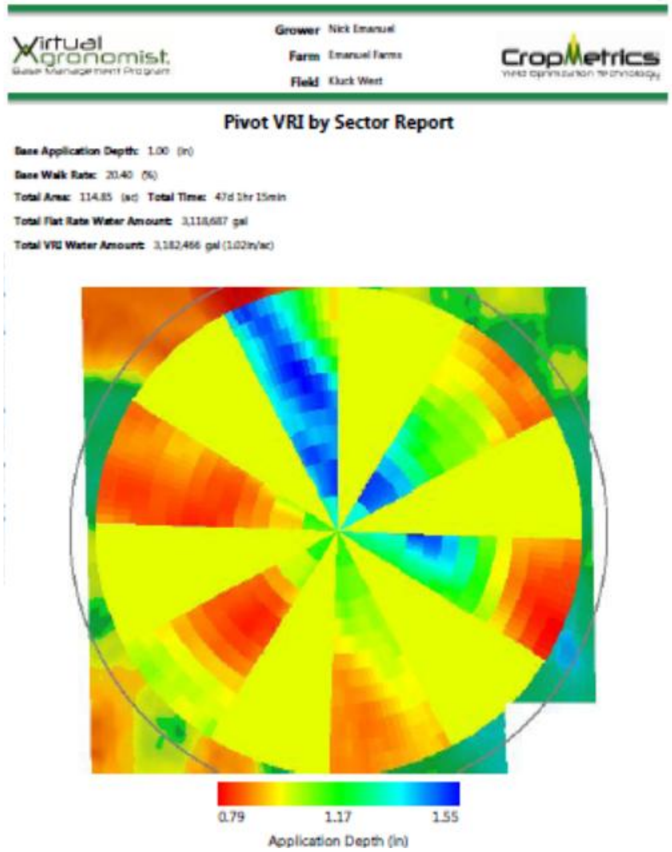


Figure 15

Figure 15 represents the prescription used for the center pivot in eastern Nebraksa. The owner working with CropMetrics wanted to do some testing of prescriptions vs. no prescriptions.

A soil moisture sensor grid was setup for this site similar to what was used at the other sites. Again due to the rainfall no specific trends could be seen.

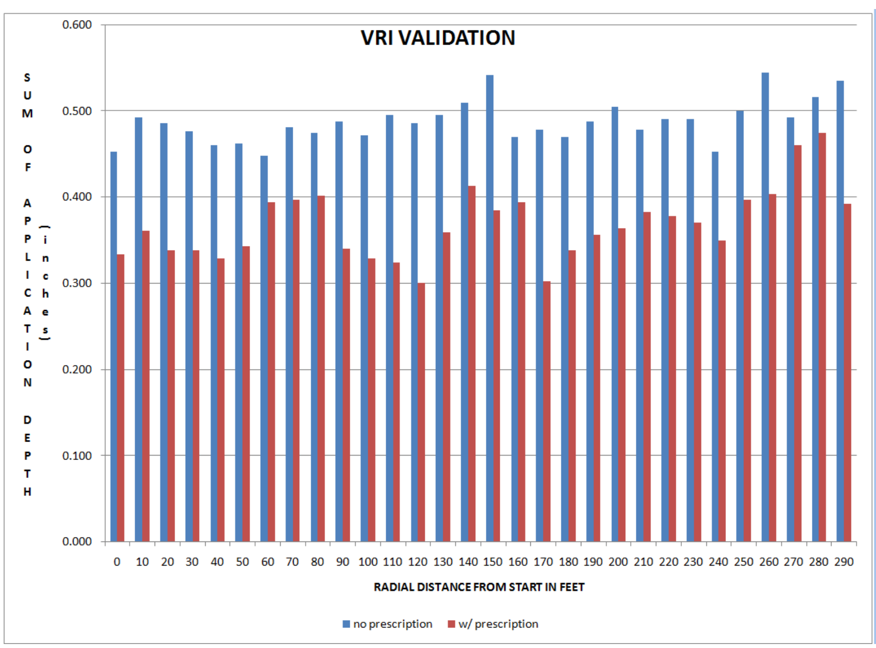


Figure 16

Catch can data is shown in figure 16. The blue bars represent the average of the three catch cans operating with no prescription and the red bars with a prescription of 100% - 50%. The sprinkler package used rotating pads on top of the pipeline.

Central Illinois

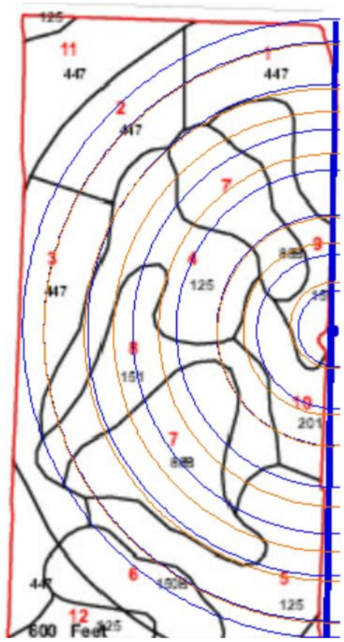


Figure 17 is an aerial image of the field used for initial planning purposes.

Figure 18 shows the soils map in relationship to the center pivot drive units and the VRI zones.

Figure 17

Figure 18

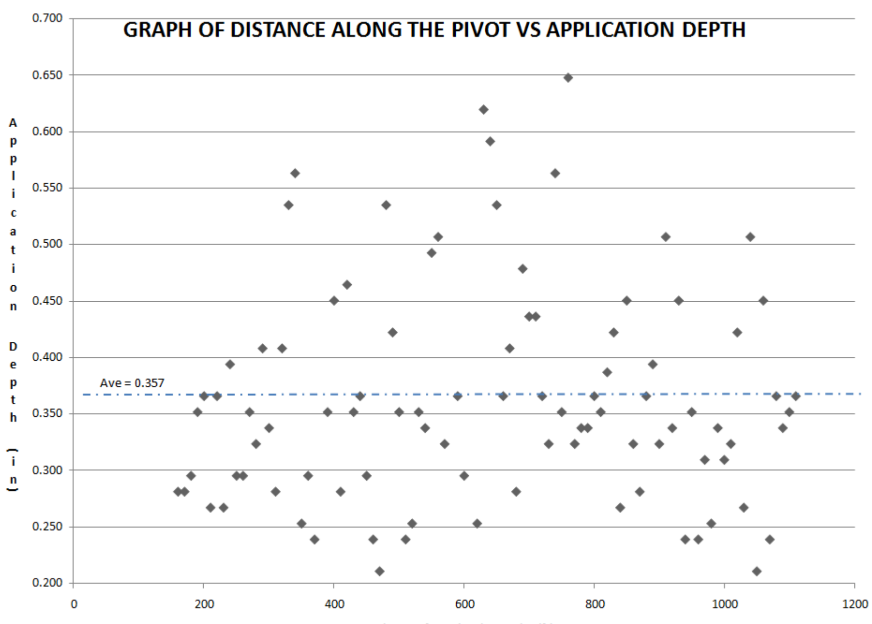


Figure 19

Figure 19 above illustrates a catch can test where the cans were set in a line 3m (10ft) apart parallel to the center pivot and the pivot run across the catch cans applying 12mm (0.50in) without a prescription running.

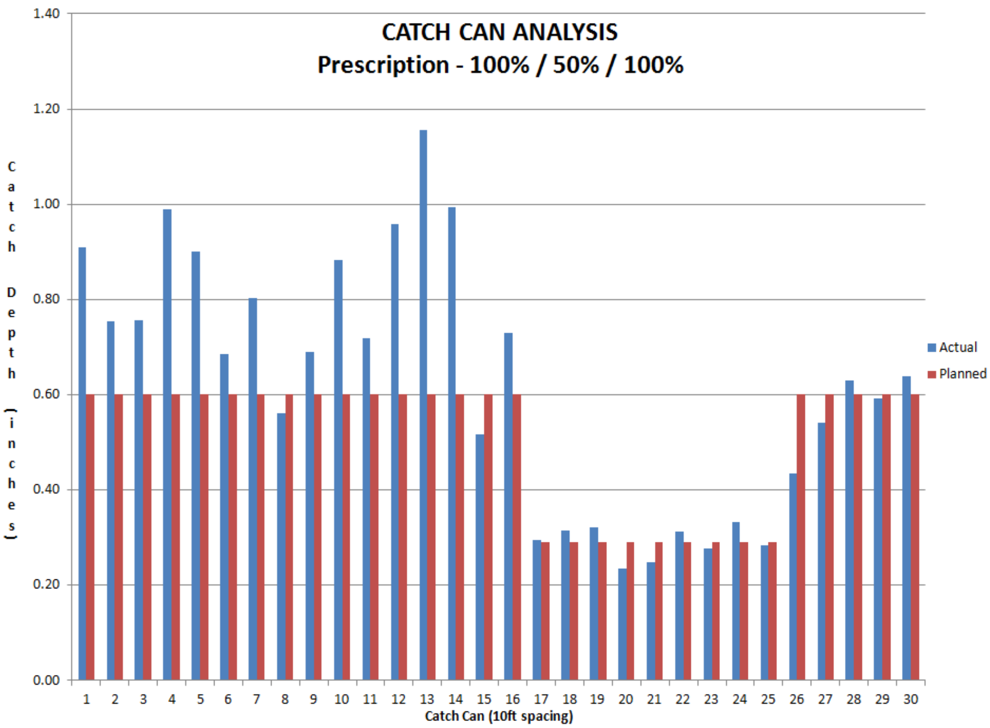


Figure 20

Figure 20 shows the average volume collected. The red line show planned and the blue the actual depth.

The sprinklers were fixed head sprays at 2m (6ft) ground clearance.

Started applying 15mm (0.60in) , switched to 4.5mm (0.30in) and then back to 15mm (0.60in)

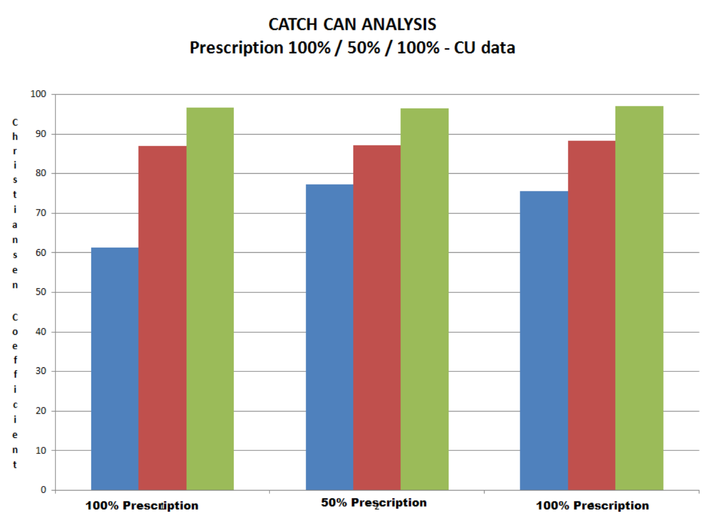


Figure 21

Figure 21 shows the Christiansen coefficient for each of the catch can segments at the various prescriptions

Conclusion

Historically, center pivot irrigation has treated the entire irrigated field the same and the goal has been to make uniform applications across the field. With variable rate irrigation, the farmer now has the ability to apply specific amounts of water to specific locations within the field. Preliminary work with validation of the performance in 2010 and 2011 indicate that while in general terms the zone control works as expected there are items that are not completely understood.

Sprinkler uniformity by catch can testing – along the center pivot. Only one good test was able to be run as shown in figure 19. This data indicated more scatter than we expected and a Heerman and Hein coefficient of 88.

Sprinkler performance in the direction of travel also was a challenge due to wind, crop growth and resources. Figures 12, 16 and 20 are the best examples of what happened in the direction of travel.

In figure 12 there are a couple of points to note:

- The transition between prescriptions appears to occur in about 6m (20ft)
- Both at 100% and 50% prescriptions applied a depth greater than expected
    - At the 100% it was determined there was an error in the panel constants which explains the difference
    - At the 50% setting even with the panel constant adjustment the difference is not totally understood. As soon as the crop is harvested additional tests will be run with more catch can tests to characterize the performance.
- The Christiansen coefficient shown in figure 13 shows good uniformity but a definite difference with higher values at 100% prescription and lower values when the nozzles are being pulsed on and off to achieve the 50% prescription which seems to make sense.

In figure 16 there is primary point to note:

- Due to the wide patterns of the rotating pad sprinklers on top of the pipe the transition is not visible between prescriptions and for tests to be meaningful need to run characterization with much larger zones.
- With vs. without prescription showed different application depths which is not completely understood and again needs more testing as the wind was at a higher speed then we would have liked for the without prescription and suspect the drift would account for the differences.

In figure 20 there are a couple of points to note:

- The transition between prescriptions appears to occur in about 6m (20ft) switch from 100% to 50% but 9m (30ft) when switching back to 100%. Again this was the best run due to wind and anticipate more testing this fall.
- Both at 100% and 50% prescriptions applied a depth close to expected

- The Christiansen coefficient shown in figure 21 indicates a difference between the lines which may be more related to the position in relation to the sprinkler head than anything. When pulsing, at 50% did not show significantly lower uniformity than at 100%.

Soil moisture grid sampling from figure 7 showed what was expected. At a reduced application depth the soil gradually dried out. As shown in figure 9 no trends were see which was true at the other sites due to rainfall refilling the profile.

Aerial imagery was not very informative as no trends were noted on the fields where a series of images were collected.

Based on the information collected in 2010 and 2011, there are a number of areas requiring additional work and evaluation:

- Validation and characterization of VRI zone control performance
    - Catch can tests
        - Show promise in providing information for specific units but require considerable resources to do and timing with crop and weather are critical in commercial fields
        - Considering possible ways to simulate
    - Grid soil moisture sensing shows promise and for 2012 want to continue with this same basic plan
    - Aerial imagery may not offer much to help evaluate and understand performance but also may have not gotten a fair opportunity in 2011.
- Need to explore more about sprinklers and how they relates to VRI performance.

References

AgSense LLC, 2011, Huron SD, http://www.agsense.net

American Society of Biological and Agricultural Engineers Standard 436

CropMetrics, 2011, North Bend Nebraska, http://cropmetrics.com

Perry, Calvin and Pocknee, Stuart. 2005. Enhancing Irrigation Efficiencies, NESPAL Vaable Rate Irrigation 2005 website, http://www.nespal.org/irreff/main.html, University of Georgia

King, B.A., Wall, R.H., Kincaid, D.C. and Westerman, D.T.. 2005. Field Testing of a Variable Rate Sprinkler and Control System for Site Specific Water and Nutrient Application, ASAE Soil and Water Division Transactions, American Society of Agricultural Engineers

Marek, Thomas and Auvermann, Brent. 2004. Irrigation Variable Rate Development, TAES-Amarillo, Texas Agricultural Experiment Station

Moody, Jimmy. 2010. - personal communication, Dyersburg Tennessee

Valmont Irrigation. 2010. – engineering and application departments, Valley Nebraska

Hobbs & Holder. 2006. Precision Irrigation Technologies, website, http://betterpivots.com/

Vories, Earl, Kitchen, Newell, Sudduth, Ken, Sadler, John, Griffin, Terry and Stevens, Gene. 2008. Using Precision Agriculture Methods to Predict Soil Suitability for Rainfed Corn Production, 2008 ASABE Annual International Meeting, Rhode Island, American Society of Agricultural and Biological Engineers, paper 084437