How to Determine the Type of VRI Best Suited for My Field

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***Abstract*.**
The center pivot has been used by a farmer/operator to apply a selected depth of water uniformly across the entire field. Currently several options are available from OEMs and third party's providing the grower the ability to apply different amounts of water and crop production products to defined management zones along the pivot's path and/or sectors around the field. The paper will discuss ways how to evaluate a field and determine which type of VRI, if any, will provide the best economic return for the field. Considered will be Speed Control, Zone Control and Individual Sprinkler Control. The paper will also review potential payback of several fields. It will close with a discussion of future needs for variable rate irrigation

Keywords. Center pivot, precision irrigation, VRI, variable rate irrigation, site specific irrigation

Introduction.

Since the introduction of center pivot irrigation in the mid 1960's, the goal has been to achieve uniform application of water both along the center pivot and in the direction of travel. In a field with uniform soil type, topography, tillage and crop health, this offers a good solution to the producer to maximize profitability. But, the agriculture community has since recognized that fields and crops are not necessarily uniform spatially or temporally. Machines to variably apply fertilizer, seed and other crop production products by management zones have become common in use. The major center pivot / linear irrigation manufacturers have followed to offer a range of hardware / software packages to meet the grower's interest in VRI. In addition some third parties offer VRI hardware and software. The available VRI packages fall into two basic categories:

- VRI speed: Varying the speed of the center pivot around the field
    - Application depth can be varied in the direction of travel by changing the speed of the center pivot
    - Application depth is uniform along the length of the center pivot
    - Overall flow remains constant through the center pivot (excluding the endgun)
- VRI zone: Controlling individual or groups of sprinklers.
    - Application depth can be varied in the direction of travel.
    - Application depth also can be varied along the length of the center pivot.
    - Overall flow varies as sprinklers are pulsed on and off in the direction of travel or along the center pivot.

It was stated in 2011 documented and proven water conservation strategies using variable rate irrigation are quite limited, and its cost-effectiveness has not been demonstrated by researchers (Evans 2011) in the last six years this has changed some. However many growers continue to look closely at VRI technology to determine the value it could bring to their operation. The potential values of VRI commonly considered are saving water, saving energy and improving yield but really the focus needs to be on overall field profitability. The questions still remains what tools are available to help me determine if VRI is a good fit for a particular field and the type of VRI which is best suited?

Discussion

As suggested by LaRue 2012, the solution for VRI decision making is a process. Based on recent experience this still seems to be true in 2018. The following is a process to help with the decision making by helping to understand the variability in the field. However if looking at adding VRI to an existing center pivot it is strongly recommended before you start to check the age and performance of your sprinkler package. You must start from a point of uniformity.

The first step is for the grower is to determine what he wants by answering a question – what does he want to accomplish? This is often done working with his irrigation dealer or farm consultant.

- Vary the application depth by management zone?
- Shut off irrigation completely for particular non-crop areas, such as ponds, drainage ditches, roads, etc.?

The second step is if the grower wants to vary the application depth by management zone is to determine sources of available data. The following is a manual way of doing. Your irrigation dealer or consultant can help with this. The data may include but is not limited to data from sources such as USDA NRCS soil maps, electro conductivity (EC_a) field surveys, yield maps and/or aerial images.

In the United States one of the easiest sources of data is NRCS USDA Web Soil Survey with an example represented in a field (Fig 1).

Mason County, Illinois (IL125)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
53B	Bloomfield sand, 1 to 7 percent slopes	2.9	0.7%
54B	Plainfield sand, 1 to 7percent slopes	4.0	1.0%
54D	Plainfield sand, 7 to 15 percent slopes	3.8	0.9%
54E	Plainfield sand, 15 to 30 percent slopes	13.3	3.3%
88B	Sparta loamy sand, 1 to 7 percent slopes	14.1	3.5%
88D	Sparta loamy sand, 7 to 15 percent slopes	56.6	14.1%
98B	Ade loamy fine sand, 1 to 7 percent slopes	6.3	1.6%
125	Selma clay loam	116.4	29.0%
131C2	Alvin fine sandy loam, 5 to 10 percent slopes, eroded	1.9	0.5%
150B	Onarga sandy loam, 2 to 5	4.9	1.2%

Figure 1. Graphical and tabular representation of the different soil types and area present in one field.

Continuing the second step, using the soil data, texture and area, one then can start to evaluate What needs to be done is to look at the soils and the area covered for both the finest textured and then the coarsest. These typically are the clays, silts and the sands and record their name, texture and area. One way to determine potential yields is to use crop productivity information. Since this field is in Illinois can use the Optimum Crop Productivity Ratings for Illinois Soil, (Olson 2000) (Figure 2). Other examples are Iowa Corn Suitability Rating (CSR/CSR2), Productivity Index (PI) in North Dakota, South Dakota and Minnesota and Nebraska Soil Rating for Pant Growth (SRPG) now replaced by NCCPI, National Commodity Crop Productivity Index. Other states have or are adding types of rating systems. Then look up the soil textures in fig 2, in the guide for soils with optimum management for the crop of interest, in this case corn and record the yield. One must assume most of the yield difference is attributable to lack of soil moisture.

Table S2. Productivity of Illinois Soils Under Optimum Management, Slightly Eroded, 0% to 2% Slopes

IL map symbol	Soil type name	Subsoil rooting[a]	Corn bu/ac	Soybeans bu/ac	Wheat bu/ac	Oats[b] bu/ac	Sorghum[c] bu/ac	Alfalfa[d] hay ton/ac	Grass-legume[e] hay ton/ac	Crop productivity index for optimum management	IL map symbol
109	Racoon silt loam	FAV	130	41	51	0	103	3.50	0.00	106	109
111	Rubio silt loam	FAV	139	44	57	70	0	0.00	4.29	114	111
112	Cowden silt loam	FAV	143	45	57	0	107	0.00	4.41	117	112
113	Oconee silt loam	FAV	148	45	57	0	107	0.00	4.75	119	113
115	Dockery silt loam	FAV	156	51	62	77	0	0.00	4.52	128	115
116	Whitson silt loam	FAV	142	45	54	68	0	0.00	4.29	116	116
119	Elco silt loam	FAV	136	45	53	68	0	3.84	0.00	112	119
120	Huey silt loam	UNF	98	38	38	0	86	0.00	3.16	89	120
122	Colp silt loam	UNF	121	38	51	64	0	0.00	3.84	98	122
123	Riverwash	Crop yield data not available									123
125	Selma loam	FAV	157	51	62	80	0	0.00	4.75	129	125
764	Coyne fine sandy loam	FAV	128	42	53	63	0	3.28	0.00	105	764
765	Trempealeau silt loam	FAV	136	46	54	70	0	3.28	0.00	113	765
767	Prophetstown silt loam	FAV	171	53	63	85	0	0.00	4.75	138	767
768	Backbone loamy sand	FAV	103	35	43	49	0	0.00	3.28	87	768
769	Edmund silt loam	UNF	106	37	50	58	0	2.60	0.00	89	769
770	Udolpho loam	FAV	124	41	50	66	0	0.00	3.73	103	770

Figure 2. Information from the Optimum Crop Productivity Ratings

Step three - For map symbol 125, the soil is Selma clay loam; from this, the estimated corn yield is 157 bu/ac. For map symbol 770, Udolpho fine sandy loam is the soil type and the estimated corn yield is 124 bu/ac. Knowing the area of each soil type, the potential impact of VRI to minimize under and/or overwatering can be estimated.

If the assumption is the lower yield of the Udolpho soil is primarily caused by under watering, and the available water for irrigation is not limited, there is a potential yield increase between Udolpho soils and others of 33 bushel on approximately 78.2 acres for a total of 2,737 bushels. For example, if the farmer uses VRI zone or individual sprinkler control, and if the price per bushel is $3.50, then his potential increase in income could be about $9,032. If the farmer uses VRI speed control, and he may experience a field corn yield increase and his potential increase in income could be $1,689.

By looking at the soil map, a “guess” can be made as to whether VRI speed will provide much benefit. Speed control does not appear to offer much potential. VRI zone or VRI individual sprinkler control would be the better choice for the field. Using a quote from you irrigation dealer you are in a position to estimate the ROI.

VRI Control Type		Years for Payback
Speed	assumes have to replace panel	2.9
Zone	assumes only need to add VRI hardware	3.3
Individual Sprinkler	assumes only need to add VRI hardware	4.6

These numbers reflect an assumption water is the main limiting factor, which is a simplistic approach.

As mentioned previously, the agriculture community recognizes that fields and crops are not uniform. Yield maps provide information on both a field’s yield and the location in the field where yield variability occur. Figure 3 is the same field as shown in Figure 1.   Yield maps help confirm soil information, as well as help to make decisions regarding the type of VRI package in which to invest, particularly if it is believed an area of the field may be improved and not under or overwatered.

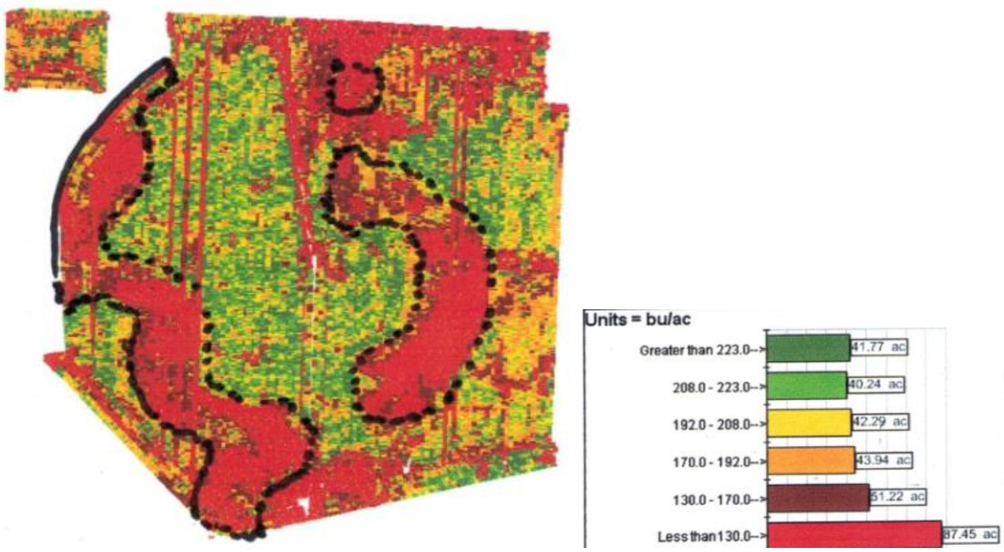

Figure 3. Yield map for field in figure 1

The yield map seems to confirm the assumptions and selections both the area more than estimated and the yields.

Figure 4 illustrates another example where the determination for VRI can be made visually via soil data.

Figure 4 Soil Map

The primary soils in this field are 8428A and 8070A, which are Ambraw clay loam and Beaucoup silty clay loam, respectively. The soils map does not show significant variability. Without a crop productivity guide or a yield map to help show specific variability or particular topographic features and the grower indicates only an 8 bu/ac variation in the Ambraw clay loam , the conclusion can be drawn that VRI may not be a good fit for this field. The ROI could be ten years or more, and, in most cases, would be hard to justify based on current economics. About 50% of the time it has been found the ROI for VRI does not meet the grower's requirements

Another approach is using automated generated prescriptions based on USDA SSURGO data as shown in (fig 5). If the assumption is the lower yield of the coarser texture soil is primarily caused by under watering, and the available water for irrigation is not limited, there is a potential yield increase between the coarser and fine textured soils. This is automatically calculated to be 15 bushel/acre on approximately 64.3 acres for a total of 965 bushels of corn. For example, if the farmer uses VRI zone it is estimated to be an additional $3,376 income or if individual sprinkler control an additional $3,554 assuming the price per bushel is $3.50. For this case due to the way the soils are aligned in the field VRI speed control is a good choice and may experience a corn yield increase and his potential income could be $2,701. The same cost assumptions apply has in the first example.

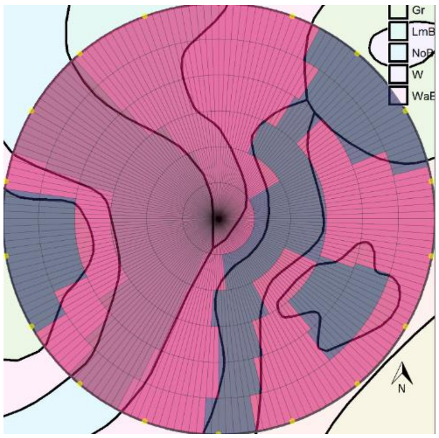

Figure 5 Automated Prescription

VRI Control Type	Years for Payback
Speed	1.8
Zone	8.8
Individual Sprinkler	11.8

A number of other options are available which automatically quantitatively evaluate a field's response to VRI. Consulting groups, such as CropMetrics™ and others offer tools using EC_a data, topographic and other sources of data to develop an estimate of the variability in the field. The assumption is if water can be applied to match the field's variability, then crop yields can be optimized and profits maximized.

Step four is to determine if the grower wants to, or should, proceed with a VRI package, and which VRI package is suited for his operation. This determination is evaluated via the information that has been collected, as well as the potential ROI.

If the farmer is water constrained, then the analysis will be different and the focus will be applying the optimum amount of irrigation on the management zones depending on the yield potential. In this case, more observation needs to be completed, so that better tools are made available to help evaluation the situation.

At the beginning of step one, the decision was made if the grower was looking to:

- Vary the application depth
- Shut off irrigation for particular areas, such as ponds, drainage ditches and other non-crop areas

During to the discussion and decisions for varying application depth, it has been determined that the grower should shut off irrigation for non-crop areas.

For cases such as this, an aerial image can typically be used to estimate the type of VRI package that is most suitable for the field. Either conventional aerial photographs, soil maps or other (Fig 6) are generally sufficient to make a determination of how to proceed along with the farmer experience. This may be utilization of VRI zone control, individual sprinkler control or other center pivot's existing features, if the pivot uses a computerized control panel. For these types of fields, VRI speed control will not generally meet the requirements. In this particular example to ensure no irrigation for non-crop areas individual sprinkler or zone control is best suited

Figure 6. Aerial image of field

The potential yield improvement is different for every field, as well as for every crop. Therefore, it is important to consider using your irrigation dealer, local consultant or advisor (assuming they have VRI experience) to help analyze each particular situation.

Conclusion

The use of VRI by farmers seems to have plateaued. Farmers who are considering VRI should follow a process to help determine the ROI of the various VRI options or if VRI is even the optimum solution. Farmers can use data to make manual estimates and/or work with their irrigation dealer and/or a consultant who can prepare a quantitative report on variability based on $EC_{a,}$ topographic, soils, yield and/or other data. With either, ROI estimates can be made. The steps to consider are:

- Determine whether want to vary the application depth for management zones scattered across the field or shutoff the irrigation for particular non crop areas.
- Decide to use either a manual or a service with an automated process to determine the type of VRI or use a consultant and software to utilize geo-referenced data
- Collect field information such as (but not limited to) soil, yield and EC_a maps and make analysis of ROI
- Make a determination of what type of VRI, if any, will best meet your particular field situation

Experience indicates the ROI of using VRI speed control can range from one to five years. Many of the center pivot control panels sold since 2010 include speed control as a function in the panel. The ROI of VRI zone control can range from three to twenty years. Also it is critical to remember the base prescription is a starting point and if varying water by management zone will need to be changed during the growing season.

Future work suggested is for additional information is needed to be supplied by states/regions to help estimate yields based on soil types and how limiting is water to yield. More observation needs to be completed to better characterize the impact of VRI with various soils, topographies, climates and other factors. Considerations also need to be made around limitations to available irrigation water. With this data and these tools, a better decision as to whether a farmer should use VRI speed, zone or individual sprinkler control can be made, as well as an estimate of the potential return on investment.

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