Variable Rate Irrigation:
The Next *Big Thing* in Irrigated Agriculture?

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Irrigation

Irrigation offers higher and more stable crop yields, and more crop choices. The 17% of the world's cropland that is irrigated produces 40% of the world's food. Alberta has almost two-thirds of Canada's one million hectares of irrigated cropland; Saskatchewan has 13%.

Since the 1890's there have been continual development of water sources and lands for irrigation in Canada, and continual technological and industry developments (e.g. higher value crops and value-added processing, irrigation scheduling techniques, nozzles and control systems). Major changes in irrigated agriculture in Canada include:

- From gravity to sprinkler irrigation: 1950's to 1970's
- Widespread adoption of centre pivot irrigation systems: 1970's
- Energy and water use efficiency improvements: 1980's to 2000's

Variable Rate Irrigation (VRI)

Soil and crop conditions vary widely within fields (Fig.1). Precision Agriculture utilizes various technologies to identify these variable conditions within the field, and to optimize operations and inputs to match. VRI is Precision Agriculture applied to irrigation - applying differing irrigation amounts to match crop water demands at a small scale within the field. Both soil/landscape mapping and real-time in-field monitoring can be used to estimate water requirement at each location.

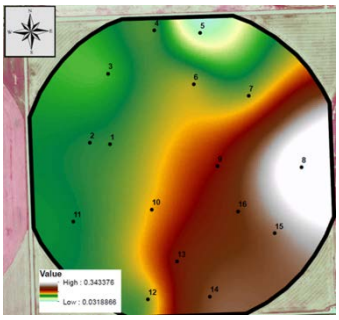

Figure 1. Field map of variation in soil moisture content.

The Equipment

Centre pivot irrigators are self-propelled mechanical move systems that apply water through sprinkler nozzles along the system as it travels around a central fixed ‘pivot’ point. To maintain uniform water application depths, sprinkler discharge increases moving out from the pivot point to account for the increased coverage area. But uniform application does not address the

inherently variable water demand in fields. VRI systems can, by adjusting application depths through cycling sprinklers on and off, thus varying the application duration and resulting depth of water applied.

A VRI system consists of a pivot irrigation system retrofitted with:

- Sprinkler control valves – water valves that open and close in response to a control signal, controlling individual sprinklers or defined banks of sprinklers;
- A pivot positioning system, usually a global positioning system, to locate the exact position of the pivot system within the field;
- An electronic control panel – processes the uploaded information provided by the operator, and sends control signals to the sprinkler valves in accordance with the pivot location in the field and the desired water application depth along the system.

Operators use provided software to develop a "prescription" to indicate the desired application depths for defined areas under the system (Fig. 2). Prescriptions are uploaded to the centre pivot's electronic control panel, which references the prescription when sending out control signals and cycles the signal to associated control valves to achieve the desired water application.

A simpler version of VRI offers only speed control, which varies water application amount by varying only the speed of the lateral as it circles the field. Managed zones thus extend the full length of the pivot from its centre to outer edge. For some situations this approach can produce some of the benefits of full VRI at much less cost and complexity.

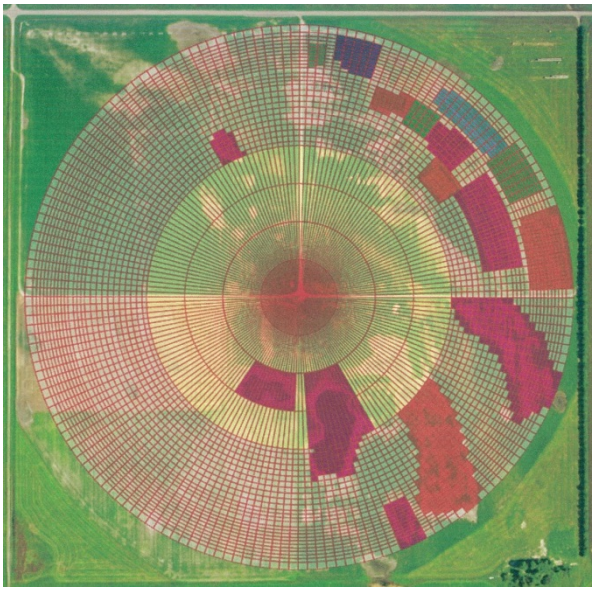

Figure 2. Diagram showing 5400 irrigation management zones in a field with VRI, and a prescription to vary irrigation amounts in areas of special soil types and research trials.

Opportunities and Benefits

- Increased yield - stresses due to drought and excess moisture are avoided; crop disease, lodging, and stress-related crop quality problems are reduced.
- Reduced water use - perhaps 5-15% in many fields, but more when and where there are substantial non-crop areas within the field. Associated savings in water cost may be less, depending on pricing structure. However, since irrigation uses 85% of all fresh water consumed globally, even small savings in irrigation water use are important.

- Reduced energy use - from reduced pumping at the field level, and from source to field. Associated savings in energy costs may be less, depending on pricing structures.
- Other problems associated with excess water are avoided - poor field trafficability, and nutrient loss by leaching and denitrification (with associated effects on the environment).
- Improved flexibility in laying out irrigation systems and fields (to avoid irrigation of non-crop areas, allow for system area overlaps, and accommodate any size and shape of field; Figs. 2 & 3).
- Potential to precision apply nutrients through fertigation.
- Improvements in water table, drainage, and soil salinity conditions, by better controlling leaching fractions and avoiding excess applications.
- Benefits vary widely from field to field and year to year, and most are difficult to quantify in financial terms. Some are long-term, and some accrue to society and the environment as a whole.

Figure 3. VRI system in use to irrigate plots separately within an irrigation study.

Costs and Challenges to Adoption

- Direct costs of the pivot modifications and control systems (currently approximately $15,000 to $40,000 for a quarter-section pivot, varying with the number of separate control zones used), maintenance, and upgrades.
- Water supply and pumps must accommodate varying water flow rates.
- Costs for field mapping (e.g. soil texture, drainage, salinity, topography, field boundaries, crop yield).
- Purchase of in-field sensors (soil moisture, crop, weather) and data from other sources.
- Time & costs for data processing, and developing prescriptions (may engage consultant).
- Adapting to complex technologies still in development stages.
- Limited information/research to-date to guide development of criteria for water application prescriptions.

Advancing and Adopting VRI

The major manufacturers of all pivot irrigation systems sold in Canada offer VRI systems. In the US approximately 200 pivot irrigation systems (0.1% of all pivots) have full VRI capability; most of these are not used for within-field zone-controlled crop water management. In Alberta there were two operational VRI systems in 2012; several more are to be installed in 2013, and a two-year project is underway to evaluate the effectiveness of two VRI systems. In Saskatchewan one system was in use in 2012 and two more are being installed for 2013 (at CSIDC-Outlook).

Currently, the cost to the producer for VRI is still relatively high, but resulting financial returns to him are uncertain. The technology is at an early stage, especially for developing prescriptions. Consequently, a cautious rate of adoption of VRI by producers might be expected. Most systems may be purchased to respond to special situations such as high value sensitive crops, small or irregular fields, very high field variability, or limited water supply.

For a recent review of the status of VRI see: Evans G, LaRue J, Stone KC, King BA (2012) Adoption of site-specific variable rate sprinkler irrigation systems. Irrigation Science. DOI 10.1007/s00271-012-0365-x.