Preliminary Quantification of Variable Rate Irrigation's Benefits

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Introduction

- Variable rate irrigation (VRI) can tailor water deliveries to each part of a field based on site-specific crop, soil, terrain, and management characteristics, yet the magnitudes of its benefits have not been well-quantified.
- This project compares VRI with well-managed uniform rate irrigation (URI) while assuming these prices:
  - Typical marginal costs of irrigation pumping are $6.87/ac-ft with 6.24¢/kWh standard electricity service and $3.32/ac-ft with 12.70¢/kWh standard electricity service (NASS, 2014; NPPD, 2014).
  - Anhydrous ammonia, 82% nitrogen (N), cost $39.60/lb of N whereas urea ammonium nitrate (UAN), 28% N, cost $57.16/lb of N (Knorr, 2015).
  - Farm prices of corn average $3.57/bu (Westcott and Hansen, 2015).

Energy Cost Savings

- Avoidance of uncropped areas
  - If average seasonal gross irrigation over the 56-acre example field is 6”, then $33-$62 would be saved each year by not irrigating uncropped areas that comprise 2.7% of the total area under the center pivot (left).
- Reduction of irrigation over soils with larger root zone water holding capacities in order to allow greater extraction of initial soil water captured from natural precipitation
- If the withheld volume is not applied elsewhere, estimates based on soil survey data (NRCS, 2014) and a center pivot map (CALMIT, 2007) suggest annual savings exceeding $200-$408, $433-$888, and $693-$1,420 for 10%, 15%, and 20% of Nebraska’s center pivots not under Natural Resources District-wide groundwater allocations (right).
- If such withholding enables a shift from standard to anytime interruptible electricity service without causing water stress, then up to $13-$26 would be saved each year on a 120-acre field with 10” of average seasonal gross irrigation.

Agrochemical Cost Savings

- Decrease of N losses through leaching
  - If leachate contains 24 ppm of N (Klocke et al., 1999) and if annual leaching is reduced by 4” over the silt loam areas of an 120-acre field that is 90% silt loam but had been managed as sand under URI, then 11 lb/ac less N would be lost through leaching in the silt loam areas, which equals annual savings of $464-$669.
- Public costs (e.g., environmental degradation and drinking water treatment) of N loading were not included here, but their consideration may become increasingly important if N pollution problems worsen.
- Lowering of application costs while complying with avoidance zones (e.g., open water)
  - Assume 1 pesticide application and 1 or more mid-seasom fertilizer application(s), totaling 60 lb/ac of N after 140 lb/ac of N pre-planting, on an 120-acre field.
  - If ground vehicles are used, custom rates (excluding chemical costs) are $6.81/ac for sprayer and $3.29/ac for anhydrous ammonia applicator (Wilson, 2014).
- If chemigation is used to apply pesticide and UAN with a total of 1” of water, equipment and maintenance costs may average to $700 per year (W. L. Kranz, personal communication, 2015).
  - Here, chemigation would save $109-283 each year; also, its timing is easier amidst weather uncertainties.

Yield Improvements

- Transfer of irrigation water away from fully-irrigated soils and onto deficit-irrigated soils:
  - Interannual variability in irrigation requirements is generally larger than spatial variability in readily plant-available water within a given field.
  - Thus, field-average yield may be increased merely by less than 2 bu/ac or $857 per season in the long term on an 120-acre field under mild single-year groundwater allocations; however, little to no benefit is foreseen under severe multi-year groundwater allocations.
- Minimization of yield losses due to over-irrigation:
  - Excessive water can encourage N losses, promote plant diseases, and impede root growth and function (Irmak, 2014).
  - If a 8-15 bu/ac reduction in corn yield (Irmak, 2014) had been suffered by the silt loam areas of an 120-acre field that is 90% silt loam but had been managed as sand under URI, then revenues could be raised by 53,084-$85,783 per season.

Future Work

- Apply some of these estimates to Nebraska’s center pivots and communicate the results to stakeholders.
- Explore the role of VRI when system capacity is low.
- Develop or adapt mechanistic models to predict over-irrigation’s impacts on N and yield.
- Incorporate soil moisture, crop status, and evapotranspiration data from ground-based, aerial, and satellite sensors to inform in-season VRI management.

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- Irmak, S. (2014). Plant Growth and Yield as Affected by Wet Soil Conditions Due to Flooding or Over-Irrigation. Nebraska Gary. Lincoln, Neb.: University of Nebraska–Lincoln.
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