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Spectral Vegetation Indices to Quantify In-field Soil Moisture Variability

J. Siegfried, R. Khosla, and L. Longchamps

Department of Soil and Crop Sciences, Colorado State University, Fort Collins, CO 80523-1170

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Abstract. *Agriculture is the largest consumer of water globally. As pressure on available water resources increases, the need to exploit technology in order to produce more food with less water becomes crucial. The technological hardware requisite for precise water delivery methods such as variable rate irrigation is commercially available. Despite that, techniques to formulate a timely, accurate prescription for those systems are inadequate. Spectral vegetation indices, especially Normalized Difference Vegetation Index (NDVI), are often used to gauge crop vigor and related parameters (e.g. leaf nitrogen content and grain yield). However, research heretofore rarely addresses the influence of soil moisture on the index. The objective of this study was to determine if NDVI derived from satellite imagery could assist in quantifying soil moisture variability in an irrigated maize production system. A variable rate irrigation pivot was used to form six water treatment zones. Each zone was equipped with a set of tensiometers installed in the center of the plots at 20, 45, and 75cm depths to individually monitor conditions in the water treatment zones. Water was applied for each treatment as a percentage of the estimated evapotranspiration (ET) requirement: i.e., 40, 60, 80, 100, 120, and 140 percent of the ET. Data collected from tensiometers was paired with the image pixels corresponding to the ground location of the tensiometers. Statistical analysis was performed separately to assess whether NDVI is representative of soil moisture at several crop growth stages. Findings from this study indicate that NDVI could quantify variability of soil moisture tension at maize crop growth stage R3 (milk) at 20cm (r^2 = 0.70, p = 0.04) and 45 cm (r^2 = 0.77, p = 0.02) depths. Results suggest that NDVI may be useful for evaluating seasonal soil moisture variability due to irrigation non-uniformity at large field-scales but is otherwise impractical for variable rate irrigation management. Further study is necessary to investigate additional crop growth stages, more crops, and other vegetation indices. Future studies are also needed to evaluate other sources of multispectral imagery.*

Keywords. *NDVI,RapidEye,satellite,multispectral,VRI,irrigation.*

Introduction

To meet the increasing demand of rapid population growth, the world's agriculturalists are tasked with producing more food, fuel, and fiber with fewer resources. Irrigation covers only about twenty-percent of cropland worldwide, yet it is responsible for over forty-percent of total food production (FAO, 2016). Agriculture already places a heavy burden on available water resources. Precision Irrigation, which uses variable rate technology to adjust the amount of water applied within different parts of a field, is one part of a broader solution to produce more with less water. Although commercial systems are available, techniques to create a water prescription for use with those systems lacks a temporal component to adjust for variability of soil moisture over time.

Remote sensing data availability has vastly increased due to advances in technology, and spatial and temporal resolutions have improved considerably. Very few studies have addressed the use of multispectral data for monitoring soil moisture, and those have utilized shortwave infrared, microwave, or thermal data (Clarke, 1997; Engman, 1991, Li et al., 2001). The objective of this study was to determine if NDVI derived from satellite imagery could quantify soil moisture variability in an irrigated maize production system.

Materials and Methods

This experiment was conducted over the 2015 maize growing season at a site located in northeastern Colorado. A variable rate irrigation pivot was used to form six water treatment zones. Tensiometers were installed in each zone at 20, 45, and 75 cm depths. Water was applied for each treatment as a percentage of estimated evapotranspiration: 40, 60, 80, 100, 120, and 140%. NDVI was calculated from orthorectified RapidEye™ satellite imagery and the image pixels were paired with soil moisture tension data at each ground location of the tensiometers. Soil moisture tension was averaged from planting until the time of image acquisition. Linear regression analysis of soil moisture tension on NDVI was performed to determine whether NDVI was representative of soil moisture conditions at several crop growth stages.

Results

The NDVI values acquired at the R3 (milk) reproductive crop growth stage had negative linear relationships with soil moisture tension measured at 20cm ($r^2 = 0.70$, $p = 0.04$) and 45cm ($r^2 = 0.77$, $p = 0.02$) depths. Water content was bound more tightly to the soil where NDVI values were lower in the image. However, NDVI values did not have strong relationships with soil moisture tension during the vegetative growth stages. NDVI shows promise for quantifying long-term soil moisture tension variability, but it does not seem to be suitable for single time points.

Conclusion

Soil moisture tension was moderately correlated with NDVI during the R3 (milk) reproductive growth stage of maize. Results indicate that NDVI could be used to evaluate within-field soil moisture variability due to irrigation non-uniformity: However, NDVI is otherwise impractical for time-sensitive variable rate irrigation management. It is important to investigate other spectral vegetation indices, more crop growth stages, and other crops. Further study is needed to evaluate other sources of multispectral imagery, such as those acquired from Unmanned Aerial Systems.

References

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