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Summary

Nowadays, good agronomical practices demand the adoption of new technologies that deliver better resource efficiency. The objective of this study was to identify and work closely with high-yielding soybean farmers in order to implement precision agriculture tools, in this case, satellite imagery. A field of 150 acres located in Perry, KS, was evaluated in the 2016 season. The study is based on working with the field variation and the selection of three productivity zones outlined according to normalized difference vegetation index (NDVI) values. *In situ* methods of data collection were performed across the entire field and data from vegetation indices (VIs) were extracted from Landsat 8 satellite (American Earth observation satellite) imagery. Results demonstrated a strong relationship between soybean dry weight (plant biomass) and NDVI. Satellite imagery proved to be a useful tool for delineating productivity zones. A precise and adequate management per zone can be planned via the use of satellite imagery.

Introduction

Vast information about crop health and development can be obtained via characterization of the temporal and spatial variability in the field; for example, with the use of satellite imagery. Satellite imagery may provide crucial information that could potentially influence the decision-making process related to all farming inputs, such as fertilizer, seeding rate, genotype selection, pesticide application, and others. Biomass data have proven to be a useful indicator of crop growth. Nevertheless, methodology of biomass collection can be time-consuming, labor-intensive, and destructive. Past research has demonstrated that remote-sensed crop characterization via collection of vegetation indices (VIs) presented a strong relationship with biomass, leaf area index, and yield. One of the most commonly used VIs is the normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI). The NDVI is an index that reflects the greenness of plant canopy at a specific growth stage. The EVI is basically an improved NDVI index, which is more sensitive to differences in vegetation.

The main objectives of this study were to: 1) explore the potential use of satellite imagery to identify productivity zones and evaluate soybean development across the growing season at the on-farm scale, and 2) explore relationships between satellite imagery data and ground-truth-based plant traits, such as plant growth and final yield.

Procedures

Sites Description

The evaluated sites were located in Muscotah, Perry, Morganville, and Gypsum, KS. For the purpose of this report, the focus will be on Perry, KS (39°3'23.544' N 95°23'18.5244' W). The size of the field at the Perry location was approximately 150 acres. For this observational experiment, no treatments were established. Agronomical practices were those suitable per site according to the cooperating producer.

Determination of Productivity Zones

A map defining three productivity zones was elaborated with 2015 NDVI data obtained from satellite imagery of the previous crop (corn-soybean rotation). The zones were classified as high productivity (HP), medium productivity (MP), and low productivity (LP) (Figure 1). The HP, MP, and LP zones contained 40, 60, and 50 acres, respectively.

In Situ Data Collection

Measurements were conducted by weekly intervals, allowing three sampling times for each site. During the growing season, measurements were done at multiple phenological stages – five-leaf (V5), full-bloom (R2), and beginning of maturity (R7). At each phenological stage, sampling was performed following the geo-located points in the field assigned to each productivity zone before the planting time. A total of three representative geo-referenced sampling points were established per productivity zone. Measurements were done on a plot (size, 50 ft long by 10 ft wide) per each productivity zone; the plot was divided into three equal parts to obtain replications within each zone. A total of 9 plots per productivity zone were sampled throughout the growing season. GPS coordinates were collected from each corner of the plot to identify the location and exact size of the sampling area. Seasonal measurements performed were plant biomass, light interception (LI-COR LI-1500), leaf area index (LI-COR LAI-2200CC), stand count on 5 ft, nodule count of 5 roots, SPAD chlorophyll readings, and soil samples. Biomass sampling was collected from an area close to 500 sq. ft. All plants located in that zone were cut at the stem base and weighed for fresh weight determination. A subsample of 5 plants was collected for dry weight purposes, dried until constant weight.

Satellite Data and Analysis

For the map with NDVI of 2015, VI values and amplitude were classified by equal area quantiles using the Geostatistical Analyst in ArcGIS 9.3.1. Imagery and VI data were downloaded from Landsat 8 satellite. A quadratic non-linear regression was tested and fitted to analyze the relationship between NDVI obtained from satellite imagery versus in-situ plant biomass trait.

Results

The comparison between the past-season productivity map and mid-season NDVI calculated from the satellite imagery shows that the MP and HP zones are similar, but a more visible difference was noticed relative to the LP zone (Figure 1). The LP zone reflects a lower NDVI at the full-bloom stage for the soybean crop.

Cumulative precipitation during growing season was approximately 30 inches, which is below the average annual precipitation for the region, ranging from 36 to 38 inches (Figure 2). Precipitation was scattered through the growing season with a lapse of 12 days of no rain when soybean was starting to flower (R1), which can be crucial for soybean development. Seasonal EVI curve reached not only higher values for the HP zone but also attained the peak earlier than the LP zone (Figure 2). Differences among productivity zones can be attributed to the topography and soil characteristics of the field.

The soil texture per zone was analyzed in the beginning of the growing season; data indicate that HP was silt loam and LP and MP were loam. Organic matter ranged from 1.1 to 2.3% across the whole field; LP zone had lower values than MP and HP zones across the three samplings. The main difference encountered per productivity zone was pH. Low productivity zones' pH ranged from 7.6 to 8 (Table 1), which is an alkaline pH and can compromise nutrient availability to the plant. The critical level for soil phosphorus (P) in Kansas is 20 ppm. The zone with the lowest soil P values during the three conducted samplings was HP; 24.7 ppm on soybean vegetative stage, 16 ppm at R2 stage of soybean, and 24.3 ppm during R7 (Table 1). The maximum availability of P is between pH 6 to 7; at pH above 7.5, phosphate ions tend to react with calcium (Ca) and magnesium (Mg) and form less-soluble compounds. Soil P values on HP productivity zone ranged from 16 to 24.3 ppm in comparison to LP zone, which ranged 38.7 to 42.3. These results may indicate that in the high-productivity environment, plants have depleted the soil P, but in the low-productivity environment, there has probably been less P absorption due to the diminished availability in relation to the high soil pH. Soil potassium (K) in the field was close to the minimum threshold assessed for Kansas (130 ppm) but none was below.

An apparent difference was not evidenced on the early vegetative stage. A trend was observed at the full bloom (R2) and beginning of senescence (R7) phenological stages; where HP zone tended to be higher than the LP zone (Figure 3). A difference of 9,464 lb/a existed between HP and LP zones at R2 stage and 5,268 lb/a at R7 stage. High productivity zone was 38% and 17% above the MP zone at R2 and R7 stage, respectively.

A strong relationship was found between NDVI calculated from the mid-season satellite imagery and measured biomass, plant dry weight. The coefficient of determination (R^2) for this relationship shows that the NDVI accounts for 86% of the variability on the plant biomass variation. Larger differences were documented between HP and LP zones (Figure 3).

Conclusion

A strong relationship was found between NDVI calculated from a satellite imagery and soybean plant biomass, portraying satellite imagery as a useful element for plant growth; nevertheless, yield data should be analyzed in the future for decision making. Satellite imagery is a promising technology that can help producers characterize on-farm variability, define management zones and improve site-specific management, optimizing resources and lowering costs. Soil characteristics were an important aspect to verify for understanding the different environments within the field. After management zones are clearly defined, on-farm seeding rate and fertilization studies must be conducted to determine optimum inputs.

Table 1. Soil chemical analysis per productivity on each sampling time at Perry, KS, during the 2016 growing season

Stage	Zone	Organic matter	pH	Phosphorus	Potassium
		%		----- ppm -----	
V5	LP	1.3	8.0	38.7	145
	MP	1.4	6.8	35.3	151
	HP	2.0	5.8	24.7	191
R2	LP	1.1	7.9	28.7	133
	MP	1.8	7.0	46.7	214
	HP	1.7	6.5	16.0	153
R7	LP	1.1	7.6	42.3	130
	MP	2.3	7.2	48.0	200
	HP	2.2	6.9	24.3	154

Soil sampling was done at different stages on different spots of each productivity zone.

Five-leaf (V5), full-bloom (R2), and beginning of maturity (R7).

High productivity (HP), medium productivity (MP), and low productivity (LP).

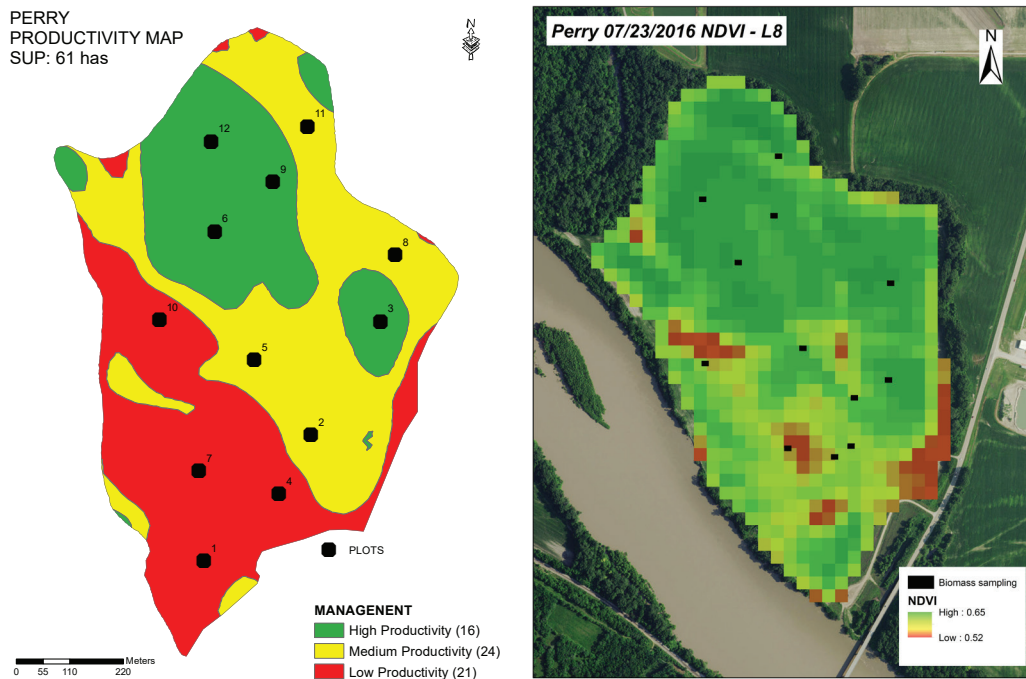


Figure 1. Productivity zone map of 2015 data (left) and mid-season (R2 phenological stage) normalized difference vegetation index (NDVI) map of 2016 (right) soybean growing season at Perry, KS, site. Black spot indicates the sampled plots.

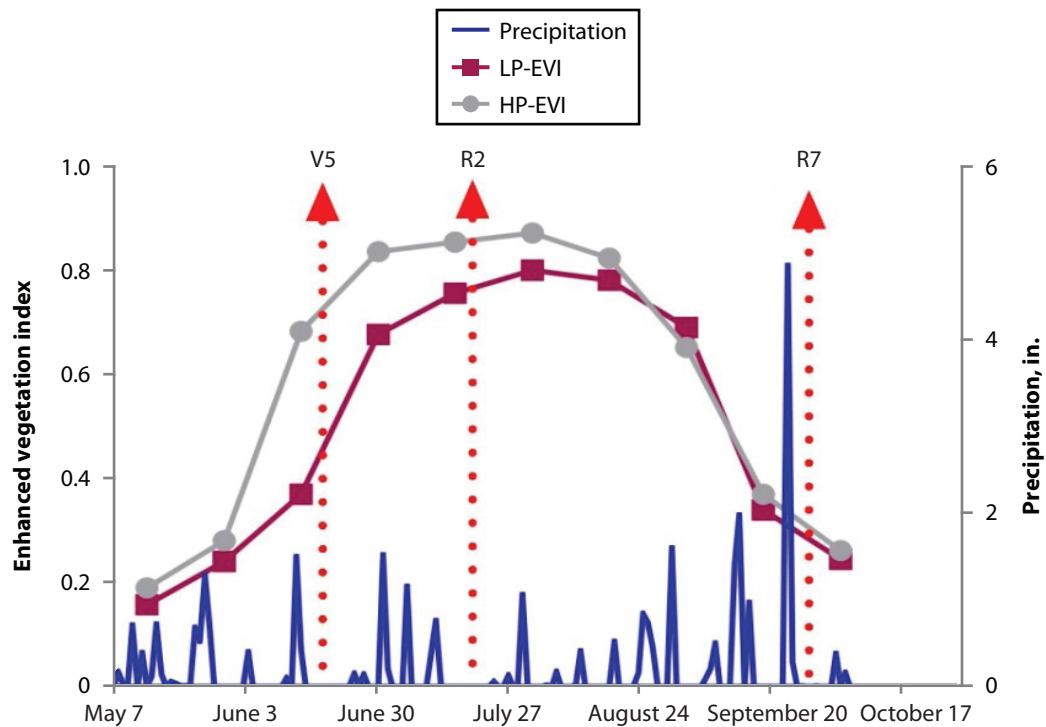


Figure 2. Enhanced vegetation index (EVI) for high productivity (HP) and low productivity (LP) zones along with precipitation data for the Perry, KS, site during the 2016 soybean growing season.

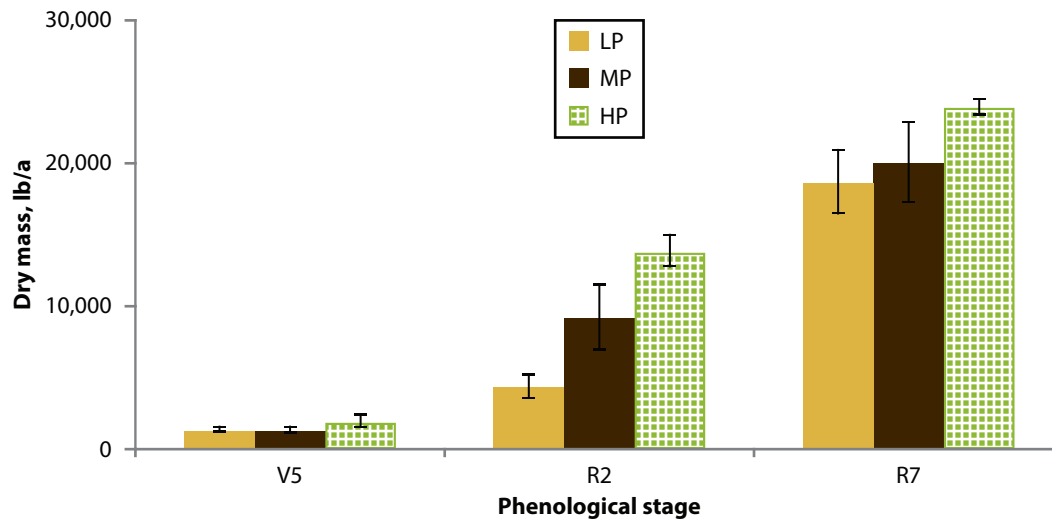


Figure 3. Dry biomass categorized by productivity zones, high productivity (HP), medium productivity (MP), and low productivity (LP), for three sampling times during soybean five-leaf (V5), full-bloom (R2), and beginning of maturity (R7) phenological stages.

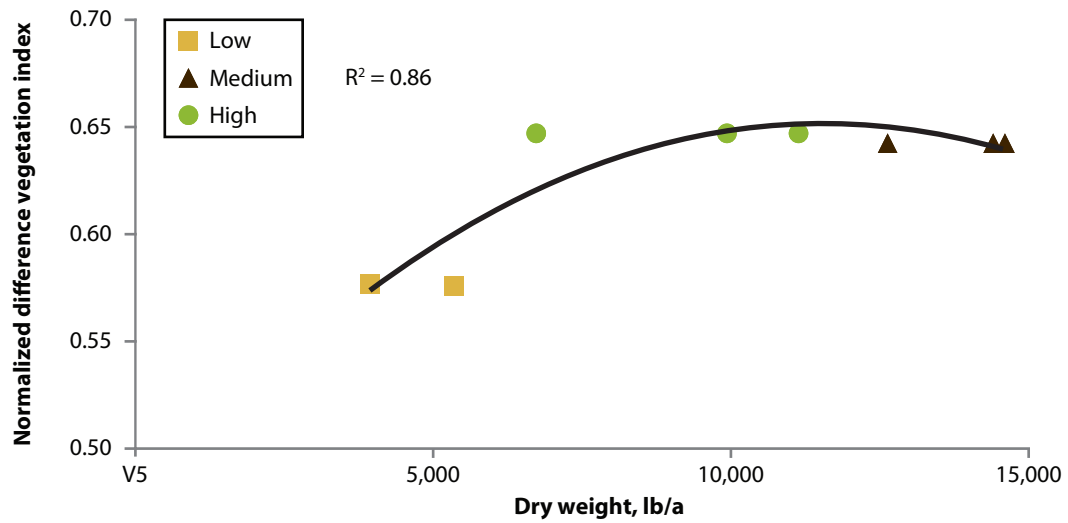


Figure 4. Relationship between normalized difference vegetation index (NDVI) and the soybean plant dry weight. Observations performed at R2 (full bloom) phenological stage sampling were used to illustrate the relationship.