Mapping Variations in Corn Growth in a Rain-Fed Crop Field using Growing Season NDVI and NDMI Images

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Abstract

Relying on spring and summer rainfall, numerous Illinois farmers grow corn and soybeans. As a result, farmers cannot precisely manage their crops' water intake and are interested in monitoring crop growth and uniformity within each field. Using Landsat-derived Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) images distributed by the US Geological Survey for the 2023 growing season growth in a 29.2-hectare field planted to corn and a 93.5-hectare field planted to soybeans were monitored. Visual and spectral analyses of the NDVI and NDMI images revealed that variations in crop growth were related to changes in elevation, which corresponded to the water holding capacity at higher and lower elevations. The NDVI and NDMI images identified the repairs done to a tile in spring 2023 as well as wet and nonproductive areas within the fields.

1. Introduction

In the state of Illinois (USA), many farmers rely on precipitation to irrigate their fields during the growing season instead of supplemental irrigation with sprinkler or pivot techniques (Bridges, et al 2014). Landsat derived spectral indices can be used to identify problem areas within a field that have a lower greenness or moisture content (Groten et al. 1993).

Landsat images and spectral indices provided by the United States Geological Survey (USGS) can be downloaded at no-cost (https://www.usgs.gov/landsat-missions/product-information). Spectral indices pertinent to analysing the greenness and moisture content of fields are the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Moisture Index (NDMI) (Groten et al. 1993). The NDVI is used to measure crop vigour/health and the NDMI is used to measure moisture content of the crop. NDVI and NDMI can be downloaded directly with no need to download individual spectral bands and calculate these indices from respective bands. These indices are used for scouting purposes as well as early detection of problems, such as drought, excess moisture in the form of flooding, disease or blight, in addition to physical damages. Problem areas within a field can also be identified via other methods, most commonly by physically scouting and investigating the field, or drones.

The primary objective of this project was to observe and map variations in growth in two fields in Illinois during the 2023 growing season. NDVI and NDMI images were analysed along with reference data obtained from the farmers reports from the year 2023 to investigate the utility of the Landsat-derived spectral bands instead of the multispectral bands.

2. Methods

2.1 Study Area

The two fields were in Kane County Illinois. field 1 was 29.2 hectares and planted to corn (*Zea mays*) in 2023 whereas field 2 was 93.5 Hectares and planted to soybeans (*Glycine max*) in the same year.

Figure 1. Satellite Image of Field 1

Photo Curtesy of Google Maps

Field 1, slopes downward from both east and west sides, with a stream running north-south and cuts east around halfway down the field, ultimately going into the adjacent field. The northwest corner is slightly elevated compared to the rest of the field. A residential plot sits on the northeast corner of the field, and south of the resident, another small high point existed. The southern half of the field was relatively flat and had a drain tile repaired during the spring of 2023. This field has historically been planted to both corn and soybeans. Field 1 was planted to corn on 11 May 2023.

Field 2 was relatively flat across the width of the field except for a wet spot in the centre of the field. This low point is non-productive. The field contains two residential areas on the northern edge of the field. No additional problems related to drainage were reported. This field has historically been planted to both corn and soybeans. Field 2 was planted to soybeans on 13 and 14 April 2023.

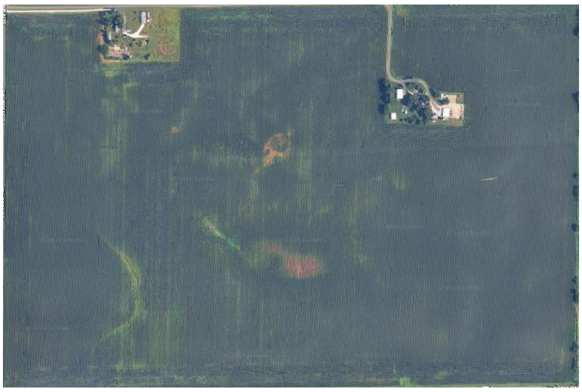

Figure 2. Satellite image of Field 2

Photo Curtesy of Google Maps

2.2 Materials

NDVI and NDMI raster images derived from the following Landsat 8/9 OLI/OLI 2 multispectral images (WRS2 2331) are listed in Table 1.

Landsat Scene ID
LC08_L2SP_023031_20230628_20230711_02_T1
LC08_L2SP_023031_20230714_20230724_02_T1
LC09_L2SP_023031_20230722_20230802_02_T1
LC08_L2SP_023031_20230815_20230819_02_T1

Table 1. Scene IDs of the Landsat image and their acquisition and processing dates. USGS derived vegetation (NDVI) and moisture (NDMI) indices from these Landsat images.

The spatial resolution of spectral indices was 30m and the revisit time of each satellite is 16 days (USGS 2020). Combining data from both satellites can reduce the revisit time to 8 days.

During the 2023 growing season, four usable growing season images were collected, each attributing to differing levels of crop development, these dates are 28 June, 14 July, 22 July, and 15 August 15 (Table 1).

2.3 Methods

Images were subset to the boundary of each field and were classified using Model Maker in ERDAS 2023 (Hexagon Geospatial, 2023). A threshold-based classification was applied due to its consistency across the fields and times of year, as the same NDVI value will be represented as the same color across images. Threshold-based classification is effective at identifying and separating croplands (Lucas et al. 2007). The classification was used to assign pixels in spectral index image into twelve classes, in 0.05 NDVI value increments (Fig.3) from 0.40 to 1.00 values. With pixels under the 0.40 NDVI value becoming background pixels

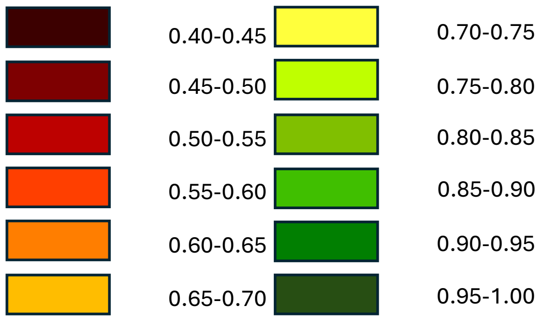

Figure 3. Threshold values used to classify the NDVI images

The twelve classes were then color-coded ranging from dark green at 1.00 NDVI value to maroon at 0.40 NDVI (Fig. 3). These classes were coarsely classed, in 0.05 value increments to identify detailed changes and problem areas within the field. NDMI images were used for interpreting the classified NDVI images but were not classified.

3. Results

3.1 Field Development

The early season NDVI values were low but even averaging 0.50-0.65 for both Field 1 and Field 2 on June 28th (Fig. 4). At this time in the field the crops had a mostly complete canopy, and the corn was reaching its middle vegetative stages, the soybeans were in their early reproductive stages. The rainfall for this time of year was below average, and the crops were in a relatively fair condition (USDA-NASS 2023).

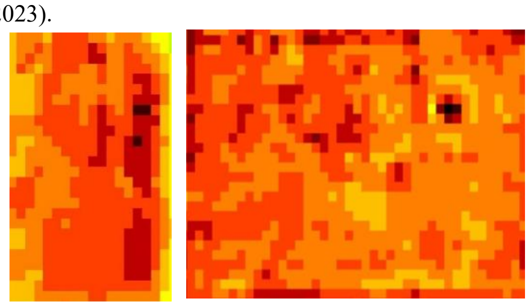

Figure 4. 22 June 2023 NDVI values for Field 1 (left) and Field 2 (right) showing early growing conditions.

The mid-season arose to standard growth across both fields, with some low NDVI areas concentrated in low and high elevations averaging 0.75-0.85 NDVI across fields (Fig. 5). The corn is in its early reproductive stage, and the soybeans are in their middle reproductive stage. Rainfall stabilized and average crop condition improved (USDA-NASS 2023).

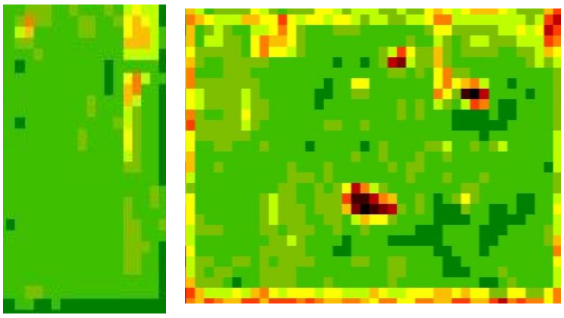

Figure 5. 14 July 2023 NDVI values for Field 1 (left) and Field 2 (right) showing early (corn) and middle (soybeans) growth stages.

Prior to crop drying and harvest, 15 August, NDVI values largely stabilized and had consistent high values averaging 0.90-0.95 NDVI with the crops in their late reproductive stages (Fig. 6). Known problem areas and residential areas were the only pixels with low NDVI readings.

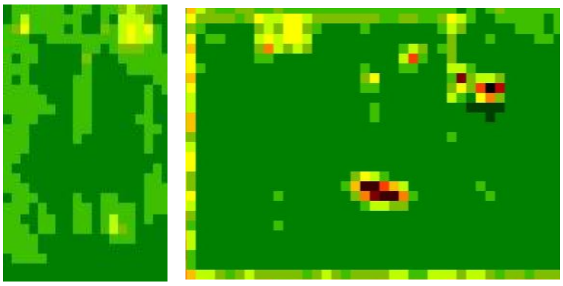

Figure 6. 15 August 2023 NDVI values for Field 1 (Left) and Field 2 (right) showing late reproductive stages for both crops.

3.2 Field Anomalies

In the NDVI and NDMI acquired on 22 July 2023 an anomaly was present in the north-west sector for Field 1 that caused an unexpected decrease in NDVI values from the average 0.85-0.95 to the 0.55-0.60 range in the affected area (Fig. 7 – middle). NDMI image also showed a random drop (Fig. 7 – right). This recovered by the next image on 15 August 2023.

However, no random decrease in NDVI values were noticed in Field 2 and had continued consistent growth (Fig. 8).

4. Discussion

4.1 Field Development

The overall field development across the 2023 growing season can be termed as 'normal' and resulted in an effective

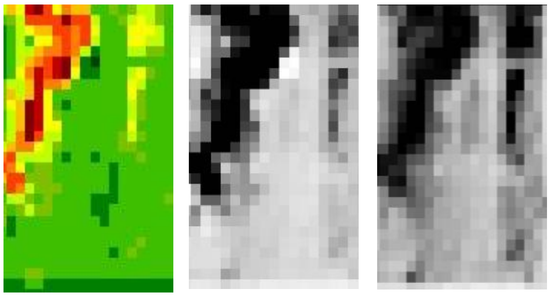

Figure 7. 22 July Classified (left) and raw (middle) NDVI values for Field 1. Raw NDMI values (right) show similar pattern.

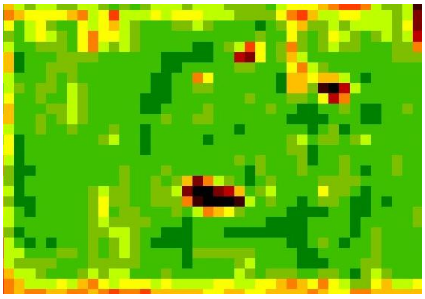

Figure 8. Classified NDVI image (22 July 2023) showing low values/spots at known location.

yield. The problem area within Field 2 was previously known. The large spot within it produced little to no crop and is often waterlogged. Despite the anomalies in Field 1, the retrospective use of the growing season imagery proved to be accurate in identifying problem areas within the field, namely in Field 1, and tracking a standard growth year.

4.2 Anomalies in NDVI and NDMI Images

In the 22 July 2023 image for Field 1, in both the NDVI and NDMI images, there was a lowering of the values in the northwest of the field (Fig. 7). The decrease in values was alleviated by the time of the next image (15 August 2023) and although the precipitation was relatively low for the spring, the rainfall increased in the mid-summer (USDA-NASS 2023). However, this does not completely explain such a decrease in NDVI and NDMI values. The location is slightly elevated, so wind may be a factor. However, by 15 August 2023 those spots (or pixels) have recovered with only a slight decrease in NDVI value and is more comparable to the are in the southeast corner of the field where a tile repair was done in the spring of 2023 (Fig. 6). The combination of factors, form the rapid recovery to the no definite environmental cause, lead us to conclude that clouds and shadows as a possible cause for these random decreases in both NDVI and NDMI values (Fig. 7). Since multispectral images were not used in this study we cannot ascertain if clouds and shadows were responsible for the decrease in NDVI and NDMI values.

4.3 Use and Limitations of No-cost Indices for Crop Growth Monitoring

The primary use of the indices (NDVI and NDMI) in this study was for detecting anomalies within the crop fields. This can be accomplished using commercial (high spatial resolution) imagery. The advantage of using the no-cost imagery provided by the USGS is the potential for reduced costs. There is a potential for the use of in-house processing of remotely sensed data rather than the use of commercial images for monitoring crop growth in farms. However, the indices are simply one aspect of using and implantation of remotely sensed data. Widely available and inexpensive software to process and use both indices and multispectral data largely is what we consider to be the missing link

The use of Landsat 8/9 OLI/OLI2 images has other concerns that are an aspect of the sensor. The 30m resolution of Landsat is a limitation that can result in small, or early problems to be missed. For a smaller field, or a farmer who wants more detailed imagery it may not meet their needs. Nevertheless, Landsat images can be used for initial screening for problems and identify areas that would require higher resolution images.

Secondly, in some areas, cloud coverage may impede available imagery, such as in the 2023 growing season in Illinois. We obtained only four images that were cloud-free with another having clouds and cloud shadows. This image was excluded from our analysis. Presence of clouds and their shadows could reduce the number of usable Landsat images despite the eight-day revisit time of the of Landsat 8/9 satellites. Under those circumstances, farmers and crop consultants must incorporate images from other satellites.

Other limitations could be the software, quick turnaround (multispectral bands to spectral bands), and reliability (no-cost) are concerns for a farmer if they choose to use this technology. In addition, the use of these images cannot fully replace field scouting. That is where the free data comes in as it can supplement, with the acquisition of a suitable software, and advise scouting for those who do not currently use commercial imagery. This in turn could help spread the use of satellite imagery in agriculture as it becomes more accessible.

5. Conclusion

Free indices that are provided by the USGS can be powerful tool to farmers in the right situation. The NDVI and NDMI indices could be used to reduce costs from commercial imagery and educate farmers on remotely sensed products and their use in their fields. Limitations of the technology are a barrier to entry, specifically the software and downloading of the indices which both take time and knowledge to use effectively. However, as more farmers begin to use remotely sensed data in their regular operations the free data provided by the USGS could be a powerful and effective tool for farmers to have in their digital toolbox.

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