#7629 MONITORING CORN (ZEA MAYS) YIELD USING SENTINEL-2 SATELLITE IMAGES FOR PRECISION AGRICULTURE APPLICATIONS

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ABSTRACT

Currently, there is a growing demand to apply precision agriculture (PA) management practices at agricultural fields expecting more efficient and more profitable management. One of PA principal components for site-specific management is crop yield monitoring which varies temporally between seasons and spatially within-field. In this study, we investigated the possibility of monitoring within-field variability of corn grain yield through satellite images in a 22-ha field located in Ferarra, North Italy. Archived yield data for 2016, 2017 and 2018 seasons were correlated with different vegetation indices derived from Sentinel-2 satellite images at different crop growth stages. Yield data were filtered to remove field boundaries and other outliers to maintain yield map accuracy. A total of 34 cloud-free satellite images (6 images for 2016, 14 for 2017 and 14 for 2018 season) were analysed and vegetation indices such as Green Normalized Difference Vegetation Index (GNDVI) were calculated. Vegetation indices of each season were compared with the actual corn yield map for the same season and model accuracy metrics were calculated for each index and image date. Results of this work are as follows: Firstly, GNDVI was the most accurate vegetation index to monitor within-field variability of corn yield with an R^2 value of 0.48 and showed the same trend for all studied seasons. Secondly, crop age of 120 days after sowing (R4-R6) showed the best results for corn yield prediction which is during summer in Italy (July to August) with less cloud probability. This study provides a tool for monitoring within-field variability that could be applied for archived satellite images to provide farmers with their historical yield spatial variability.

INTRODUCTION

Yield monitoring for within-field variability is a fundamental component for precision agriculture (PA) system. Crop yield varies spatially within the same field and temporally between seasons due to several reasons such as soil physiochemical variability, management practices and environmental impact. Crop yield maps are used for the delineation of management zones and support farmers for their management decisions.

Traditional yield measurement practices are laborious, destructive and time consuming. Moreover, it is not suitable for in season measurements especially from large fields. Currently, remote sensing from satellite images provides continues observations with high spatial resolutions and temporal frequency. For instance, Sentinel-2 satellite images from the European Space Agency provides images every 5 days with a spatial resolution of 10m with 12 different spectral bands. Satellite images are used to derive vegetation indices, which could describe crop vigor and subsequently predict crop yield through empirical models. Corn yield prediction through vegetation indices such as normalized deference vegetation index (NDVI), enhanced vegetation index (EVI) and green NDVI (GNDVI) was investigated in several studies while most of them were at the country and county scale or used just limited field observations. Furthermore, the current availability of yield monitors mounted on combine harvesters provides an accurate and detailed yield data from agricultural fields. Yield monitors could provide thousands of yield observations from each field according to the field size, harvester width and the yield monitoring sensor specifications. Both Sentinel-2 and yield monitors provided huge amount of data from previous seasons, which could be fused using machine-learning techniques to provide more robust yield prediction models. Therefore, the main objective for this study was to predict corn yield variability within field scale using Sentinel-2 images through vegetation indices.

MATERIALS AND METHODS

This study conducted in a 22-ha field located in North Italy and cultivated by corn in 2016, 2017 and 2018 growing seasons. The sowing date was by the beginning of April and harvesting after 160 days in average. Archived yield data was collected at harvesting time from the three studied seasons using a calibrated grain yield monitor mounted on a combine harvester. The harvester working width was 6m and the yield monitor could record yield observations every one second, which is equivalent to 1.5m long in average. A total of 20,000 ground yield data were collected from the study field every season. This data was filtered by removing outliers over ±3 standard deviation from each season. Then yield data was interpolated to 10m pixels to match with Sentinel-2 spatial resolution.

Sentinel-2 satellite images level 2A were acquired from the Copernicus Open Access Hub. A total of 34 cloud free images covering the study period where 6, 14 and 14 images acquired from the 2016, 2017 and 2018 seasons, respectively. All sentinel-2 images bands were resampled to 10m and several vegetation indices were calculated such as NDVI and GNDVI. Vegetation indices were correlated with corresponding yield at different crop growing stages corresponding to each image date. Equations 1 and 2 describes the calculation of NDVI and GNDVI from Sentinel-2 images as an example.

Equation 1. NDVI = (B8-B4)/(B8+B4)
Equation 2. GNDVI = (B8-B3)/(B8+B3)

Where B8 is the NIR band, B4 is the red band and B3 is the green band of Sentinel-2 satellite images.

RESULTS AND DISCUSSION

Results showed that GNDVI was the most accurate vegetation index to predict corn grain yield with an R^2 value of 0.48 while the most suitable period to predict corn grain yield was between R4-R6 growing stages. In general, all studied vegetation indices showed the same trend across studied seasons where the R^2 values were < 0.3 until crop age of 90 days after sowing (DAS) and increased to reach the beak around 120 DAS then decreased significantly before harvesting time. This trend repeated for the three studied seasons and this result in agreement with previous studies (Peralta et al., 2016 and Schwalbert et al., 2018). Figure 1 shows an example from the 2018 season ground yield data and the best correlated GNDVI map from Sentinel-2 acquired on 7 August 2018. Gitelson et al. 1996, highlighted the sensitivity of GNDVI to the chlorophyll concentration where the reflectance range between 520 and 630 nm could describe chlorophyll content variability. Also, GNDVI is the most correlated index to FPAR for corn and subsequently to corn yield (Tan et al., 2013). Much detailed descriptions about this study methodology, analysis and results are available on a recently published article in the remote sensing by Kayad et al., 2019.

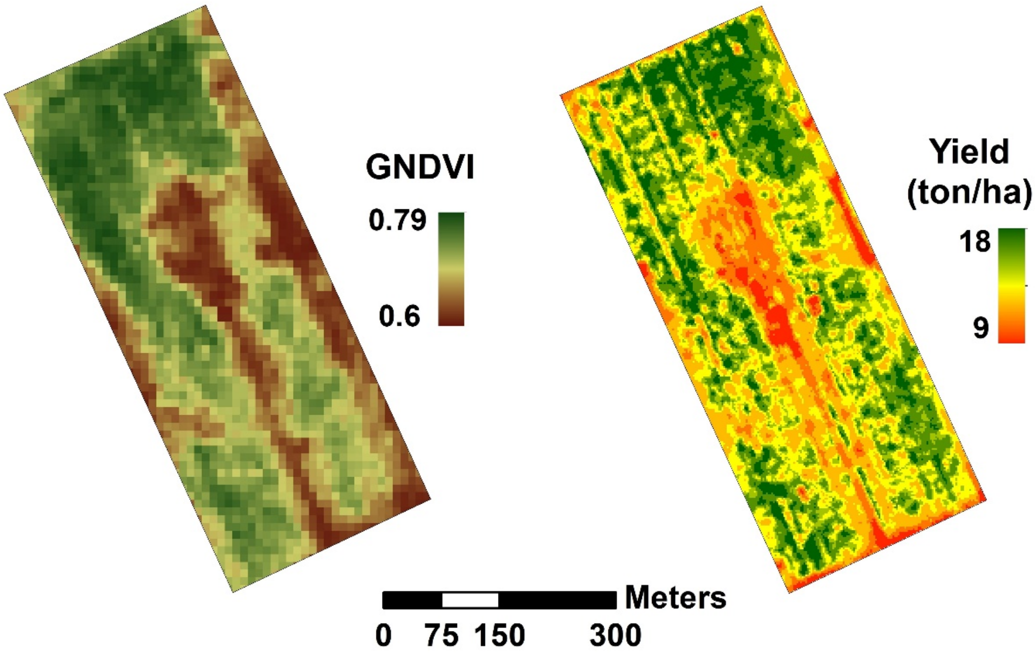

Figure 1. GNDVI map calculated from the Sentinel-2 image acquired on 7 August 2018 and the ground corn yield map for 2018 season.

REFERENCES

Gitelson et al, 1996. Use of a green channel in remote sensing of global vegetation from EOS-MODIS. Remote Sens. Environ. 58: 289–298.

Kayad et al, 2019. Monitoring Within-Field variability of Corn Yield using Sentinel-2 and Machine Learning Techniques. Remote Sens. 11: 2873.

Peralta et al, 2016. Mid-season high-resolution satellite imagery for forecasting site-specific corn yield. Remote Sens. 8: 848.

Schwalbert et al, 2018. Forecasting maize yield at field scale based on high-resolution satellite imagery. Biosyst. Eng. 171: 179–192.

Tan et al, 2013. Using hyperspectral vegetation indices to estimate the fraction of photosynthetically active radiation absorbed by corn canopies. Int. J. Remote Sens. 34: 8789–8802.