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Remote sensing of winter wheat growth under conventional and no-tillage cultivation

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Introduction

Remote sensing has been proved a valuable management tool in agriculture (Thieme et al., 2020). Data from new generation satellites, such as Sentinel-2, are expected to provide significant improvements in retrieving quantitative information on several crop biophysical parameters. The involvement of such data in crop performance monitoring will facilitate not only management interventions but also yield prediction.

The purpose of the present study was to explore the potential of Sentinel-2 satellite data in depicting winter wheat performance under different tillage treatments, by combining remote sensed data with ground-measured Leaf Area Index (LAI) and final yield of the various treatments.

Materials and Methods

Study site and experimental design

The study was conducted in central Greece, (39°34'52.13"N, 22°35'46.22"E) during November 2018 - June 2019. The experimental field of 6.7 ha was divided into three parts, with the following treatments:

1. Ploughing based conventional tillage (CT) and sowing on December 6, 2018.
2. No-tillage (NT1) and sowing three weeks earlier, on November 16, 2018.
3. No-tillage, (NT2) and sowing at the same date as CT.

The CT treatment was ploughed and prepared with a tine cultivator, prior to sowing. The no-till drill (Kuhn SDliner 3000) was used for both no-tillage treatments, where residues of the previous cultivation (cotton), were present (Picture 1). Seeds of the winter wheat cultivar "Svevo" were sown at 230 kg/ha.

Satellite data and vegetation indices

During the growing period, time-series of two vegetation indices (VIs), the Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI) was obtained from radiometrically and atmospherically corrected (Level2A) Sentinel-2 images, according to the following equations:

$$NDVI = \frac{R842 - R665}{R842 + R665} \qquad EVI = 2.5\,\frac{R842 - R665}{R842 + (6*R665) - (7.5*R490) + 1}$$

Leaf area index and yield measurements

Leaf area Index (LAI) was measured with the ACCUPAR LP-80 PAR/LAI Ceptometer (Decagon Devices Inc.). Final yield was monitored with a combine harvester equipped with a yield monitor (John Deere S660i) at a spatial resolution 1.5x1 m.

Results and Discussion

The time series of NDVI and EVI revealed different growth patterns for the three treatments (Fig. 1). Until the end of February, the later sown CT and NT2 showed a similar delayed pattern compared to NT1, with the earlier sowing with direct drilling on NT1 proving to be advantageous for seedling early emergence and performance. After March however, NT1 showed a delay and CT outperformed both NT1 and NT2. The weather data revealed a shortcoming of rainfall from 5/2 to 10/3 which coincided with the critical stage of stem elongation on NT1. Therefore, growth was suppressed. On the contrary, the two later sown treatments (NT2 and CT) evaded this adverse period because plants were still at the less sensitive, tillering stage. The superiority of CT lasted until the beginning of grain filling (end of April), while NT2 slightly outperformed after that date (May).

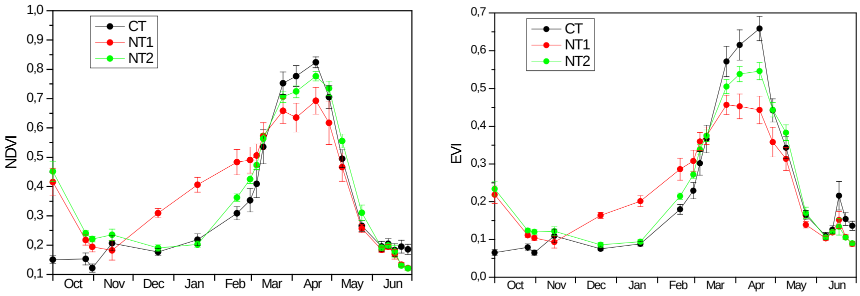

Figure 1. Time series of NDVI and EVI derived from Sentinel-2 data for the three treatments during the experimental period.

The above-described growth pattern was confirmed by LAI seasonal fluctuation (Fig. 2) and LAI and both VIs were found to correlate well (Fig. 3). Since LAI is an important indicator of biomass and percent vegetative ground cover, its retrieval though satellite-derived data might be a useful tool for crop monitoring at high spatial and temporal scales (Verrelst et al., 2015).

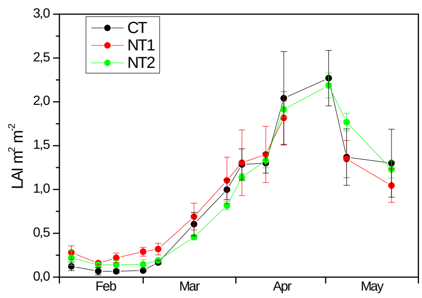

Figure 2. The seasonal fluctuation of LAI for the three treatments during the experimental period.

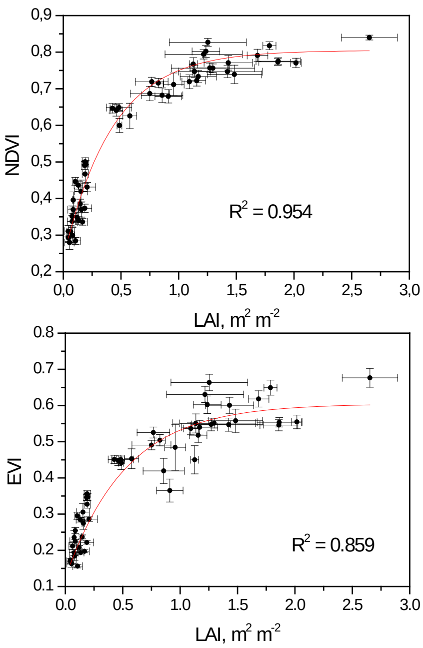

Figure 3. Regression analysis between NDVI and EVI with LAI, all treatments incorporated.

Picture 1. Image of the no-tillage treatment NT1.

Final yield data showed that both NT treatments were more efficient than the CT treatment (1.61, 2.22, and 2.73 t/ha for CT, NT1 and NT2 respectively). VIs, LAI, and yield data collectively imply that early May – when assimilates from photosynthesis are translocated from the leaves and the stem to the grain – was a decisive period for wheat productivity.

Conclusions

- No-tillage treatments resulted in higher yields compared to conventional tillage.
- Early planting of winter wheat (NT1) may be a profitable option, though late planting (NT2) showed the best performance in terms of productivity.
- VIs depicted well the phenological stages of the crop and indicated critical points during plant development that may account for shifts in plant performance.
- Remote sensing proved to be a valuable tool for phenological monitoring between treatments, but also for determining critical periods during growth. Such data in conjunction with weather information are essential and could support decision making systems under the framework of precision agriculture. They may provide guidelines to enhance yield quantity and quality when sustainable systems like Conservation Agriculture are adopted and the ordinary cultivation practices have to be adapted accordingly (i.e. earlier sowing, modification of irrigation and/or nitrogen application).

References

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