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Remote sensing based monitoring of durum wheat under water stress treatments

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ABSTRACT. Nowadays, the remotely provided information is urgently needed for various decision makers and remote sensing is widely used for different purposes. An evaluation and standardization of the remote sensing techniques is becoming a necessity after the increase of the sensors number and way of data acquisition. The use of remotely sensed information is of crucial importance for agricultural sector as the monitoring of agricultural activities faces special problems related to the spatial and temporal variability, physical landscape, as well as climatic driving variables and agricultural management practices. Requests for objective information will increase in the future, because of the expected modernization of agricultural sector and needs for a more efficient use of resources. This research aims to provide a comparison of two remote sensing techniques (satellite and ground-based) as tools describing the variations of crop stress related indices under different water regimes (case of durum wheat). The experimental layout was established in Policoro (Matera) located in Southern Italy about 3 km far from the Ionian coast. The growing season was from February to June 2015 with three distinguished water management practices (rain-fed, 50% and 100% of irrigation requirements). The Landsat 8 images and ground-based sensing data were acquired regularly in April, May and June together with plant physiological parameters. The overall results indicated no significant differences in terms of both biomass and yield among the irrigation regimes because of the abundant precipitation (355 mm) which limited the irrigation supply. Moderate correlations appear to be evident for satellite and ground-based derived LAI, NDVI and SAVI regressions, with R^2 values close or higher than 0.5. The best performance was obtained for the WDI with ($R^2=0.81$). Nevertheless, the satellite data could provide reasonable indications about the crop status if applied with higher resolution.

KEYWORDS: Remote sensing; satellite; ground-based; Landsat 8; water stress.

1. Introduction

The Mediterranean water resources are almost fully exploited in many areas and the impacts on water scarcity are projected to multiply under climate change. The most effective mean to save water appear to be through the adoption of carefully managed irrigation strategies. Plant indicators enable the grower to use the plant directly for clues as to when irrigate (Usman et al., 2010). These indicators could be obtained through the use of remote sensing that is widely involved in numerous disciplines such as agriculture.

Remote sensing has been an effective tool to monitor irrigated lands in many locations around the world under a variety of environmental conditions. It provides synoptic coverage of irrigated fields in several spectral regions and with temporal frequencies sufficient to assess vegetation growth, maturity, and harvest (Glenn et al., 2008).

The main objective of this study is the comparison of remote sensing techniques (satellite and ground-based), for the case of durum wheat under three water regimes: i) Full irrigation (I_{100}), ii) Deficit irrigation (I_{50}), iii) Rainfed (I_0).

Spectral reflectance and canopy temperature properties were investigated by computing the NADI, SAVI and WDI.

2. Materials and methods

2.1. Study site and experimental design

In order to fulfill the aim of this study, the experimental work has been conducted at the experimental field 'E. Pantanelli' of Bari University, located in the area of Policoro, in Southern Italy (Province of Matera), about 3Km from the sea with the altitude of 40°17' N, longitude of 16°40' E, and an altitude of 15 m above sea level (Fig. 1).

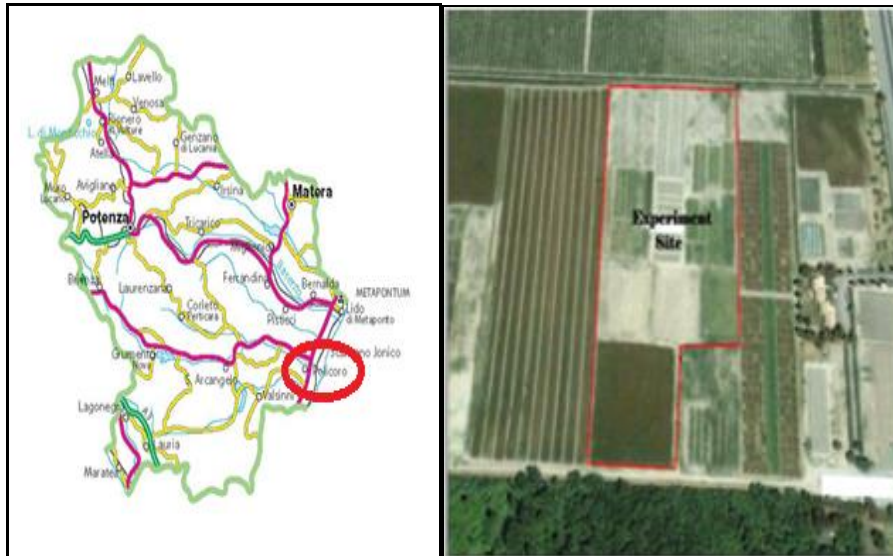


FIGURE 1. Experimental Field location in Policoro region

Spring durum wheat was sown on 21st February 2015 at the experimental field 'E. Pantanelli' (Policoro, MT) on a 1.76 ha surface.

Spring durum wheat has been grown under three irrigation treatments: full irrigation (I_{100}), deficit irrigation (DI) by applying 50% of irrigation requirements (I_{50}) and, rainfed treatment (I_0). Each treatment was replicated thrice. A completely randomized block design was adopted; the three irrigation treatments were randomly distributed in each block which leads to a total of 9 plots. The field was divided into experimental plots of 42 * 42 m.



FIGURE 2. Experimental Field design

2.3. Crop measurements

2.3.1. Ground-based sensing measurements

The following crop measurements were computed during the experiment:

A FLIR portable thermal imaging camera (Flir B335) was used for the monitoring of the canopy temperature and the estimation of thermal indices (WDI);

A FieldSpec HandHeld 2 spectro-radiometer was used to measure the canopy spectrum. Data collection is thereafter processed by means of specific software provided with the instrument (View Spec). Spectral vegetation indices will be then elaborated;

Biometric measurement (Leaf Area Index ‘LAI’) are based on an optical leaf area meter.

2.3.1. Satellite sensing measurements

Moderate resolution imagery (Landsat 8) were used in this research. The satellite images were analyzed and calibrated based on ENVI software. In order to generate high resolution LAI mapping, vegetation indices Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI) and Enhanced Vegetation Index (EVI) were computed.

Land surface temperature estimation and WDI assessment were computed as mentioned in the organizational chart:

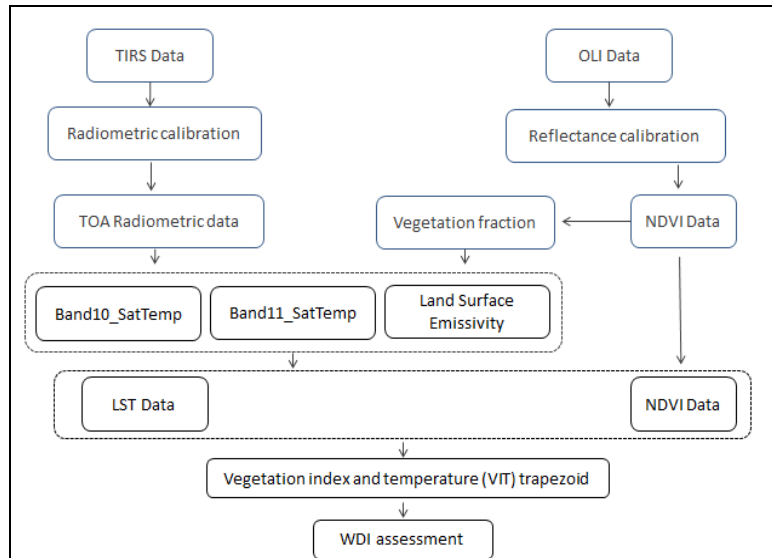


FIGURE 3. LST and WDI assessment steps

3. Results and discussion

Statistical analysis for the total dry biomass (TDB) and the yield (Kg/m²) for the three water regimes showed no significance between the three water regimes.

TABLE 1. Yield and TDB statistical analysis of spring wheat for the three water regimes

	Yield (Kg/m ²)	Biomass (Kg/m ²)
I ₀	0.33	0.69
I ₅₀	0.29	0.72
I ₁₀₀	0.31	0.74
WR	NS	NS

Figure 4 (a, b, c) describes the type of relationships between LAI, NDVI and SAVI measured from satellite and LAI, NDVI and SAVI measured from ground-based sensing method.

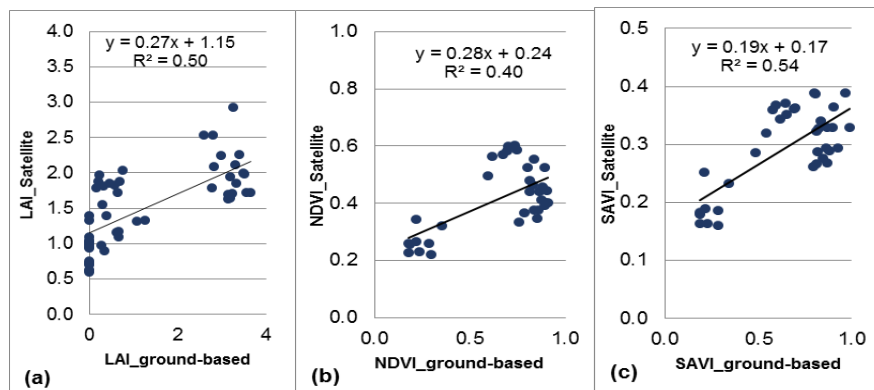


FIGURE 4. Satellite vs. Ground-based LAI and vegetative indices (SAVI & NDVI) comparison

The linear regression function was chosen to show the general trend of the existing relationships. Moderate correlations appear to be evident for LAI, NDVI and SAVI regressions, with R² values close to 0.5. The higher determination coefficient (R² = 0.81) was obtained in the case of WDI.

TABLE 1. Correlations between satellite and Ground-based derived WDI

	a	b	R ²
WDI_Ground-based vs. WDI_Satellite	4.41	-2.02	0.81

Biudes et al. (2013) study's reported that LAI estimated on ground-based extinction were positively correlated with crop growth; however, in some cases satellite-derived estimates of LAI exhibited no correlation with crop development. NDVI result is in agreement with Hmimina et al. (2013) study where relationships between in situ and MODIS NDVI measurements are significant ($R^2 = 0.56$).

4. Conclusion

In this study, ground-based and satellite remote sensing techniques were used to evaluate and to compare crop growth and crop water status of the spring wheat (*Triticum durum* Desf.) under three water regimes.

Using the ground-based measurements acquired from the field, a direct comparison was made between the satellite derived VIs and the associated ground-based VIs values for spring wheat crop. This study was used to separately test the ability of proximate and earth observation remote sensing methods for crop growth monitoring. The overall results showed that the correlations between the satellite and ground-based results ranged from 0.5 to 0.8.

Nowadays, the remote sensing applications are becoming a common tool and can be used at different scales, from canopy and farm to irrigation districts and regions. The technology is becoming mature and the data elaborations followed common automatic procedures available by different data providers. This reinforced the arguments for enhancing investments in agricultural monitoring systems. It follows the strong conviction that a close monitoring of agricultural production systems is necessary in order to stabilize and increase the yield while using the resources in the most efficient way.

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