Proocedings of the 51st National conference of the Italian Society for Agronomy

Botanical garden – University of Padova

19 - 21 September 2022

Società Italiana di Agronomia (SIA)
www.siagr.it

ISBN: 978-88-908499-5-4

Maize Water Stress Monitoring By Sentinel 2 Spectral Indices

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Introduction

Remote sensing is a modern and enhanced tool for data acquisition useful for supporting crop management practices. It provides an accurate picture of crop status during growing season and highlights stresses. Vegetation indices (VIs) application is becoming quite common due to its capability of investigating vegetation status and crop production. NDVI (Near Difference Vegetation Index) and NDRE (Near Difference Red-Edge index) are the most widespread indicators in agriculture, but other indices such as NDMI (Normalized Difference Moisture Index, El-Hendawy et al., 2017), NDWI (Normalized Difference Water Index, Jackson et al. 1996) could be correlated to the give information soil and crop water content. The main goal of this work is to monitor the maize response to water stress using VIs detected through mission Sentinel-2 (S2), focusing on productive and qualitative traits.

Materials and Methods

In 2021 a field experiment was carried out to monitor water stress in maize. DKC6092 hybrid was sown in March 30th at Villafranca P.te (Torino, Piedmont, Italy) in a 5 ha field (hereinafter called FOI – field of interest) characterized by two different soil zones: North area (Plot N) with sandy soil and South area (Plot S) with loamy soil. Agronomical practices adopted have been the common ones of the growing area. During the growing season two irrigation were performed the 14th of July and the 10th of August distributing 50 mm of water each time. To emphasize water stress, Plot N was irrigated only the first time. The 1st of October maize of the two different areas were harvested and weighted separately. Subsequently, qualitative traits such as test weight (TW), protein and fumonisin content were evaluated. To monitor FOI using S2 VIs, perimetral points has been collected using GNSS receiver, then a FOI vector file was created. In this work, S2 T32TLQ tile was selected based on FOI location, then four cloud-free S2 images were used (03/06/2021, 17/08/2021, 29/08/2021 and 13/09/2021). Using SAGAGIS 7.4 software, different VIs (NDVI, NDRE-5, NDRE-6, NDWI-1, NDWI-2, NDWI-3) were calculated as reported in Table 1 for each date.

Table 5. Vegetation Indices formula's considering Sentinel-2 bands and respective central wavelengths (ρ).

Vegetation Index (VI)	Sentinel-2 bands formula	Sentinel-2 wavelength formula
NDVI	B8-B4 / B8+B4	ρ842-ρ665 / ρ842+ρ665
NDRE-5	B8-B5 / B8+B5	ρ842-ρ705 / ρ842+ρ705
NDRE-6	B8-B6 / B8+B6	ρ842-ρ740 / ρ842+ρ740
NDWI-1	B8-B11 / B8+B11	ρ842-ρ1610 / ρ842+ρ1610
NDWI-2	B8-B12 / B8+B12	ρ842-ρ2190 / ρ842+ρ2190
NDWI-3	B3-B11 / B3+B11	ρ560-ρ1610 / ρ560+ρ1610

S2 bands with ground sample distance of 20 m (B5, B6, B11 and B12) were resampled at 10 m using a bilinear interpolation. To classify maize status in FOI, for each date, all the VIs pixels pertaining FOI were clustered in three classes using K-means iterative minimum distance approach (max 100 interactions). Subsequently, all VIs pixels of all dates were clustered again using the same approach to obtain only two classes. Finally, a confusion matrix was carried out to evaluate the classification accuracy.

Results

Figure 1 shows final pixels clustering in two different classes considering all VIs calculated in different dates. In the Plot S, most of pixels were clustered together because soil characteristics and agronomical management led to healthy and homogeneous maize vegetation with similar VIs. Conversely, Plot N was characterized by the presence of both Cluster 1 and Cluster 2 pixels: in fact, the area where Cluster 1 pixels dominate had a soil texture much more similar to the one characterizing Plot S. Therefore, water stress was probably much less severe. Confusion matrix (Table 2) shows the clustering process goodness. The overall accuracy was high (0.78). User Accuracy of 0.84 and 0.74 for class two and one means that pixels were well classified with only 16% and 26% respectively of false positive pixels clustering (Errors of Commission). High Producer Accuracy (75% for Plot N and 83% for Plot S) indicates that few pixels were not correctly classified in the correct Plot. Only 25% of pixels in Plot N did not belong at the class 2, while the 16% of pixels classified in Plot S were in cluster 2.

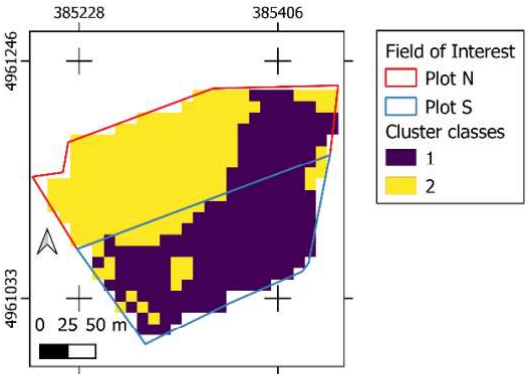

Figure 15. Final pixels clustering by considering all vegetation indices (VIs) calculated in four different dates.

Table 2. Confusion Matrix derived from cluster process

Class	Plot N	Plot S	Sum User	User Accuracy	Errors of Commission
2	160	31	191	0.84	0.16
1	54	150	204	0.74	0.26
Total	214	181			
Producer Accuracy	0.75	0.83	Overall Accuracy	0.78	
Errors of omission	0.25	0.17			

Table 3. Quantitative and qualitative traits of two plots.

PLOT	Grain yield (t ha^{-1})	Moisture (%)	TW (kg hL^{-1})	Fumonisin (ug kg^{-1})
N	13.4	21.0	79.6	1080
S	16.7	22.4	80.3	2740

Maize differences predicted by VIs are found also in quantitative and qualitative data (Table 3). In Plot S grain yield was about 3 t ha^{-1} higher, with a slightly higher TW. As expected, moisture was lower in drier Plot N according to soil characteristics. Since the water stress led to shorter ripening in Plot N, the fumonisin content was lower.

Conclusion

All Sentinel-2 vegetation indices exploited in this work are goods predictors of maize status. Biomass spectral indices (NDVI, NDRE5, NDRE6) and specific water spectral indices (NDWI-1, NDWI-2, NDWI-3) are both able to spot stressed maize. Cluster analysis can separate pixels correctly. Quantitative and qualitative field evaluations show the goodness of VIs suggestions. S2 data are confirmed to be helpful in monitoring crops status by remote and to manage different crops areas in different ways according to crops needs.

References

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