Testing the possibility of mapping vineyards covered with plastic sheets by Copernicus Sentinel 2 imagery

Testing Possibility of Mapping Vineyards Covered with Plastic Sheets by Copernicus Sentinel 2 Imagery

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Abstract

Quantity and quality of crop production are markedly influenced by natural variability of plant and field conditions and by erratic application of cultural practices. Monitoring vine growth and vineyard conditions can improve precision of input deliveries and help to predict crop productivity and quality trends. Covering vineyard by plastic sheets to protect foliage and grapes from adverse climatic conditions is an increasing practice, especially in table grape plantings. Detection by remote sensing of vineyards covered by plastic sheets is presently a challenging issue, given the intrinsic nature of plastic covers themselves that are expected to heavily impact reflectance from the underlying vegetation. Sheets are expected to condition the radiative transfer process from vegetation to sensor, introducing new approximations. They can change both signal transmission and absorption, and possibly generate artefacts in reflection due to their close-to-specular reflecting behavior. In this context, when trying to figure out the behavior of the underlying vegetation by remote sensing, a multi-temporal approach is mandatory. This study was conducted in Apulia (South Italy) with focus on table grape vineyards covered with polyethylene sheets. Air temperature and shoot growth, were monitored during the 2016 growing cycle. Fourteen suitable Copernicus Sentinel 2 (Level 2A product) images were used to investigate if vine phenology can be similarly described with and without plastic covers. A time series of S2 Level 2A images were used and the correspondent NDVI maps generated. Spectral signal was analyzed, comparing responses of two vineyards, covered with different plastic sheets, with two uncovered ones. Three tests were performed, included a comparison of data obtained from NDVI and MSAVI2 spectral indices. All the results demonstrated that no significant limitations were introduced by plastic sheets while monitoring spectral behavior of covered vineyards.

Keywords: table grape, protected cultivation, spectral signals through plastic covers, NDVI, MSAVI2

INTRODUCTION

Quantity and quality of crop production are markedly affected by natural variability of plant and field conditions as well as by erratic application of agricultural practices. The mapping of cultivated plots helps their management in many ways, such as monitoring plant growth and requirements, improving precision of input deliveries, forecasting the trend of yield and quality of production. This also facilitates post-harvest planning. Covering table grape vineyards with plastic sheets in order to condition canopy microclimate and/or

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protect foliage and grapes from rains and related attacks of pathogenic organisms, light hail, and excess of solar radiation, is a largely applied technique in Southern Italy and it is now spreading in the main grapevine growing areas to cope with current climate change. Detection by remote sensing of vineyards covered by plastic covers is presently a challenging issue, given the intrinsic nature of plastic sheets that are expected to heavily impact reflectance from the below vegetation. In fact, they interact with the radiative transfer process from vegetation to sensor introducing further and unknown players possibly related to lighting conditions. Plastic sheets are expected to change both transmission and absorption signals, and to generate artefacts in reflection due to their close-to-specular reflecting behavior. In this context, when trying to figure out the behavior of the underlying vegetation by remote sensing, a multi-temporal approach is mandatory. The aim of the present work was to run preliminary tests on table grape vineyard plots covered with polyethylene sheets, using signal provided by Copernicus Sentinel 2 (Level 2A product) free optical data.

MATERIALS AND METHODS

Study area and test vineyards

Two adjacent 1-hectar table grape vineyards of *Vitis vinifera* L. table grape 'Victoria' grafted onto 1103 P, sited in South Italy (Apulia region, BT province, Laporta farm), at 41° 18' 29.58" N - 41° 18' 29.58" E, and at 41° 18' 27.02" N - 16° 0' 49.12'' E, were covered from 10th March to the end of October 2016 with two types of plastic sheets that were, respectively: Coverlys agrotextile (C, provided by Beaulieu Technical Textiles, Belgium), and Serrosol film (S, provided by Serroplast, Italy) (Figure 1).

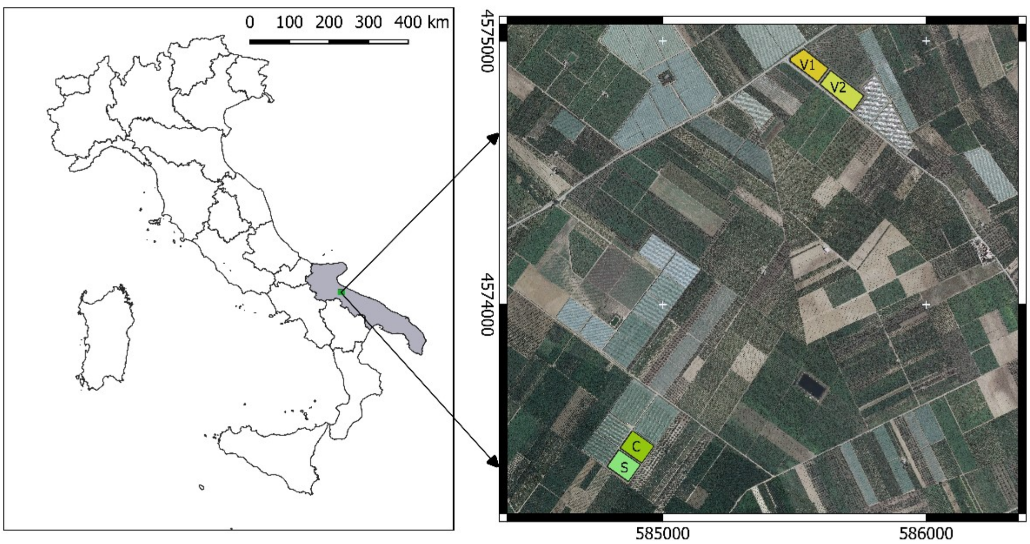

Figure 1. Study area: test vineyards located in SE Italy, close to Foggia area (S and C: vineyards covered two types of plastic sheets; V1 and V2: uncovered vineyards).

Both types of sheets were made by polyethylene plus additives, were transparent to solar radiation and were 200 μm thick. Two uncovered vineyards (V1, V2) were found outside the farm, at distance of 1.67 km apart as the crow flies, and were taken as a reference (Figure 1). All vineyards were trained to *tendone* trellis and had same vine distance (2.4 x 2.4 m).

Available satellite data

Fourteen Copernicus Sentinel-2 Level 2A images were obtained from the THEIA system (theia.cnes.fr). A 2A products consists of a 100 km^2 tile [16] orthoprojected in the WGS84 UTM system and is already calibrated in at-the-ground reflectance. Main features of Sentinel 2 data are reported in Table 1, together with dates of acquisition.

Only images with no clouds over the vineyards of interest where considered for the 2016 growing season, namely 14 of the thirty-six S2 images available in the reference period. Selected images referred to the following dates of acquisition: 14/01/2016, 13/02/2016, 23/05/2016, 22/06/2016, 02/07/2016, 12/07/2016, 22/07/2016, 01/08/2016, 21/08/2016, 31/08/2016, 20/09/2016, 30/09/2016, 10/10/2016, 09/12/2016.

Table 1. S2 data technical features.

Band	Wave Length Center (nm)	Band Width (nm)	Ground Sampling Distance (m)
b1	443	20	60
b2	490	65	10
b3	560	35	10
b4	665	30	10
b5	705	15	20
b6	740	15	20
b7	783	20	20
b8	842	115	10
b8a	885	20	20
b9	945	20	60
b10	1380	30	60
b11	1610	90	20
b12	2190	180	20

Available ground data

The main microenvironment variables were continuously monitored at 2 m height: photosynthetic active radiation, air temperature and humidity (Decagon's ECH2O sensors and data loggers) in C and S vineyard and in open air. From temperature data, the Growing Degree Days (GDD) were calculated from 1st April 2016 (budbreak under cover) to two 1st August 2016 (two days after grape harvest) as difference between daily mean temperature and base temperature of 10 °C (Winkler at al., 1974). Vine phenology and vineyard general status were monitored weekly; in the two covered vineyards, the primary shoot length of was also measured, on two canes of 10 vines per plot, from budbreak to berry-set.

Testing spectral differences: bands and indices

For this study, only bands 2-8, 11 and 12 were utilized since they are the most suitable and used for horticultural purposes (Vanino et al., 2018). Three tests were conducted.

In the first one, two spectral vegetation indices were compared: Normalized Difference Vegetation Index (NDVI, eq. 1), and Modified Soil-Adjusted Vegetation Index, version 2 (MSAVI2, eq. 2):

$$NDVI = \frac{(\rho_{b8} - \rho_{b4})}{(\rho_{b8} + \rho_{b4})} \quad (1)$$

$$MSAVI2 = \frac{[2 \cdot \rho_{b8} + 1 - \sqrt{(2 \cdot \rho_{b8} + 1)^2 - 8 \cdot (\rho_{b8} - \rho_{b4})}]}{2} \quad (2)$$

where ρ_{b8} and ρ_{b4} are at-the-ground reflectances of band 8 (NIR wide range band) and band 4 (RED band), respectively. NDVI is well known to be related to vegetation phenology (Testa et al., 2018); MSAVI2 is considered more suitable for cases in which vegetated rows alternate with non-vegetated inter-rows (Laosuwan and Uttaruk, 2014): this situation occurred also in *tendone* trained vineyards for part of the growing season. Specific effectiveness of the two indices was explore by testing the correlation (r) between their mean values and between their standard deviations obtained by considering together all the values of the 4 vineyards and all dates of measurement. Results highlighted a very high degree of correlation, making possible to proceed on with respect to NDVI solely.

As a second step, the mean temporal profiles of selected bands and NDVI from each of the 4 vineyard plots were extracted and compared. The spatial distribution of reflectances detected within each vineyard plot was compared with that of the other plots by means of the coefficient of variation (CV, eq. 3) computed, for each date, considering all the pixels falling in each vineyard:

$$CV_j(t) = \frac{\sigma_j^i(t)}{\mu_j^i(t)} \cdot 100 \quad (3)$$

where $\mu_j^i(t)$ and σ_j^i(t) are the mean and standard deviation values of the *i-th* band/spectral index for the *j-th* vineyard; *t* is the date of acquisition.

As a third step, in order to investigate the persistence of the biophysical meaning of NDVI under the plastic sheets, the well known relationship between NDVI and Growing Degree Days (GDD, McMaster and Wilhelm, 1997) was tested for the 4 vineyards. It is worth to remind that such relationship is well modelled by a second order polynomial according to eq. 4 (Walker et al., 2015; de Beurs and Henebry, 2004):

$$NDVI = a \cdot GDD^2 + b \cdot GDD + c \quad (4)$$

where *a*, *b* and *c* are the coefficients to be estimated by Ordinary Least Squared according to satellite and ground data. Once the model of eq. 4 was calibrated, the following phenological parameters were obtained:

$$GDD_{max} = -\frac{b}{2a} \quad (5)$$

$$NDVI_{max} = c - \frac{b^2}{4a} \quad (6)$$

where GDD_{max} and $NDVI_{max}$ are the GDD value corresponding to the maximum value of NDVI and the estimated maximum NDVI value along the season, respectively. Only 6 of the 14 available images proved to be useful for the model calibration, given the starting and ending dates of the GDD computation from ground measures.

RESULTS AND DISCUSSION

Correlation between NDVI and MSAVI2 data proved to be very high in terms of both mean values (r =0.9998) and standard deviations (r =0.8562) (Figure 2). This result showed that: i) the data obtained by applying the two spectral indices were comparable; ii) MSAVI2 did not prove to add more significant information respect to NDVI. Basing on this latter consideration, NDVI was assumed as a reference index for the following comparisons.

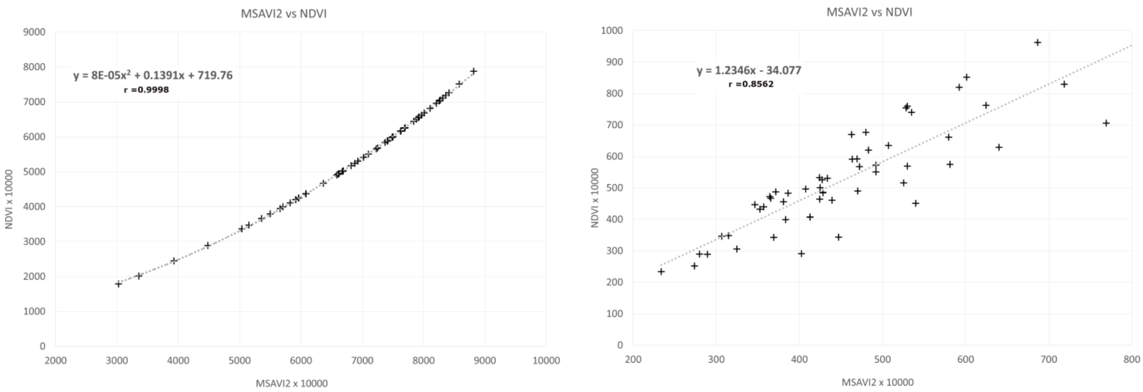

Figure 2. NDVI versus MSAVI2 in terms of average values (left) and standard deviations (right). All data acquired and computed for each of the 2 covered and of the 2 uncovered vineyards were jointly considered.

Concerning the spatial distribution of spectra signal within vineyards, the annual trend of NDVI CV figured along the growing cycle (Figure 3 left) showed large fluctuations among vineyards at the beginning and at the end of the season, namely, when the vine canopies were not still developed or started to decline. These data were likely related to the soil management, i.e. to the different abundance of weeds that covered the soil on the measurement dates. For example, at the time of the vineyard inspection which took place in mid-January, close to the acquisition date of the first valid satellite image, both the covered vineyards had the soil colonized by a fairly developed seeded cover crops (horse bean, *Vicia faba* L. var. *minor*), of similar density in C and S plots, while V1 showed a very dense and tall resident weeds, and V2 a fairly bare soil, recently plowed. On the other hand, NDVI CVs of the 4 vineyards were similar and quite stable in the central part of the growing season, that is, when the vine canopies were already expanded over most part of the vineyard trellises. The primary shoot length measured in C and S vineyards was 149.50 cm and 166.66 cm respectively: vines of the S plot showed a slight tendency to grow more vigorous. The average annual CVs calculated for each of the 11 selected S2 bands (Figure 3 right) were lower and more stable in the case of the following 4 bands: b6 which is one of those sensitive to the position of the red edge, b7 which is sensitive to the leaf area index (LAI) and to the edge of the near infrared plateau, b8 which is also sensitive to LAI, b11 which is sensitive to starch and lignin contents. At the opposite, the higher and more variable CVs were found for b2, b3 and b4, which are all associated to the visible radiation and are the most sensitive to the leaf pigment contents. All these general tendencies pointed out in terms of NDVI CVs and S2 band CVs were common to covered and uncovered vineyards. The logic of these results lead us to consider the reflectances detected through plastic covers as quite reliable.

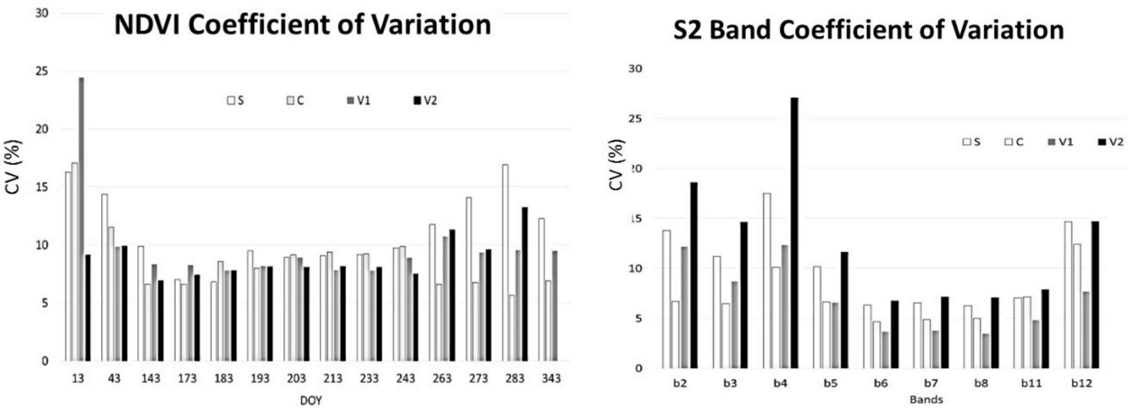

Figure 3. Spatial distribution of spectral signal in the 2 covered and the 2 uncovered vineyards: annual trend of NDVI CVs figured along the 14 dates of measurement (left), and average annual CVs of the 9 selected S2 bands (right).

Finally, as regards the relationship between NDVIs and respective GDDs calculated for each vineyard, a 2nd order polynomial equations, as expected basing on scientific literature, were found for both covered and uncovered vineyards (Figure 4). NDVI and GDD data were strongly correlated; according to the coefficients of determinations (R^2), 98-99% of NDVI variations could be explained by the corresponding GDD variations. Each of the 4 curves that express the NDVI vs. GDD relationship is representative of a foliage biomass that, to a different extents, increases up to a certain date and then remains constant or slightly decreases, as it is typical of crop canopies.

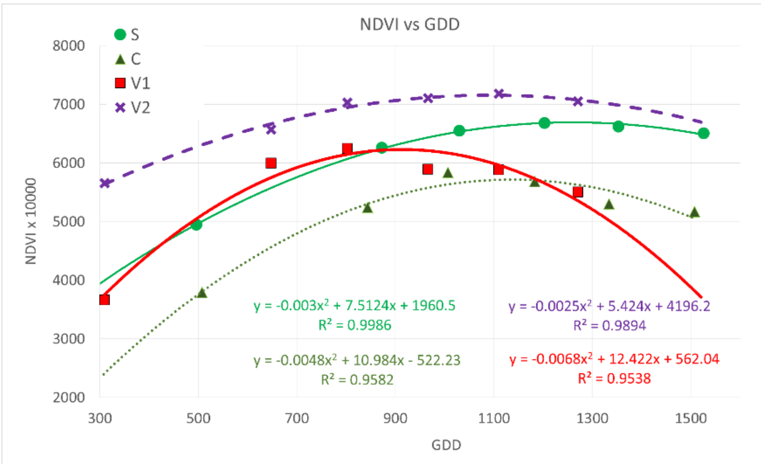

Figure 4. Relationship NDVI versus Growing Degree Days (GDD) for each of the 2 covered and of the 2 uncovered vineyards: model formulas and coefficient of determination is reported for each of the 4 vineyards.

CONCLUSIONS

The present study was devoted to ascertaining whether vegetal spectral signals are able to pass through the plastic sheet covers that are more and more widely used to protect table grape vineyards, as well as to evaluate the signal reliability, given the lack of this type of information. Copernicus Sentinel 2 optical data were used in consideration of the Copernicus program policy that allows open access to all users.

Of the two spectral indices initially tested in the study, namely NDVI and MSAVI2, the latter did not show to improve information resident in NDVI, which is currently still the spectral index most largely applied to acquire information on the biophysical properties of crop canopies.

All the tests conducted in the trial, as well as the comparisons of data collected from the vineyards covered with two types of plastic sheets and from the uncovered ones, proved that: i) spectral signals pass through the plastic sheets and can be detected by Copernicus Sentinel 2; ii) NDVI is a good predictor of vegetation dynamics even in the case of vines grown in protected cultivation. However, this being the first study conducted on such a specific topic, longer and more in-depth investigation and more case studies are needed to confirm the present results.

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