# Identifying the Existence of Grass Coverage in Vineyards by Applying Time Series Analysis in Sentinel-2 Bands

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***Abstract*— The increasing tendency of the population puts pressure on vineyard farmers to supply food. In this context, grass coverage will be a low-cost solution to reduce outlays and reduce the maintenance of crops. In this paper, we present a remote sensing technique for determining the existence or absence of grass coverage in vineyards. To perform this study, we use Sentinel-2 images using red, green, and blue bands, as well as a water vapour band, near-infrared band, and normalized difference vegetation band. This technique has certain limits, such as low spatial resolution, and cloud presence when the images are obtained. The selected images have 10 m x 10 m spatial resolution, except for the band of water vapour band (60 m x 60 m). In this study, we propose the use of time-series analysis to overcome the problem of low spatial resolution. To perform this study, we obtain images from January and June of 2020. Using ArcGIS software, we applied different tools to obtain qualitative and quantitative information. Then, we analyzed the significance of observed differences in the time series analysis, applying Single Analysis of Variance. Our results indicate that the best results are related to the Near-infrared band with a p-value of 0.0020. Finally, the pixel values obtained for the time series analysis of Near-Infrared band indicate that the plots with grass coverage have values from -1000 to -1200. Meanwhile, values from -1200 to -1500 are found in the plots without grass coverage.**

***Keywords- Precision agriculture; Image processing; Sentinel-2 bands; Vineyard monitoring.***

## I. INTRODUCTION

The world population is increasing, expecting to reach between 8.1 billion and 10.6 billion by 2050. This growth causes the necessity to maximize the production of food [1]. The existing farming systems are not able to attain efficient food production levels. In this context, the research for new techniques is one of the concerns of the population instead of optimizing the use of natural resources. On the other hand, the pressure of the increment of food demand and the decrease in prices forces the farmers to try to increment their crop production. Thus, in some cases, farmers are using dangerous substances for the environment, massive use of water, or excess use of fertilizer to maximize their harvest. Nonetheless, the implementation of sustainable agriculture might increase productivity, minimizing the environmental impact of the activity. The proper management of natural resources will be an interesting way of solving the actual problem [3].

In this context, the inclusion of new technologies in Precision Agriculture (PA) has been revealed as a technological solution. PA consists of the application of different techniques for the management of the agricultural stock. Therefore, it is possible to obtain optimum control of the production and of the required resources, and guarantee the sustainability of the activity. PA can be a solution to the problem of food security [4]. Another alternative is the application of conservation agriculture, which is based on the minimum disturbance of soil and the maintenance of grass coverage in the crops [5]. Its main advantages are the reduction of erosion and the improvement of water retention. In order to evaluate the degree of adoption of this practice, we need to evaluate with remote sensing the existence of grass coverage.

One of the techniques used for monitoring crops is image processing. This technique has been used to a huge range of purposes such as detecting weed plants [6], monitoring the plant health [7], quantifying the harvest [8], and evaluating pollutant presence. To maximize the results, this method can be applied combined with terrestrial techniques [9]. One of the problems with image processing and remote sensing techniques is the low resolution of the used images. The images with high spatial resolution, are more expensive and are not usually utilized for general research. When the available spatial resolution cannot fit the requirements, there is an alternative, the use of time series analysis. The use of time series analysis has been done in [10] with sunflowers and Unmanned Aerial Vehicles (UAV).

In this paper, we propose the use of images from the Copernicus Sentinel-2 satellite, with 10 m pixel resolution, to determine the existence or absence of grass coverage in vineyards. This evaluation will be done using images obtained at different moments of the year. We apply this methodology in the inner region of Spain, in the crops of IMIDRA, which is located in Alcala de Henares (Madrid). To obtain the required accuracy, we include in this analysis the following information from the satellite, including red band, green band, blue band, Water Vapour Band (WVP), Near-Infrared Band (NIR), and Normalized Differential Vegetation Index (NDVI) which is a combination of the Red band and NIR band.

The rest of the paper is structured as follows. The related work is outlined in Section 2. Section 3 presents the different techniques and the process of the study. The results are discussed in Section 4. Finally, the conclusions and future work are summarized in Section 5.

## II. RELATED WORK

In this section, we outline the state of the art. In the summarized contributions, we include systems proposed for

PA and image processing techniques for monitoring different parameters of the land.

Sun et al. [11] used a multispectral image to monitor the chlorophyll content in the field. They applied different fertilizers to the crops and used a multispectral Charge-Coupled Device (CCD) camera to collect ground-based images in the green, red, and NIR bands. They developed a new Normalized Difference Vegetation Index (NDVI). Besides, they obtained the correlation between image parameters and chlorophyll content obtaining R2 of 0.88. They concluded that vegetation indices derived from a multispectral image could be used to monitor the chlorophyll content. Mishra et al. [12] applied advances in Object-Based Image Analysis (OBIA) and machine learning algorithms in dry savanna ecosystems for forest detection. To do this, they use remote sensing-based in the characterization of vegetation properties is savannas. In this case, they used a stack of Landsat Thematic Mapper (TM) imagery, NDVI, and topographic variables with six different scale factors resulting in a hierarchical network of image objects. Additionally, individual vegetation morphology classes differed in the segmentation scale at which they achieved the highest classification accuracy, reflecting their unique ecology and physiognomic composition. Finally, their results showed the utility of the OBIA.

Other authors, as Parra et al. [13] proposed image techniques to detect prejudicial weeds in lawns. To perform this study, they used a mathematical operation where the red, green, and blue bands, as well as, edge detection techniques, are used. Besides, they use a post-processing operation to reduce the false positives, changing the combination between the selected bands. Clever at al. [14] used the Sentinel-2 and Sentinel-3 images for the estimation of total crop and grass chlorophyll and N content by studying in situ crop variables and spectroradiometer measurements obtained for four different test sites. The obtained results confirmed the importance of the red-edge bands, particularly in Sentinel-2 for agricultural applications, because of the combination with its high spatial resolution of 20 m. Rokhmana et al. [15] displayed some practical experiences of using UAVs based platform for remote sensing in supporting PA mapping. They proposed a system based on the aerial platform from Radio-Controlled plane, point and shoots digital cameras, and data processing with digital photogrammetric mapping.

In this paper, we present a low-cost method for determining the existence of a grass coverage in the vineyard using plots with grass and others without grass coverage. To perform the study, we use Sentinel-2 images from different timelines. This application will be useful, to elaborate maps and analysis about the adoption of conservation agriculture. Furthermore, it can be used to study the need for specific actions to maximize its adoption in certain regions or to evaluate the changes in the agroecosystems after certain activities.

## III. MATERIALS AND METHODS

In this section, the used materials and the methodology for the analysis of the data are presented.

### *A. Selection of Satellite*

Satellite images are selected for detecting the grass coverage in vineyards. We use free satellite images to obtain a low-cost system of determining the existence of grass coverage. In this context, we decide to use images from Copernicus Sentinel-2. The Sentinel-2 is characterized by two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180º to each other. Moreover, Sentinel-2 provides information every ten days, which is enough for our objective. Besides, this satellite has two types of images. Firstly, we have “Level-1C” products, which give information on the top of atmosphere reflectance in cartographic geometry, and “Level- 2A” offers data of the bottom of the atmosphere reflectance in cartographic geometry.

Moreover, Sentinel has a huge range of multispectral images, where the highest resolution is 10m x 10m. In this paper, we use only the six different bands included in Table 1 and the Normalized difference vegetation index (NDVI). Table 1 displays the characteristics of the used bands.

### *B. A proposed approach for the time series analysis*

Following we detail the principle that we follow to perform the time series analysis and detail the changes along the year in the studied plots with and without grass coverage.

Regarding the obtained images with Sentinel-2, each pixel contains information about the surface, which includes the vineyard, the soil, and if it grass coverage exists. Nonetheless, the grass coverage is not present during the entire year, its presence in maximum in winter and almost null in summer, see Figure 1.

In winter, the plant cover is greater due to the climate conditions. It is characterized by being wet and cold with a considerable rate of precipitation. On the other hand, in summer high temperatures predominate, where rainfall is drastically reduced, causing vegetation to wither and tend to disappear. These changes based on the season could be used to detect different pixel values in the bands. In this context, we hypothesize that, during the period in which grass coverage has a maximum presence (winter), the pixel values will be different from when the grass coverage is not present (summer) for plots with grass coverage.

TABLE I. SENTINEL-2 SPECTRAL BANDS

| **Bands** | **Wavelength (nm)** | **Resolution (m)** | **Description** |
|---|---|---|---|
| B2 | 490 | 10 | Blue |
| B3 | 560 | 10 | Green |
| B4 | 665 | 10 | Red |
| B8 | 842 | 10 | Visible and Near Infrared (VNIR) |
| B9 | 945 | 60 | Water vapour |

Nonetheless, for plots without coverage, the pixel values of both seasons will be very similar. The differences between the data from winter and summer based on our hypothesis are displayed in Table 2.

To perform the study, we select images from January and June. We select these images taking into account the live cycle of the vineyard and grass in the different parts of the seasons. This information is essential to select the crucial moments in which images are gathered. In this case, in January the vineyard does not have any leaves because it is the part of the year when the tree is pruned. On the contrary, in June the vineyard begins to have leaves. Meanwhile, grass coverage changes between winter and summer. In this area, winter is cold with a high precipitation rate, and summer is characterized by high temperatures of low precipitation.

### *C. Studied Zone*

The studied zone that we selected is located in the community of Madrid in the facilities of IMIDRA. We selected this location because there are huge vineyards where we have plots with grass coverage and others with non-coverage. It constitutes an optimum scenario to test the proposed system for monitoring the changes in the grass to determine the presence or absence of grass coverage.

We classify the selected plots in two types: The ones that contain grass coverage (GC=1), and the ones that do not present grass coverage (GC=0). The plots and the classification can be seen in Figure 2. We select seven plots, 4 of them without grass coverage, and 3 with grass coverage. We represent in red colour and label them as 1, the crops without grass coverage. On the other hand, we use the blue colour to represent plots with grass coverage, which are labelled as 0. In this context, we have the information on which plots present grass coverage and which do not.

### *D. The software selected of analysis of time series*

For the analysis, we use a combination of the different bands detailed in Table 2, from the different seasons. A specialized program is needed for treating the obtained satellite images. In this case, we select the ArcGIS [16].

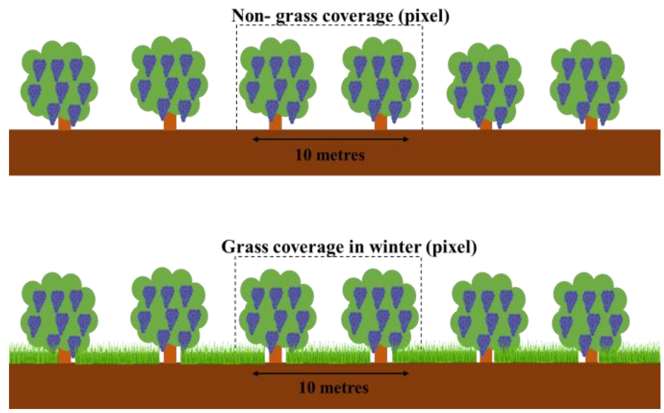


Figure 1. Scheme of pixel information content.

TABLE II. SUMMARY OF EXPECTED CHANGES ACCORDING TO OUR HYPOTHESIS

| **Bands** | **Reflectance GC=1** | **Reflectance GC=0** | **Differences in reflectance GC=1** | **Differences in reflectance GC=0** |
|---|---|---|---|---|
| B2 | Low | Low | Low | Low |
| B3 | Higher | High | High | Low |
| B4 | Low | High | High | Low |
| B8 | High | High | Low | Low |
| B9 | Higher | High | High | Low |
| **Pixels of:** | **GC=1 Winter** | **GC=1 Summer** | **GC=0 Winter** | **GC=1 Summer** |
| Vid | High percentage | High percentage | High percentage | High percentage |
| Soil | Almost null | Low percentage | Low percentage | Almost null |
| Green grass coverage | Low percentage | Almost null | Almost null | Almost null |

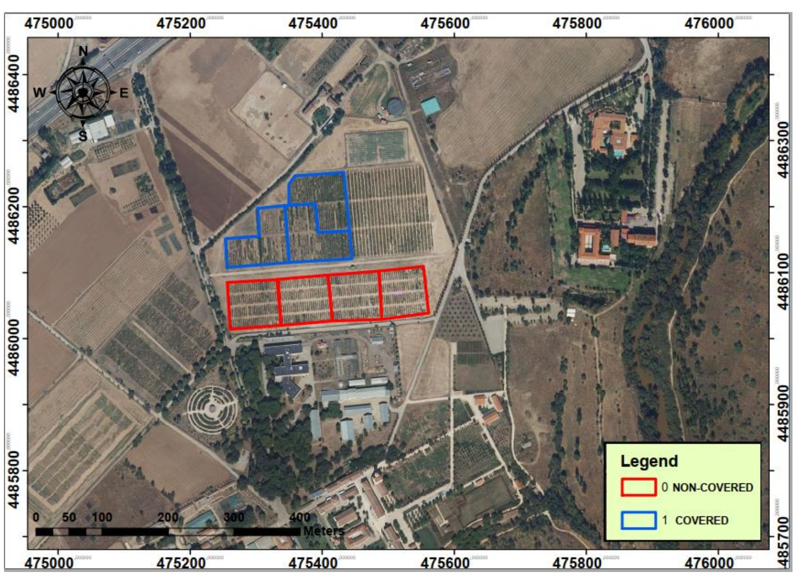


Figure 2. Classification of plots in the studied zone.

In this context, we use some operations using this software. The first operation that we apply is the “Raster calculator”. This tool allows us to observe the qualitative differences between the same areas on both dates. The output for these tools is a new raster in which the pixel values are the differences between the initial (January) and final (June) scenarios. Thus, we will be able to identify the different colouration in pixels that represent plots with or without grass coverage. In addition, we will extract quantitative information as a raster by applying “Zonal Statistics as table” to obtain a table with pixel values for each plot.

Finally, with the obtained data, we will use statistical software, Statgraphics Centurion XVIII [17]. With this software, we will perform statistical analyses to determine if the observed differences are statistically significant.

## IV. RESULTS

In this section, we display the obtained images and the time series analysis that we use to determine the existence of grass coverage. First, we evaluate the different bands, analyzing which combination provides the highest visual difference between plots with and without grass coverage. Finally, we use statistical analysis to verify if differences are statistically significant or not.

### *A. Band combination*

According to the analysis of data of obtained images, we can identify the following differences. In the range of bands from the visible spectrum (B2 to B4) of January, we find that the green band has the highest pixel values in plots with grass coverage. The blue band presents medium values, and the red band has the minimum pixel values in the plots with the grass coverage. On the other hand, in non-covered plots, the red band obtains higher values because there is more soil represented in the pixel, and it increases the reflectance in that specific wavelength. In addition, between NIR, WVP, and NDVI bands for the same season, the NIR band presents the highest pixel values for covered and no-covered plots. Figure 3 represents the RGB composition band and the single bands displayed. Besides, Figure 4 displays the other bands: the NIR band, WVP, and NDVI band.

In order to evaluate the differences in grass coverage in all the selected plots, it is necessary to combine each one of the bands from winter and summer seasons as pointed in the time series analysis. Figure 5 shows the results of the combination of bands. In this case, red, green, blue, NIR, WVP, and NDVI seasonal band combinations displayed that the plots with grass coverage present low pixel values, represented in a darker colour. The pixel represents the difference between the winter and summer values in each band. Besides, plots without grass coverage will display higher pixel values, symbolized in a lighter colour.

Figure 5 displays the image combination results. Moreover, in the visible spectrum (red, green, and blue bands), the obtained changes are not visually significant. Nevertheless, in the NIR, WVP, and NDVI bands, we can observe differences in pixel values between the selected plots (red plots and blue plots).

Considering the spatial resolution of used images, it is relativity challenging to observe visual changes in the crops. Therefore, the use of a statistical analysis will be necessary to determine which band combination is the best one for detecting the presence of grass.

### *B. Statistical analysis*

It is necessary to quantify the changes in the pixel value numerically. The Statgraphics software allows us to analyze the pixel values obtained from the combined results, getting statistical information from each image.

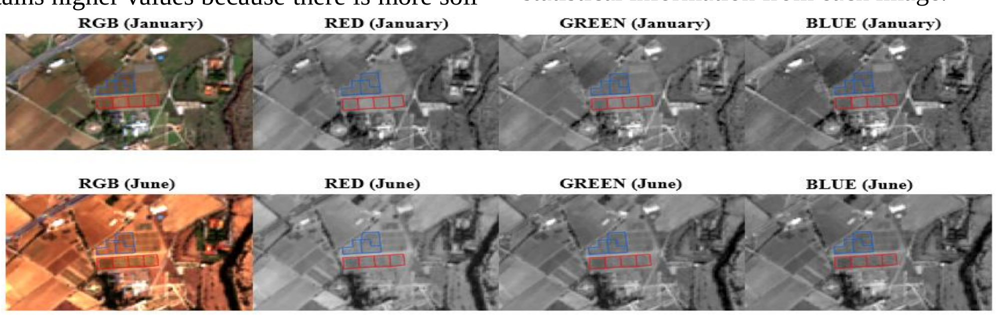


Figure 3. Visible spectrum bands.

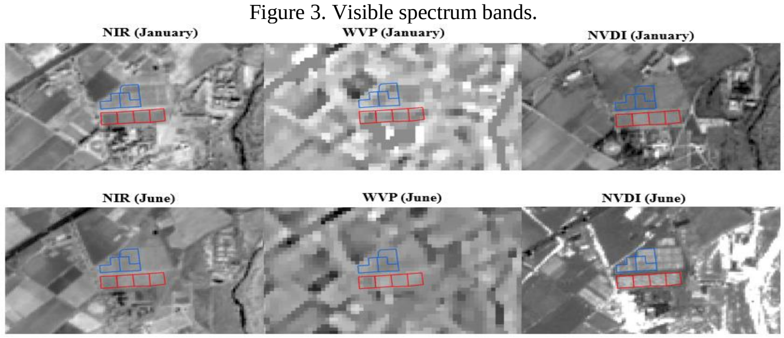


Figure 4. Near-infrared band, water vapour band, and vegetation index band.

Table 3 displays the “MEAN” for all the bands for different value in each one of the evaluated plots. With this, we can observe the differences between winter and summer, analyzing which band is the best for detecting changes.

Then, the application of an Analysis of Variance (ANOVA) procedure is required. This method is used to evaluate the values for each band combination and determine the significate grade of the values. To better illustrate the differences between the plots with and without grass coverage, we present Figure 6. Figure 6 is composed of six graphics. These graphics represent the data of the two classifications of plots as a box and whiskers diagrams. The box and whiskers diagrams, also known as box-plots, represent the similarity between the values of grass-covered plots and plots without grass. The data present higher similarities among them when there are higher overlapping between the plots classified as 1 and 0. The purpose is to find the band for which the difference among the calculated raster is maximum for both groups (GC=1 and GC=0). In this case, we can observe that all graphics indicate a certain distance between the values of both groups of plots. Nonetheless, the blue band is the only one that has the values of both groups close to each other. To complete the verification, we determinate the statistical significate of the values. We use the p-value to verify the significance of the observed differences. To be considered as a significant difference, the p-value must be smaller than 0.05.

Table 4 summarizes de p-values for all the band combinations. We observe that all the bands have significant values, except for the blue band. The best range of values is represented in the NIR, NDVI, and WVP bands, with the most accurate results being of the NIR band (p-value of 0.0020).

TABLE III. MEAN OF THE PIXEL VALUES OF DIFFERENT BAND COMBINATIONS FOR COVERED AND NON-COVERED PLOTS.

| Classific. | Red | Green | Blue | NIR | WVP | NDVI |
|---|---|---|---|---|---|---|
| 1.GC=0 | -775 | -632 | -456 | -1336 | -831 | -0,12 |
| 2. GC=0 | -618 | -623 | -422 | -1464 | -881 | -0,16 |
| 3. GC=0 | -775 | -697 | -491 | -1399 | -871 | -0,11 |
| 4. GC=0 | -892 | -756 | -557 | -1411 | -870 | -0,09 |
| 5. GC=1 | -1246 | -854 | -620 | -1113 | -785 | 0,02 |
| 6. GC=1 | -1179 | -797 | -582 | -1006 | -763 | 0,03 |
| 7. GC=1 | -1061 | -798 | -553 | -1176 | -799 | -0,02 |

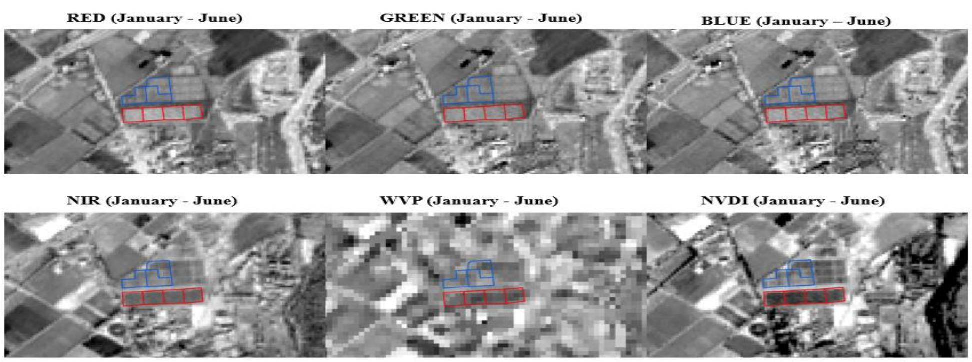

Figure 5. Results of combined images of January and June.

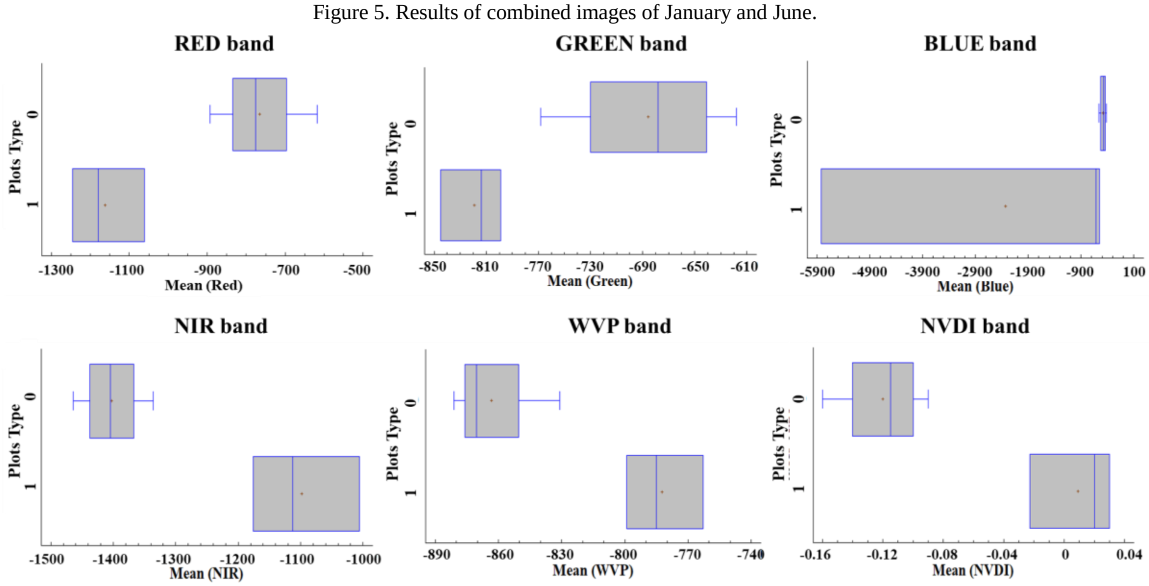

Figure 6. Box and Whiskers diagram of band values.

TABLE IV. THE P-VALUE OF ANOVA ANALYSIS FOR SELECTED BANDS

| **Bands** | **B4** | **B3** | **B2** | **B8** | **B9** | **NDVI** |
|---|---|---|---|---|---|---|
| **p-Value** | 0.0043 | 0.0184 | 0.2611 | 0.0020 | 0.0036 | 0.0021 |

The results show that the best band to differentiate whether vineyard crops have grass cover or not is the NIR band. The pixel values of the resultant raster (time series analysis) for this band have different values for plots wit and without grass coverage. Plots with grass coverage have pixel values from -1000 to -1200. On the other hand, plots without grass coverage are composed of pixels with values from -1200 to -1500.

Although we have demonstrated that the time series analysis might help to overcome the drawback of the low spatial resolution in this application, the methodology used in this study presents certain limitations. The presence of clouds might be a limitation in cases that, due to life cycles of crop and grass, images form periods with high presence of clouds are required. Moreover, the technique used could increase its efficiency considerably in plots with a greater extension, resulting in getting relevant information. Furthermore, due to the limited extension of the studied area and its low variability, our results cannot be applied in the different regions of Spain.

## V. CONCLUSION

We present a methodology, based on time series analysis to determine the existence or absence of grass coverage in vineyards. The target of this system is to provide a fast, remote, easy to use, and cheap method to evaluate the adoption of conservation agriculture. In this study, we use Sentinel-2 images, using different bands such as red, green, blue, NIR, WVP, and NDVI bands. The comparison of bands from different moments of the year allows us to evaluate the changes between the selected plots to determine the existence or absence of grass coverage. Our results indicated that the best band for the time series analysis is NIR band, followed by the NDVI band, and WVP band.

For future work, we will improve our study by including different region vineyards to verify the efficiency of this application. Furthermore, we will evaluate if it is possible to use other time series combinations avoiding the use of data from January due to the high probability of clouds in this month. Finally, we plan to test this method in orange crops. These present an added difficulty due to the position of the crops (trees more closely together) and the arrangement of leaves throughout the year, which may cause a greater probability of error when detecting the grass cover. The introduction of a soil gloss correction, such as the SAVI and MSAVI, will also be explored.

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