A Proposal for Monitoring Grass Coverage in Citrus Crops Applying Time Series Analysis in Sentinel-2 Bands

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Abstract. The growing trend in the world population causes an increment in the demand for food as fruits like oranges. In this context, crop grass coverage becomes essential to reduce the resources in tree maintenance and improve the harvest. In this paper, we propose the use of remote sensing for monitoring the grass coverage. To do so, we have compared in times between plots with and without initial coverage. In our work, we present image-processing techniques that consist of using different bands of Sentinel-2 images for different periods of the year, of obtaining reliable information for changes in the grass-coverage of the selected plots. The pixels of the selected images have a resolution of 10 m × 10 m wherein our experiment represents information about orange trees plus grass coverage or soil. In addition, we present the results of the study, demonstrating the best behaviour of the presented technique. For this experiment, we use five different brands of the satellite: red band, green band, blue band, near-infrared band, and water vapour band. As well as normalised vegetation index using combinations of red and infrared bands. The significance values are obtained applying Single Analysis of Variance, a Statistical analysis. In this case, the higher results are located in WVP band with F- Reason of 42.56 and P-Value of 0.000 blue bands with F-Reason of 38.61 and P-Value of 0.000.

Keywords: Image treatment · Image processing · Sentinel 2 bands

1 Introduction

Taking into account the ever-growing trend in population, as well as the socio-economic issues we are living, there is no doubt there will be a food problem [1]. We have been headed for a long time towards a future in which the availability of resources may not be as easy as we thought. Although, it is to be noted that, we have also been focusing on finding new techniques in order to subvert this situation. To better manage our resources and secure that everybody is provided of them.

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The world we would deal with in case we were not trying to find solutions for these problems such as hunger, scarce resources and the consequences of both factors, would be a terrible one. That is the reason behind many technological advances humankind has achieved in the past century. It is also, what motivated this paper.

Precision agriculture is the name given to the techniques and methods aimed to enhance the management of the agricultural stock. It is a crucial element for sustainable use and production of resources. Another option to improve the sustainability of agriculture is implementing alternative management solutions such as conservation agriculture, which promotes minimum soil disturbance and the maintenance of grass coverages.

Precision agriculture aims to improve the use of resources through technological advances [2]. The technical developments which came from the pursue of precision agriculture range from the creation of new materials and improvement of devices to new techniques and methodologies. The importance of imaging techniques is to be noted in precision agriculture. They can be used for many purposes, from detecting plant diseases [3] and weeds [4] to calculate the yield [5]. They can even be combined with terrestrial techniques [6]. Although the issue with these techniques is the pixel size, satellite images can have different pixel sizes, which affect the resolution of the image. The smaller the pixel size, the more information an image holds. Nonetheless, the resolution of the image determines its price, images becoming more expensive as the pixel size gets smaller [7]. In order to measure small changes, such as the presence of grass coverage, using large pixel sizes, images from different moments must be used [8].

In this paper, we will use images from Sentinel 2 from different moments to determine the maintenance or removal of grass coverage in citrus plots. We will be focusing on orange groves, which are predominant on the east of Spain. Using images from summer and winter, which present a difference in the presence of grass coverage, a method will be created. In order to create the method, different bands and the Normalised Difference Vegetation Index (NDVI) [9] will be analysed. Not only that but also images from different moments will be used in a multitemporal approach since the change we want to detect is small compared to the pixel size. We use these images because they are free, obtaining a low-cost system.

The rest of the paper is structured as follows. Section 2 presents some research related to the one developed in this paper. Then, the techniques used, as well as the process, is shown in Sect. 3. Next, results are explained in Sect. 4. Finally, Sect. 5 deals with the conclusions and presents the future line of this research.

2 Related Works

In this section, some methodologies used for precision agriculture are explained, focusing on those who deal with image processing techniques. In addition, the NDVI is explained. Moreover, they are contrasted with the experiment developed in this paper in order to ascertain their differences and point out the strengths of imaging techniques.

Zhang et al. [9] compared the use of Landsat-8 and Sentinel-2A images to calculate the NDVI. Both satellites have similar resolutions and coverages. Nevertheless, they present angular, spectral and spatial differences. It was proven that it is essential to adjust the sensitivity of filtering and atmospheric correction, as well as the adjustment to the nadir Bidirectional Reflectance Distribution Function (BRDF), adjusted reflectance. Both datasets presented similar results after applying the adjustments. Mahlein [3] used optical techniques such as 3D scanning, which can collect information related to crop plant vitality. The developed work focused on the reliable and accurate identification of plants infected with diseases. One of the strong points highlighted in this paper is the non-destructive nature of this method. Moreover, it also discusses the phenotypical use of these techniques besides precision agriculture use.

Parra et al. [4] used imaging techniques in order to detect weeds, which can be harmful to other plants, in lawns. The early detection of said weeds is critical to assess the problem before it gets out of hand. To do so, they used a mathematical combination of the red, green, and blue bands, as well as edge detection techniques. Nevertheless, some post-processing operations had to be done in order to reduce false positives. The combination of both methods (band combination and edge detection) also reduced the false positives. Parra et al. [5] used images from Sentinel-2, the same used in this paper, to estimate the performance of different varieties of an oil-producing plant. They used six varieties of said plant, grown during the months from February to June, being harvested in June. Only one image from every month was used in order to determine productivity. Using the differences in spectral signatures and the correlation using vegetation indices, they were able to estimate the yield accurately.

Kharuf-Gutierrez et al. [10] highlighted the importance of imaging techniques to analyse several parameters regarding crops. Factors such as hydric stress, nitrogen levels and vegetal strength can be monitored through the use of imaging techniques. They proved the use of those techniques to calculate the number of stems, the foliar mass, and the level of vegetal strength. Nevertheless, an Unmanned Aerial Vehicle (UAV), not from a satellite, obtained the images they used. Müllerova et al. [11] used different types of remote sensing, among them satellite imagery, to detect plant invasions. They tested their methods with four different plant species. For satellite images, with less resolution, they used pixel and object-based approaches. These methods were useful for species with complicated architecture.

The use of UAVs can be combined with the use of Unmanned Ground Vehicles (UGVs), as proven by Tokekar et al. [6]. They developed a symbiotic system, which solved the two main problems the use of both vehicles presents. These problems are the time-consuming soil measurements done by the UGVs and the limited energy or UAVs. Using both technological advances as well as new algorithms, the problems were solved, both theoretically and on real soil experiments. Ezenne et al. [12] developed an Unmanned Aerial System (AUS), which could estimate the water needs of crops using specific indices. They were able to determine the water stress through thermal imagery. Moreover, the UAS could be adapted for real-time irrigation. Taha et al. [13] proposed the use of mobile cameras for environmental surveillance. To provide better QoS for ultra-high definition (UHD) mobile users in the handoff process, they propose an intelligent handover algorithm model to decide on the handover process and the load balance among the network devices in the coverage area.

These fine researches show many applications of imaging techniques as well as prove the usefulness of the NDVI and Sentinel-2 images. Nevertheless, it is essential to note the importance of pixel size and economic availability of these techniques. Those that deal with small changes need either high resolution (small pixel size) or a multitemporal approach to make them economically viable.

This paper presents a method for the detection of grass coverage, which could disturb the growth of cultures, namely, orange trees. That is achieved by using images from different time series and using indexes to help identify the coverage. Creating a tool as useful as the one proposed in this paper could help farmers improve the managing of their crops.

3 Materials and Method

In this section, we are going to present the different materials and the methodology that we use in the performance of this experiment. Likewise, we have framed this section in different subsections as characteristics of the satellite, studied zone, and performance of the experiment.

3.1 Characteristics of the Satellite

The experiment aims to analyse and detect temporal changes in the grass coverage of the citrus crops. In this context, it will be necessary the use of image treatment of images from different temporal frames. To perform this experiment, the use of satellite images will be necessary.

We determinate to use the Copernicus Sentinel-2. This system is based on two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180º to each other. Likewise, this allows the monitoring variability in land surface conditions and its full swath width of 290 km. Moreover, it has a high revisit time of 10 days at the equator with 1 satellite, and five days with 2 satellites under cloud-free conditions with results in 2–3 days at mid-latitude. Likewise, this characteristic allows this project to monitor Earth´s surface changes [14], with coverage limit from latitudes 56º south and 84º north.

Furthermore, this satellite has a Multispectral Imager (MSI) providing 13 different spectral bands from 10 to 60 m of pixel size. Table 1 represents the ranges of the bands that we use in the experiment and their characteristics. This will be useful to extract specific information from the image using different combinations of the bands. Moreover, some of the operations that we can perform with these images include the achieve of Natural Colour, combining red, green and blue bands (B4, B3, B2); Colour Infrared, that is composed by B8, B4 and B3 are used to obtain a reflecting of chlorophyll; Short-Wave Infrared using B12, B8a, and B4 detects vegetation. Besides, other applications will be the agricultural use to detect the health of crops by combining B11, B8, and B2; the geological use to detect faults and lithology using B12, B11, and B2; and the bathymetric use (B4, B3, and B1) whitch is optimum to estimate sediment in the water.

Table 1. 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

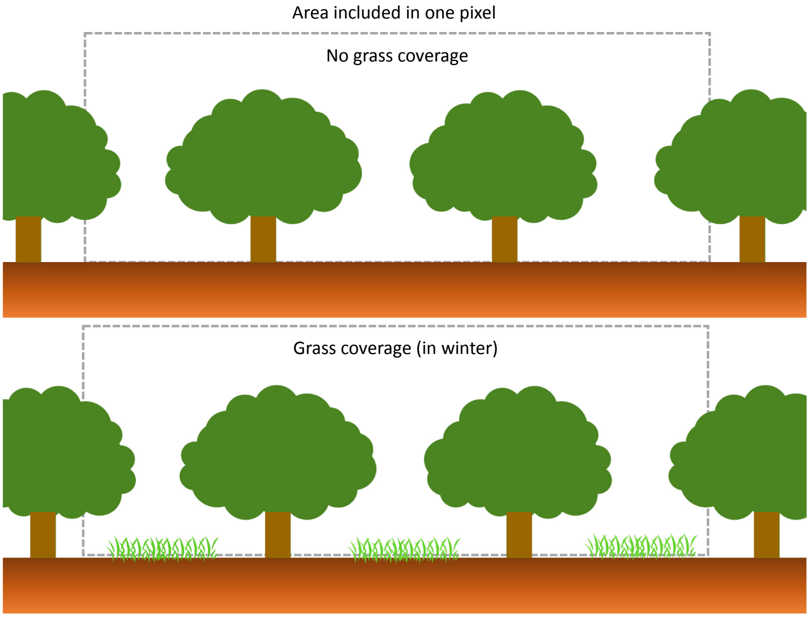
Finally, the last two applications are for obtaining the Vegetation Index and Moisture index. Furthermore, the Copernicus Sentinel-2 offers two types of products (images). Firstly, we have "Level-1C" products, which give information on the top of atmosphere reflectance in cartographic geometry. Otherwise, "Level-2A" offers data of the bottom of the atmosphere reflectance in cartographic geometry.

3.2 Studied Zone

The working zone is situated in Spain, specifically in Gandia (Valencian Community). This is one of the communities with higher areas of orange tree crops. Likewise, this area represents an optimum scenario to apply the proposed system for monitoring the changes in the grass coverage. This coverage has considerable benefits in these harvests as moisture retention that is very necessary because of the climate. In this case, we decide to use Sentinel-2 images because they have a resolution of 10 × 10 m each pixels in some bands. This cannot be considerate as an excellent resolution, but it is the best pixel size that we can find in open source images. This pixel resolution will contain information about the different surfaces included in this 10 × 10 m. Although it will not be possible to distinguish the trees, grass (coverage) and soil, we expect to find differences in pixels when they contain grass coverage ($GC = 1$) or no grass coverage ($GC = 0$) as it is defined in Fig. 1.

We hypothesise that during the period in which the grass of the agriculture plots is green the values of the pixel of the plots will be different than in summer when the grass is dead and is not present. The summary of the expected differences (subtraction between data from winter and data form summer), based on our hypothesis, is depicted in Table 2.

For the performance of this study, we use the software ArcGIS [15]. This software is needed to apply image treatment to the selected images. Figure 2 represents the selected orthoimage of Gandia, where we determinate the orange plots that we will evaluate. To do this, we select 21 plots, and we classify the plots in two categories, No-Cover (with number 0) and Covered (with number 1). The classification was done using some criteria: trees should be separated, grass cover should be visible, and the plot should be in productions (cannot be abandoned). This would be necessary to determine changes in grass coverage.



	The pixel will represent the reflectance of:			
	GC=1 Winter	GC=1 Summer	GC=0 Winter	GC=1 Summer
Orange threes	High percentage	High percentage	High percentage	High percentage
Soil	Almost null	Low percentage	Low percentage	Low percentage
Green grass coverage	Low percentage	Almost null	Almost null	Almost null

Fig. 1. Scheme of our hypothesis

Table 2. 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

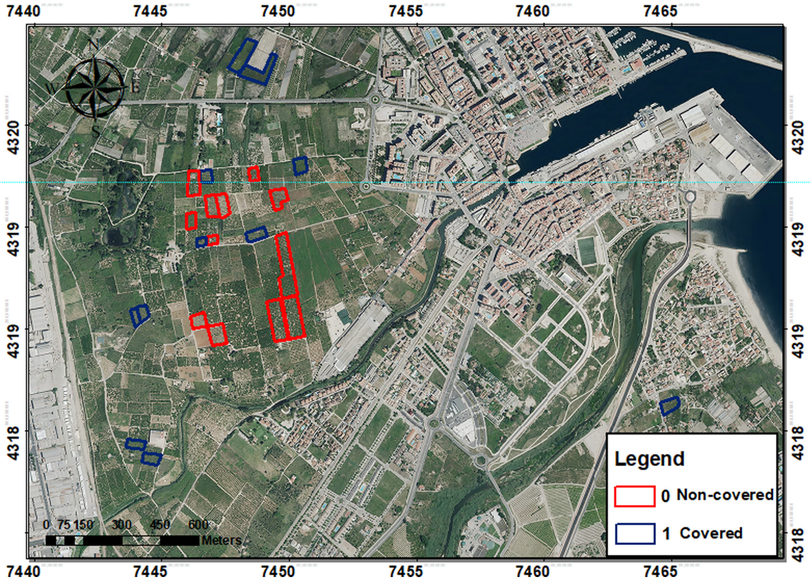


Fig. 2. Plots classification of the studied zone.

3.3 Performance of the Experiment

In this monitoring system, we select Sentinel- 2 images from January and July, taking into account the tree life cycle and situation of grass coverage in the different seasons of the year. These variables have a high relevance when it comes to detecting changes in coverage. In this context, oranges trees need 5 to 7 years to grow up and be productive. Likewise, this could cause different leafiness in the plots obtaining different results in the experiment. These two images will allow us to obtain the possible differences of coverage in citrus crops. We perform the test, evaluating the different changes between all of the bands, including NDVI. In this context, we use B2 (Blue), B3 (Green), B4 (Red), WVP, and NVDI. To do this, we applied the command of “Raster Calculator” to obtain the differences between the bands for the two images. In the case to achieve the vegetation index firstly, we use a combination of B8 that represents the VNIR, and B4 that is the red band. The purpose of these operations is to obtain two types of pixels: the tree with soil and tree with coverage. Finally, we use a “Zonal Statistics table” to get quantifiable information instead of qualitative information.

The obtained results in this proposed monitoring system are to provide an economical device for counselling the farmers in the monitoring of the citrus crops, analysing grass coverage changes in the harvests.

4 Results

In this section, we show the obtained pictures and the processing techniques used to quantify the evolution of grass coverage in citrus crops. First, we evaluate the different combinations of bands. Finally, we quantify and analyse the changes in grass coverage between winter and summer images.

4.1 Evaluation of Different Band Combination

To start, for this proposal it is necessary to evaluate which bands of the images can be used to detect grass covereage changes in the crops. In this context, the size of the pixels is about 10 m. This causes that some pixels will contain values from the areas with grass-coverage, and some from the areas without. In the case, in the plots with covereage the pixel values will be high in the green band, intermediate in the red band, and low in the blue band. Likewise, in Fig. 3 the RGB composition, the representation of the single bands, for January and July are presented. Otherwise, Fig. 4 illustrates the NIR band, WVP band, and NVDI image obtained by a combination of B8 and B4. For the representation of the images, we use a colour ramp between black and white, where the first one displays the lowest values of the pixel; and the second one, the highest values.

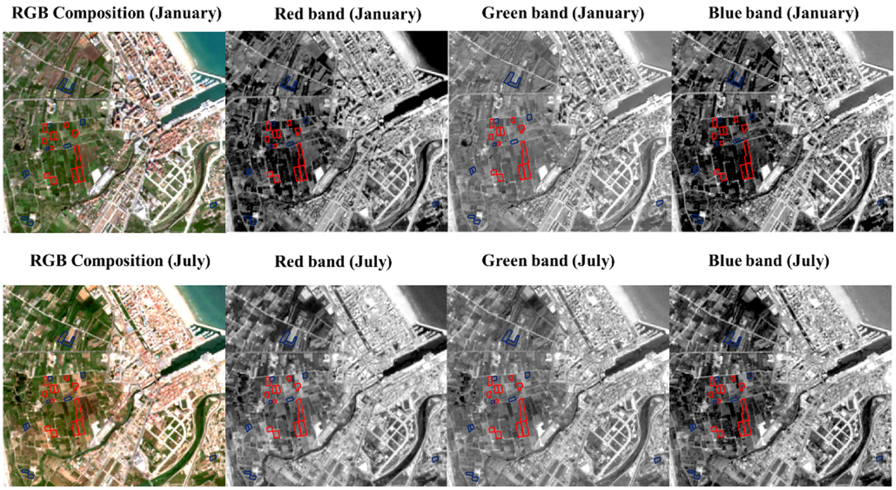


Fig. 3. Single bands of the January and July.

Furthermore, it is necessary to combine the individual bands of different dates to obtain the differences in the grass coverage for all the plots. The purpose of this paper is to maintain the system operation as simple as possible. In this case, we applicate only one command with "Raster Calculator" using the mathematical operation subtract in all of the bands. Moreover, Fig. 5 displays the different image results using greyscale. From those combinations, the covered plots should have low values (black colour pixels) because this pixel contains information about the orange trees and grass coverage. On

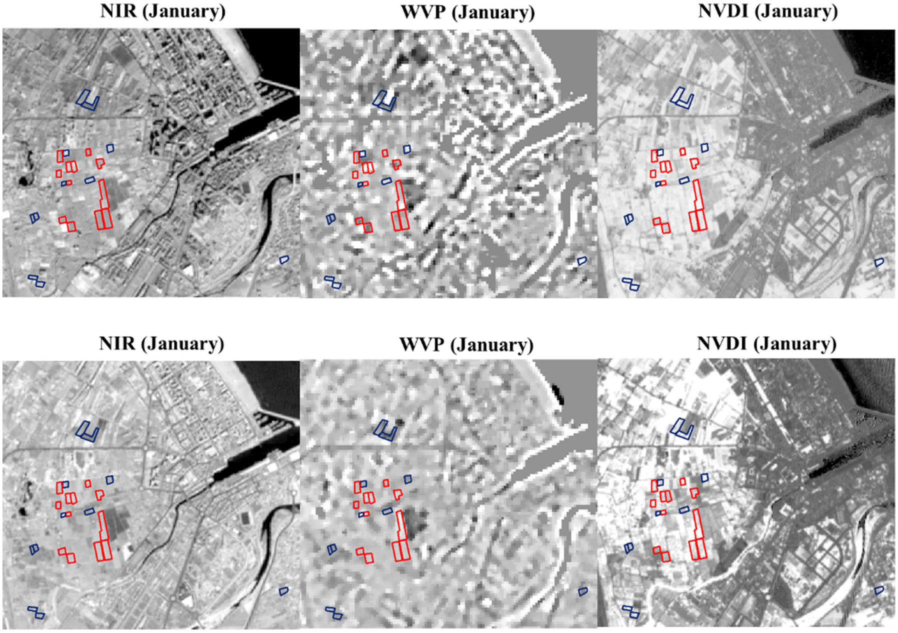


Fig. 4. Near-infrared band, water vapour band, and vegetation index of January and July.

the contrary, non-covered plots, in which orange tree information is combined with the soil without coverage, have high values (white colour pixels). Besides, visually, it is difficult to find differences due to the resolution of the image (10 × 10 m). Figure 5 represents the band combination results. Moreover, the visible spectral bands as red, green, and blue bands encompass the wavelengths that have optically fewer changes between plots marked in blue and red. Otherwise, the combination bands of NIR, WVP, and NVDI represent more clearly the possible changes between both classifications of crops. To obtain more reliable data from the images, we decide to evaluate the values using statistical analysis.

4.2 Analysis of Data

The next step is to obtain a statistical analysis of the obtained results. Our purpose is to evaluate if the values of non-covered crop and covered crops have significate differences. In our case, we use the specific statistical software Statgraphics [16] to analyse the values to obtain more information from the resultant images. Tables 3 and 4 represent the "MEAN" of the pixel values for both types of classified crops in the six images. In this table, the changes between the plots covered and non-covered are better appreciated. Moreover, the blue band, infrared band, and vegetation index bands are three of the bands that represent more unstable values between classifications.

Otherwise, the red band, the green band, and the WVP displayed some changes in the range of covered and non- covered crops. These values will have a marked pattern being minimum in classification 0 and maximum in 1.

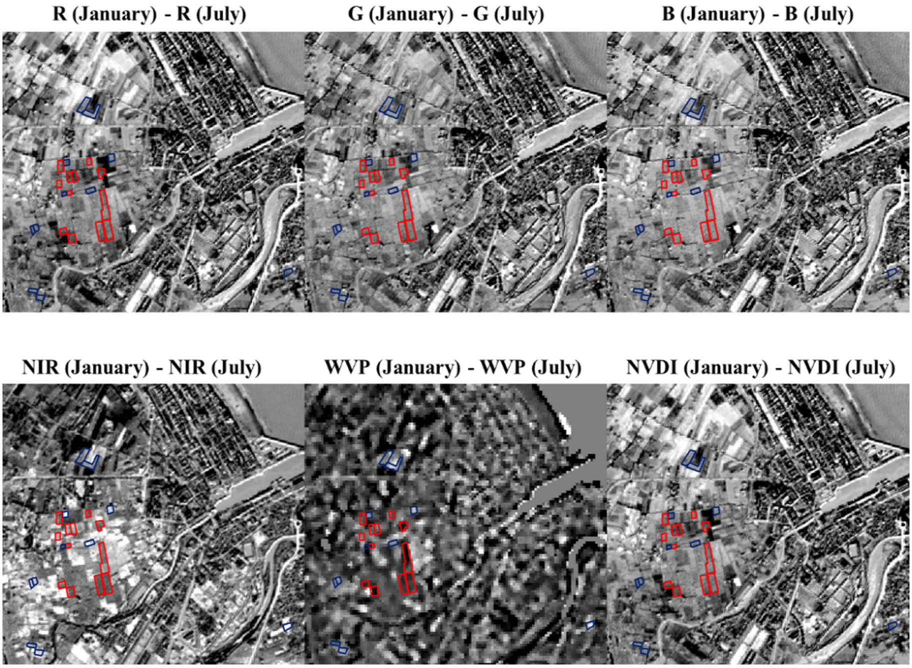


Fig. 5. Resultant images of band combination.

In addition, some of the data do not correspond to their classification being in some cases higher in covered plots or lower in non-covered crops. This will be caused by the different variables of the land and human uses, such as different sizes of the orange trees (old or young trees), the separation between the trees, or unexpected human actions in the crops. To minimise these errors is required to apply this technique in crops with more information and with the participation of the farmers that can contribute with the necessary data of the crops to use this image treatment technique with more efficiency.

In this context, it is necessary to run a more thoroughly evaluation to determinate the values for each band which are more statistically significant. To obtain these results, we applied a Single ANOVA procedure.

Figure 6 illustrates graphics where the differences between the two classifications of plots can be appreciated. For example, the more overlapping there is between the grey boxes for covered and non-covered plots values, the higher similarities the data presents between them. The excessive overlapping is considered as the values are not being significant, which means the limited validity of the band to detect changes in grass coverage for orange trees.

Table 3. Mean of the pixel values of different band combinations for covered plots.

Plots	B2	B3	B4	B8	B9	NVDI
1	−172	−239	−503	349	−1454	0.29
2	−62	−158	−356	−238	−1417	0.2
3	−76	−165	−239	−330	−1416	0.14
4	−119	−228	−317	650	−1482	0.14
5	−183	−250	−557	12	−1383	0.31
6	−150	−328	−448	370	−1569	0.24
7	−204	−320	−584	313	−1497	0.28
8	−227	−289	−548	528	−1457	0.33
9	−229	−257	−594	1039	−1450	0.37
10	−132	−167	−526	−823	−1335	0.28

Table 4. Mean of the pixel values of different band combinations for non-covered plots.

Plots	B2	B3	B4	B8	B9	NVDI
12	−419	−340	−145	214	−1491	0.23
13	−554	−410	−214	−783	−1676	0.18
14	−546	−368	−189	−760	−1670	0.2
15	−470	−311	−153	−310	−1733	0.2
16	−796	−410	−215	−439	−1704	0.25
17	−752	−450	−296	−417	−1701	0.2
18	−721	−379	−202	−518	−1732	0.26
19	−528	−400	−211	−569	−1608	0.18
20	−608	−430	−247	−568	−1662	0.23
21	−882	−474	−325	−20	−1558	0.34

Furthermore, to determine the statistical signification of the values, we use F-Reason and P-Value parameters. In this case, there will be a significant difference between the data for “Mean” and “Plots type” when the P-Value of F-Reason is smaller than 0.05 with a level of significance of 5%.

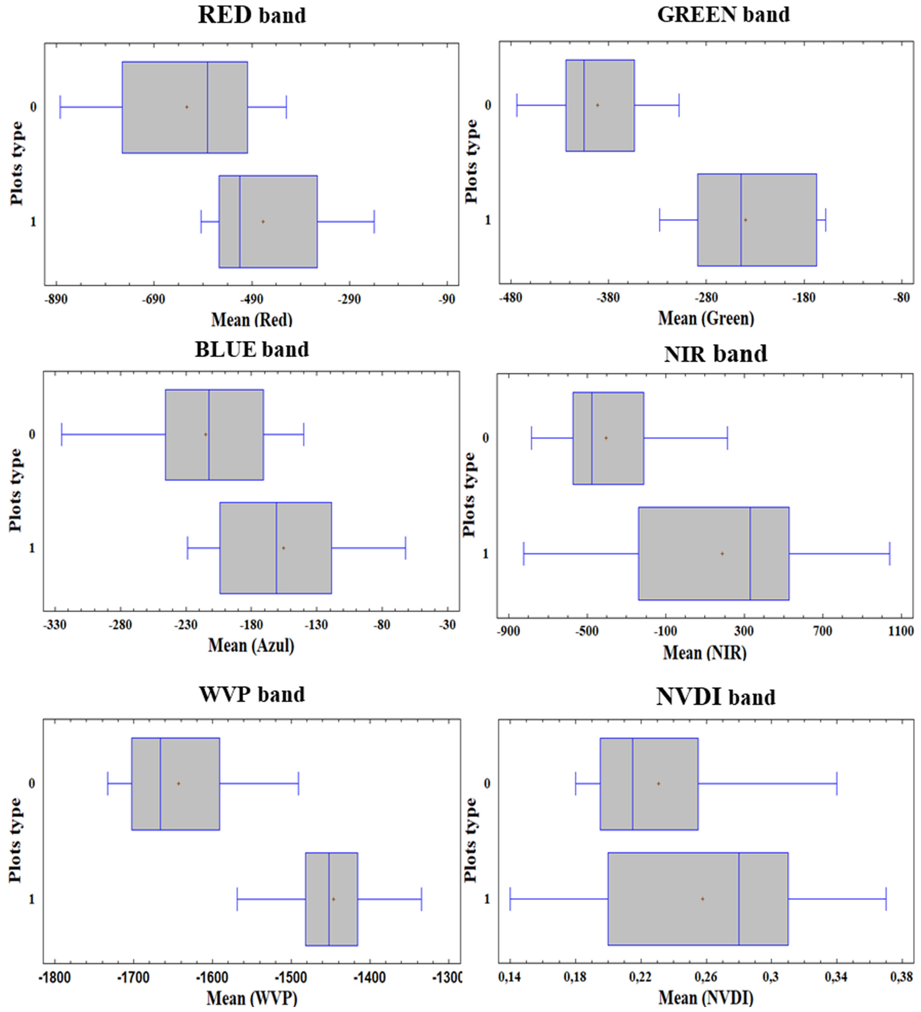


Fig. 6. Box and whiskers diagram of band values.

Moreover, Table 5 represents these two parameters for all band combinations. In this context, we verify that only the NVDI combination band is not significant because the P-Value is higher than 0.05 with a value of 0.3366. Otherwise, the rest of the bands fulfilled the required parameters to be considered significant values. Besides, the WVP band displayed the best results obtaining 0.0000 for P-Value and 42.56. Otherwise, the green value showed fascinating results with 0.0000 of P-Value and 38.61. It can be considerate that the best band combination is located in the green WVP bands. For this case, the data confirmed our hypothesis of monitoring grass coverage in orange crops. Besides, we verify the possible use of the NIR band in this experiment.

Table 5. F-Reason and P-Value parameters.

Bands	F-Reason	P-Value
B4	6.68	0.0177
B3	38.61	0.0000
B2	5,83	0.0254
B8	10.57	0.0040
B9	42.56	0.0000
NDVI	0.97	0.3366

5 Conclusions

We propose a system to evaluate the changes in grass coverage between covered plots and non-covered plots between summer and winter. The proposed monitoring system aims to obtain an economical device for farmers to consult the status of grass coverage in crops to obtain more quality and quantity of harvest. We use Sentinel-2 imagery to obtain images in the different bands of RGB, NIR, WVP, and NDVI for different times of the year to evaluate changes between plots with coverage and plots without grass coverage. The changes between the different classifications of crops are not easy to see in the band combination images. Nevertheless, they are observed in the statistical analysis of the pixels values. The highest differences are located in the combination of green bands and the WVP band. The obtained results are impressive because the NDVI has the lowest functionality when this band combination is one of the most used band to monitor vegetation. Furthermore, the result will be improved, increasing the information on studied plots and cooperating in person with the farmers. The developed system is useful to differentiate between orange trees and grass coverage. Nevertheless, is not optimum for differentiating between diverse plants.

For future works, we will improve new studies using drones as well as developing this monitoring system, collaborating with the farmers, and applying new image operations to obtain better results when consulting the crops.

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References

1. Prosekov, A.Y., Ivanova, S.A.: Providing food security in the existing tendencies of population growth and political and economic instability in the world. Foods Raw Mater. **4**(2) (2016)
2. Narvaez, F.Y., Reina, G., Torres-Torriti, M., Kantor, G., Cheein, F.A.: A survey of ranging and imaging techniques for precision agriculture phenotyping. IEEE/ASME Trans. Mechatron. **22**(6), 2428–2439 (2017)

3. Mahlein, A.K.: Plant disease detection by imaging sensors–parallels and specific demands for precision agriculture and plant phenotyping. Plant Dis. **100**(2), 241–251 (2016)
4. Parra, L., Parra, M., Torices, V., Marín, J., Mauri, P., Lloret, J.: Comparison of single image processing techniques and their combination for detection of weed in Lawns. Int. J. Adv. Intell. Syst. **12**(3–4), 177–190 (2019)
5. Parra, M., Parra, L., Mostaza-Colado, D., Mauri, P., Lloret, J.: Using satellite imagery and vegetation indices to monitor and quantify the performance of different varieties of Camelina Sativa. In: GEOProcessing 2020 The Twelfth International Conference on Advanced Geographic Information Systems, Applications, and Services. IARIA, Valencia, Spain, pp. 42–47 (2020)
6. Tokekar, P., Vander Hook, J., Mulla, D., Isler, V.: Sensor planning for a symbiotic UAV and UGV system for precision agriculture. IEEE Trans. Rob. **32**(6), 1498–1511 (2016)
7. Sozzi, M., Marinello, F., Pezzuolo, A., Sartori, L.: Benchmark of satellites image services for precision agricultural use. In Proceedings of the AgEng Conference, AgEng, Wageningen, The Netherlands, pp. 8–11 (2018)
8. Sagawa, T., Yamashita, Y., Okumura, T., Yamanokuchi, T.: Shallow water bathymetry derived by machine learning and multitemporal satellite images. In: IGARSS 2019–2019 IEEE International Geoscience and Remote Sensing Symposium, Yokohama, Japan, pp. 8222–8225. IEEE (2019)
9. Zhang, H., Roy, D.P., Yan, L., Li, Z., Huang, H.: Comparison of Landsat-8 and Sentinel-2A reflectance and normalised difference vegetation index. In: AGUFM 2017, vol 2017 EP23B–1919
10. Gutierrez, S.K., Morales, R.O., Díaz, O.D.L.C.A., Ruiz, E.P.: Multispectral aerial image processing system for precision agriculture. Sistemas Telemática, **16**(47) (2018)
11. Müllerová, J., Brůna, J., Dvořák, P., Bartalo, T., Vítková, M.: Does the data resolution/origin matter? Satellite, airborne and uav imagery to tackle plant invasions. In: International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences, vol. 41 (2016)
12. Ezenne, G.I., Jupp, L., Mantel, S.K., Tanner, J.L.: Current and potential capabilities of UAS for crop water productivity in precision agriculture. Agric. Water Manag. **218**, 158–164 (2019)
13. Taha, M., Parra, L., Garcia, L., Lloret, J. An Intelligent handover process algorithm in 5G networks: the use case of mobile cameras for environmental surveillance. In 2017 IEEE International Conference on Communications Workshops (ICC Workshops), Paris, France, , pp. 840–844. IEEE (2017)
14. Sentinel ESA. https://sentinel.esa.int/web/sentinel/missions/sentinel-2. Accessed 25 May 2020
15. ArcGis Software. https://www.arcgis.com/index.html. Accessed 19 Feb 2021
16. STATGRAPHICS Centurion XVIII Software. https://statgraphics.net/descargas/. Accessed 28 May 2020