Estimating the Canopy Cover of *Camelina sativa* (L.) Crantz through Aerial RGB Images

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***Abstract*—In rainfed agriculture, where crop extensions are high, yields are low and profit margins are tight, expensive solutions for crop monitoring are ineffective. Therefore, achieving an effective, fast, low time consuming, and cheap Crop Coverage or Canopy Cover estimation is important, as it is an indicator of the crop vigor or any issue taking place during the plant growth. Moreover, it is also an interesting way to estimate and evaluate the soil covered by vegetation in degraded rural areas and assess problems with soil erosion due to the lack of vegetation. The use of Remote Sensing Technologies as satellite MultiSpectral images offers numerous advantages, as it is a powerful tool. However, lacks the speed of an Unmanned Aerial Vehicle or drone when gathering images, as it depends on the satellite acquisition calendar. On the other hand, gathering images with conventional cameras is not possible on large farms and plots or hard-to-reach areas. The use of a commercial non-professional drone to gather conventional images of a crop is a useful tool to estimate the canopy cover of the crop in different growth stages. This estimation allows detecting problems during the seeding phase or detecting areas where the crop is not growing, along with measuring the percentage of covered soil by the plant. As showed in this paper, we have managed to estimate the canopy coverage of camelina in an experimental plot seeded in two different dates, and assess the crop performance in a reliable way. The average canopy cover for the late seeded plot was 15.55 %, while the in the early seeded plot was 76.09 %.**

Keywords—camelina; remote sensing; canopy cover, soil erosion.

I. INTRODUCTION

Soil erosion is one of the most important factors in land degradation and one of the principal mechanisms of desertification at national and regional levels [1][2]. Due to its geographical location and climate, Spain is one of the country's most severely affected by soil erosion in the European Mediterranean region [3]. The main effects caused by erosion are the loss of agricultural and forest soil fertility, increased degradation of vegetation cover, and a decrease in natural hydrologic control. All these interrelated processes are linked to the threat of desertification and global climate change [4].

In rural areas, poor soil use has negative effects such as loss of fertility, degradation, and desertification. Therefore, it is a natural resource suffering from gradual deterioration; and generates a negative impact on the environment. For this reason, recovery processes of the vegetation and soil cover must be carried out, along with control and mitigation measures of erosion. In addition, it is recommended to implement natural mechanisms that do not generate new environmental impacts. Thus, the use of natural materials or vegetal covers is proposed as a natural remediation [5].

The establishment of vegetal covers is an excellent alternative to prevent erosive processes, since it increases the hydraulic resistance of the land by increasing the stability of the soil aggregates. The soil acquires protection against the impact of raindrops by increasing its infiltration capacity and stopping runoff. Native plants are the best guarantee of a healthy ecosystem, since they are adapted to the characteristics of the field [6].

Camelina sativa (L.) Crantz [camelina] has emerged in recent years as an alternative oilseed and cover crop from the Brassicaceae family. Camelina seed meal and oil can be used for both animal feed and human food, but also has many industrial applications [7]. With a short life cycle, camelina can be an ideal rotational crop as it has two distinctive biotypes, spring, and winter. Winter biotypes require a vernalization treatment to enter the reproductive phase, while spring biotypes do not [8][9]. Increased interest in broadening the diversity of winter-hardy cover crops to reduce soil erosion through the winter months has led this crop to become an excellent choice [8][10]–[12].

As an example, camelina cultivation in the central area of Spain (Comunidad de Madrid, Castilla-La Mancha and Castilla y León) has increased in the past years due to the effort of private and public actors such as Camelina Company Spain [CCE] and Madrid Institute for Rural, Agricultural and Food Research and Development [IMIDRA] [13]–[17]. Therefore, camelina is considered as a growing crop in Spain, leading a special interest in crop diversification. It is a practical and economically viable alternative, supported by its short growth period. At present, institutions promote the production of non-food biomass to contribute to the worldwide change of energy policies. This requires fast-growing species to produce energy or raw materials to produce other combustibles. Two areas of emerging interest from the agricultural sector have converge in recent years: 1) the convenience to promote new systems of agrarian production that result in sustainable rural development in Spain, and 2) the need to substitute the demand of fossil energy with renewable energies, based on the benefit of the environment [18].

Within the CAMEVAR project, we are assessing several varieties of camelina provided by CCE, together with cultivation techniques and practices in combination with new technologies. In this paper, we analyze the use of Red, Green and Blue [RGB] images gathered with a Parrot Bebop 2 UAV [Unmanned Aerial Vehicle] to estimate the Crop Coverage or Canopy Cover [CC] of camelina. We will determine the percentage of soil and vegetation through a combination of the images bands to assess the evolution of the crop, seeded in two different dates.

The rest of the paper is structured as follows: Section II outlines related works; Section III describe the materials and methods; Section IV analyzes the results and highlights the importance of assessing the evolution and coverage of certain crop; finally, conclusions and future work are summarized in Section V.

II. RELATED WORK

In this section, we summarize some of the related works to estimate crop coverage through remote sensing, either with RGB images or MultiSpectral [MS] sensors.

Alatorre et al. [19] analyzed the temporal evolution of plant activity on vegetated areas and in erosion risk zones in a small area of the central Pyrenees during the period 1984-2007 from two Landsat Normalized Difference Vegetation Index [NDVI] time series for the months of March and August through MS sensors. This allowed the analysis of the spatial and temporal dynamics of plant activity in areas with good plant cover (forests and dense scrub) and in degraded areas affected by erosion processes (gullies and erosion risk areas). Through a multivariate regression, NDVI trends were analyzed considering climatic factors. The spatial resolution of the Landsat image allowed a good representation of the selected covers. The study showed that in the Pyrenees there has been an increase in plant activity in the last 24 years due to the increase in temperature. However, the extreme conditions that exist in this area with active erosion and areas at risk of erosion did not allowed the recovery of the vegetation among the study period. The issue about MS sensors is that they are more sensitive and expensive compared to RGB sensors.

Basterrechea et al. [20] proposed a system to evaluate the changes in grass coverage between covered plots and non-covered plots, between summer and winter. They aimed to obtain an economical device for farmers to consult the status of grass coverage in crops and to improve the quality and quantity of harvested fruits. The study used the Sentinel-2 satellite platform to gather images in the different bands of RGB, Near InfraRed [NIR], Water Vapor Permeability [WVP], and NDVI index for different times of the year to evaluate changes between plots with coverage and plots without grass coverage.

Regarding the use of RGB images, an alternative to obtain high-resolution spatial and temporal images is the implementation of UAVs equipped with digital cameras. In images with high spatial resolution, it is necessary to know the vegetation index that best identifies the pixels that contain vegetation and those that do not, as well as the threshold value that allows separating both classes. Marcial Pablo et al. [21], used the Otsu-Valley algorithm to estimate the plant cover of the corn crop combined with the Excessive Greenness index [ExG]. This algorithm establishes that the optimal threshold to separate the image into differentiated classes resides in the value of the spectral histogram located between its two maximum peaks. As it calculates the most appropriate threshold during the intermediate stage of crop growth, with accuracies greater than 94 %. Therefore, they accomplished a high precision in the estimation of vegetation cover using the ExG index and the Otsu algorithm in early stages of crop growth.

As Asahpure et al. recall [22], RGB-based CC estimation methods can be divided into two categories: 1) thresholding method that requires the specification of the color thresholds or the ratios to identify canopy pixels; and 2) pixel classification methods that use a supervised or unsupervised pixel-wise classification method to identify canopy pixels. Though pixel classification methods are highly accurate, they are time consuming and computationally extensive. Supervised classification methods require training samples to be collected, which is expensive and prone to human error. However, pixel classification methods are particularly useful to calibrate thresholding methods [23].

There is a large amount of work in the literature that uses RGB sensors to compute CC. Early work in this direction includes the quantification of turfgrass cover using digital image analysis by Richardson et al. [24], where digital image analysis proved to be an effective method to determine turfgrass cover, producing both accurate and reproducible data. Lee and Lee [25], estimated canopy cover over the rice field using an RGB sensor which is a nondestructive, low-cost, and convenient method for estimating CC using digital camera image analysis. CC was estimated by the ratio of plant pixels to total pixels with an image analysis program developed in Visual Basic to extract RGB features from the mosaic images. Then they calculated the RGB-based color index and compute the minimum segmentation error for separating rice plant from background.

Finally, Marín et al. [26] showed the accessibility, easy use and low cost of digital RGB cameras as a perfect device for turfgrass green biomass estimation and water management, especially under limited growing conditions.

As we have showed, the use of RGB images is common in CC estimation of diverse crops, but there is no evaluation of these methods in camelina; as most of the studies are based on MS index to evaluate other crops performance or yield [27][28]. The use of UAVs for proximal remote sensing on a crop as camelina offers better results than satellite remote sensing, ground taken images or Unmanned Terrestrial Vehicles [UTVs]. Therefore, using UAV imaging produces a detailed CC map of the field in timely and inexpensive manner. Moreover, the crop growth can also be monitored by using UAVs and generate on-go vegetation index to assess the crop health and determine if it is necessary to apply fertilizers or herbicides [29].

III. MATERIAL AND METHODS

In this section, we will detail the procedure followed to gather and process the data from the field, as well as the software and hardware employed to obtain and analyze the results.

A. Crop seeding

Within the framework of CAMEVAR project, IMIDRA collaborates with CCE in assessing several camelina varieties and how they adapt to the central area of Spain. To perform this essay, we seeded four replicas of a winter camelina variety (V11) in two different dates (December 2nd, 2020 and February 18th, 2021) in "Finca El Encín", Alcalá de Henares, Madrid (Spain) facilities. The soil at this location is a typical Fluvisol (Calcaric), according to the World Reference Base for Soil Resources 2014 [30]. These soils are developed in fluvial deposits as river plains, valleys, lake depressions and tidal marshes on all continents and in all climate zones. They lack of groundwater or high salt contents in the topsoil. In addition, many Fluvisols under natural conditions are flooded periodically. Also, these soils profiles have evidence of stratification and a weak horizon differentiation, but a distinct topsoil horizon may be present.

We used two seeding techniques and applied two concentrations of Urine derived Fertilizer [UdF] (low-60 and high-90). Therefore, each plot had a combination of two different seeding methods: 1) broadcast, without burying the seed and 2) in rows, burying the seed. Each individual plot was 1m wide and 15m long. For this purpose, we used a Wintersteiger self-propelled TC plot seeder. The seeding dose was 8 kg/ha and the plot had no irrigation, as it is a rainfed crop. The distribution of the individual plots was as follow: (A) 1st seeding date – broadcast – 60UdF; (B) 1st seeding date – broadcast – 90UdF; (C) 1st seeding date – rows – 60UdF; (D) 1st seeding date – rows – 90UdF; and (E) 2nd seeding date – broadcast – 60UdF; (F) 2nd seeding date – broadcast – 90UdF; (G) 2nd seeding date – rows – 60UdF; (H) 2nd seeding date – rows – 90UdF (H) (Figure 1).

B. UAV specifications and image gathering

Images to estimate the camelina CC where taken on April 19th, 2021 at X475093 Y4486168 ETRS89-30N. We used a Bebop 2 UAV with a 24-bit color RGB camera and a resolution of 1440x1080 pixels to take zenithal pictures of the camelina canopy at 15 m height. This UAV has an autonomy of 25 min, enough to capture the study area or even larger surfaces.

C. Image processing

We selected QGIS 3.16.4-Hannover [31] to process the images, as it is a free and open software, to simplify the CC calculation. First, images where cropped to treat each image individually (P1 to P8) (Figure 1). And they were later included in QGIS.

A RGB image is composed of three bands. The linear combination of these bands produces the picture that the naked eye sees. Nonetheless, when these bands are combined in a different way, several indexes appear. As we wanted to estimate the CC, we choose to differentiate soil form vegetation. We also supposed that all the crop present in the picture was camelina, as the presence of weeds was low. Later we processed the images according to a soil index Eq. (1) [32].

$$\textit{Soil Index (SI)} = G_{band}/R_{band} \tag{1}$$

P4	F.1	G.2	F.3	H.4	C.1	B.2	A.3	A.4	**P5**
P3	E.1	F.2	G.3	F.4	B.1	A.2	D.3	C.4	**P6**
P2	G.1	H.2	H.3	E.4	A.1	C.2	B.3	B.4	**P7**
P1	H.1	E.2	E.3	G.4	D.1	D.2	C.3	D.4	**P8**

Figure 1. Plots disposition for each seeding date.
(A to D: first seeding date; E to F: second seeding date).
P1 to P8 are enumerated according to the flight order of the UAV (clockwise).

This index is based on the fact that the soil has higher values of brightness in the red band [R] than in the green band [G]. Therefore, it divides the green band by the red band obtaining a new image, which gives information about the soil/plant coverage. Following, each image was reclassified with a determinate threshold to differentiate soil from vegetation. Pixels between 0 and 1 where reclassified as 0 and considered soil (black pixels); pixels over 1 where classified as 1 and considered vegetation (white pixels) (Figure 2 and Figure 3). Once the images were reclassified, we used the QGIS tool "*zonal statistics*" to calculate the numbers of pixels with 0 and 1 value. Finally, we estimated the proportion of CC in each plot from this numbers, expressed as a percentage of soil covered by the camelina canopy (Table I).

IV. RESULTS

In this section, we will analyze the obtained data. We will compare the CC of the same camelina variety, seeded in two different dates and with differential fertilization rates.

A. Canopy cover

We have considered the camelina CC in two different growth stages of the crop. One, almost fully developed with flower and fruits appearing (1st seeding date – P5 to P8) and 40 cm to 50 cm height (600 BBCH scale [33]), and another as a rosette with the plant at ground level (2nd seeding date – P1 to P4). The differences in the CC are remarkable and as expected. Camelina phenological stages are different so the percentage of soil covered is higher as the plant is bigger (TABLE I). The average CC for P1 to P4 plots is 15.55%, while the average CC for P5 to P8 plots is 76.09%.

In addition to the CC ratio, there are other interesting parameters that can be assessed with the RGB processed images: the correctness of the seeding procedure or the effects of the different crop management procedures employed, as long as if there are differences in the applied fertilization dose.

We must emphasize that this paper we are presenting is a work in progress, as the crop is still growing, and we keep gathering data.

Nevertheless, we have detected some issues with the Wintersteiger plot seeder: the middle of the seeding route has less density than the edges. This is a phenomenon that happens in all the plots (P1 to P8) (Figure 2 and Figure 3). Because of this, the central area CC is lower, as is the density of plants too. Even though the dose of seeds was the same, the blooming of the plant was not.

TABLE I. CAMELINA CANOPY COVERAGE

Camelina Canopy Cover (CC)	PLOT (P)
14.88%	1
27.04%	2
9.67%	3
10.64%	4
69.17%	5
76.19%	6
78.24%	7
80.76%	8

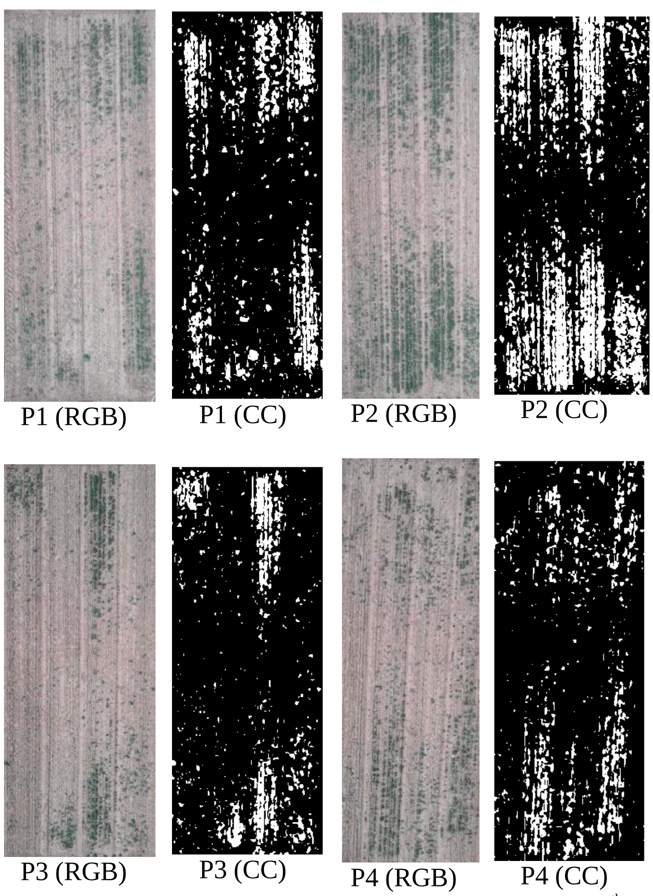

Figure 2. Camelina coverage. Plots seeded on February 18th, 2021.

If we analyze P5 to P8, as they were seeded first, we appreciate some differences in the seeding procedure: P5-C.1 and P8-D.1-D.2-C.3-D.4 replicas were seeded using the rows procedure (the seed is slightly buried in the ground) and they have a higher CC (Figure 3). The visible density of white pixels is higher in those bands. When compared to P1 to P4 plots, the rows seeding procedure seems to behave better, as there is a higher density of white pixels in those bands too, e.g., P2-G.1-H.2-H.3 and P4-G.2-H.4.

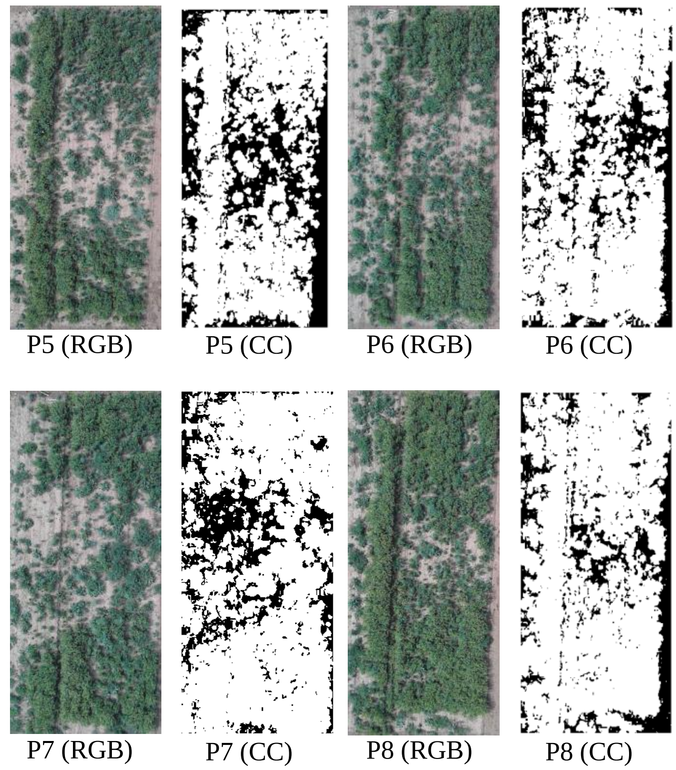

Figure 3. Camelina coverage. Plots seeded on December 2nd, 2020.

Regarding the use of two fertilizer doses, results are not conclusive yet. As we have to harvest the crop and calculate the seed yield per hectare and plant weight (biomass). However, the CC results are quite promising. When comparing P8-D.1 to P5-C.1 (same seeding date and procedure, but different UdF doses), P8-D.1 (90UdF) seems to have a more consistent CC of camelina. The remaining bands do not seem to show remarkable differences when compared by the fertilizer dose. Still, we expect to appreciate these differences in further UAV flights, when the crop is in a later phenological stage.

V. CONCLUSIONS

Through this paper, we have presented an easy, cheap, and effective way to assess the canopy coverage of camelina crops. This is relevant as it allows the farmer or investigator to assess the growing of the crop and determine if there has been any issue during the seeding procedure. Even though, once the essay or crop are seeded, if there is any problem it would be difficult to solve. So by flying the UAV as a check procedure, this could be issued in further campaigns to avoid echoing the previous mistakes. Capturing images with this kind of UAVs and RGB cameras is very cheap, as well as the post processing of the images. In addition, the information gathered could be a potential game changer in the management of large rainfed crops areas, where the benefits of the crop are tight.

As this paper is a current work, we aim to compare the gathered data with results from seed yield and plant development, and with thermal images in larger plot areas. Therefore, we could aim to assess detecting diseases in large crop areas, or not growing spots that could reduce the final yield of the crop.

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