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Study of the Relationship between Biomass and Fractional Green Canopy Cover of Two Forage Crops Using Canopeo®

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Abstract: Rapid and accurate estimation of biomass is crucial for the assessment of the crop nutrition status and the improvement of crop management strategies. The study was conducted in Setif province (Northeast of Algeria). Canopy cover was calculated using Canopeo® application, at stem elongation, booting, and heading stages for triticale, and V5, R1, and R3 for lentil. The results indicate a high correlation between canopy cover and triticale biomass, at the stem elongation stage with R^2 = 0.98 and 0.89 under no till and conventional till, respectively. The RMSE was 0.1 and 0.06t/ha, under the two modes. The lowest correlation is seen at heading stage with a value of 0.21 and RMSE of 0.65t/ha, under no till mode. For lentil, the high correlations between are observed at R3 (early pod), and R1 (early bloom) stages, with a coefficients of 0.85 and 0.98, under zero till and conventional respectively. The RMSE was 0.17t/ha. This smartphone application is suitable for assessing triticale and lentil biomass; it is rapid, easy, and could replace the destructive sampling method.

Keywords: Correlation, RMSE, Biomass, FGCC, Canopeo®.

Introduction

Rapid and Accurate estimation of biomass is crucial for the assessment of crop nutrition status and the improvement of crop management strategies (Lu et al., 2019). The measurements of crop biomass and height are usually done by direct sampling or using devices such as the rising plate meter, capacitance meter and meter stick (Viljanen et al., 2018). However, this method is not practical for repeated large scale measurements. It consumes considerable time, destructive, labour and resources. Precision farming and high-throughput phenotyping measurements and digital imaging has the potential to provide more information to make more informed management decisions on a canopy scale in real time (Kipp et al., 2014; Barmeier & Schmidhalter, 2017; Elsayed et al., 2018).

In recent years, indirect and non-destructive optical methods based on canopy cover have been used, especially in field environments (Bendig et al., 2014; Chen et al., 2018; Hufkens et al., 2019). It can be measured by processing digital images of the canopy taken directly above the crop. It is generally defined as the proportion of the ground area covered by the vertical projection of the plant canopy (Büchi et al., 2018).

Researchers used this function to measure perspectives on high throughput phenotyping in developing countries and proved that this method could be applicable in specific situations where research budget is tight. It has been widely tested and proven as an accurate, easy and fast method to estimate canopy cover of durum wheat (Casadesús et al., 2007), barley (Neumann et al., 2015), sorghum (Chung et al., 2017), canola (Pandey et al., 2016), onion (Córcoles et al., 2013), and turf grass (Richardson et al., 2001).

There is recent progress in developing application software that permits rapid, user-friendly measurements of canopy characteristics for pasture management and research, like ImageJ, Assess and Canopeo softwares (Büchi et al., 2018; Schindelin et al., 2015; Xiong et al., 2019). According to Patrignani and Ochsner (2015) fractional green canopy cover can be calculated using the mobile device application, Canopeo® (Oklahoma State University, Stillwater, OK), which automatically classifies pixels as green or not green. Canopeo correctly classified 100% and 90% of pixels in images of winter wheat produced under conventional tillage and no-tillage, respectively.

The main objective of this study is to determine if the fractional green canopy cover analysis using Canopeo® is suitable to evaluate the biomass of triticale and lentil. If it is so, this method would replace the hand-collected data to achieve same goal.

Methodology

Site Description

The study was conducted in Saleh bey region (35°87′24″ N, 5°30′83″ E). It is located in the South-West of Sétif province (Northeast of Algeria) with an area of 27400 ha. The climate of the region is arid; it receives an amount of precipitation less than 300 mm per year. Average temperatures are very high in summer (34°C) and low in winter (5°C), but minimum temperatures remain very low until april with a significant risk of late spring frost. It is characterized by limestone soils and a silty-clayey texture, with pH around 8.5, and organic matter around 2.5%.

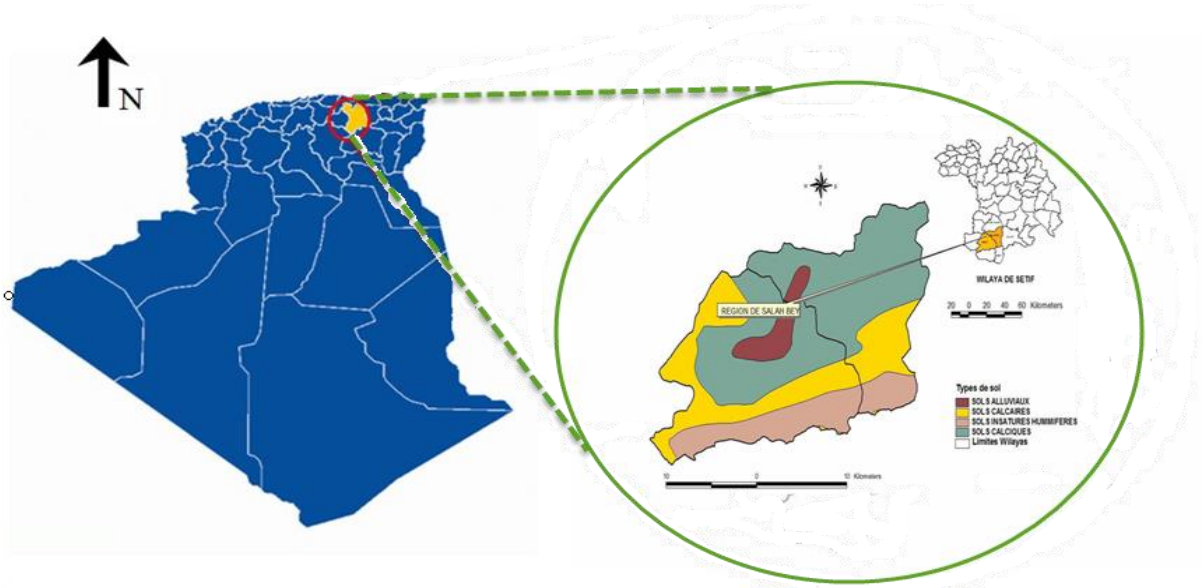

Figure 1. Geographical situation of the study area.

Experimental Design

The experiment was a complete randomized block with one factor (tillage mode), and three repetitions. Destructive above-ground biomass sampling of 0.5 m^2 was carried out within the sampling areas with three repetition of each forage crop (triticale, lentil). Fractional green canopy cover was calculated using the mobile device application, Canopeo®. It is an authomatic color threshold image analysis tool developed in the Matlab programming language, using color values in the red-green-blue (RGB) system. The analysis is based on the selection of pixels according to the ratios of R/G, B/G and the excess green index. The result of the analysis is a

binary image where white pixels correspond to the pixels that satisfied the selection criteria (green canopy) and black pixels correspond to the pixels that did not meet the selection criteria (Patrignani & Ochsner, 2015).

In order to capture three rows of crops, the camera height and length of row was varied based on canopy height (Figure 2). Crops canopy cover was measured, at stem elongation, booting and heading stages for triticale, and V5, R1, R3 stages for lentil. To analyze the relationship between fractional green canopy cover (FGCC), and biomass (BIO), simple linear regressions were calculated using Microsoft Excel (2013) and the Agrimetsoft (2022) on line calculator.

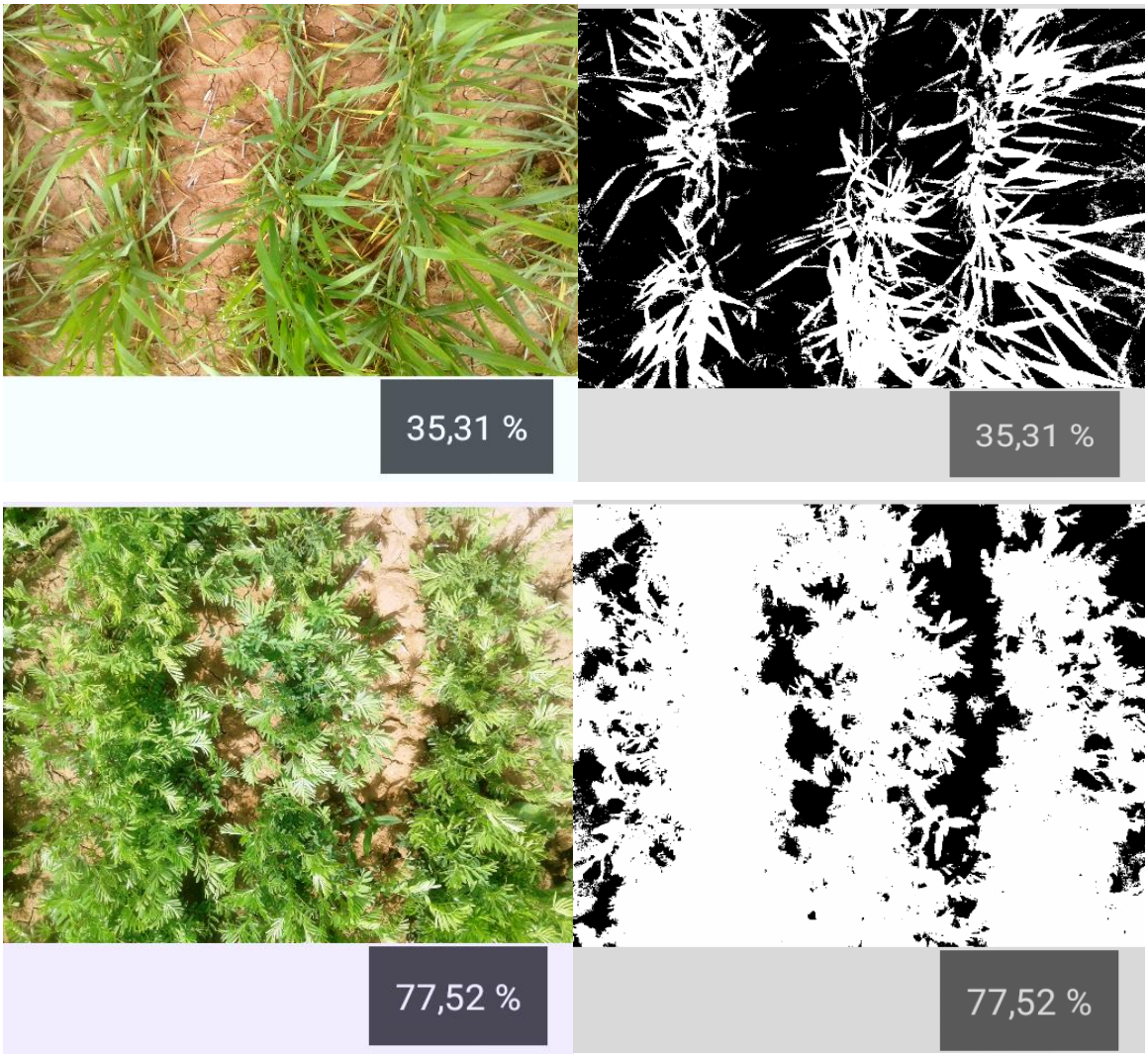

Figure 2. Fractional green canopy cover of triticale (top) and lentil (bottom): original image (left) and Canopeo® processed image (right).

Results and Discussion

The correlation and the root mean square error (RMSE) between fractional green canopy cover, and biomass measurements at three growth stages of forage crops is shown in Table 1. For triticale, the strong correlations between FGCC and BIO are observed at stem elongation stage, with coefficients of 0.99 and 0.89 under no till and conventional till, respectively. The RMSE was 0.1 and 0.06t/ha, under the two modes. The lowest correlation is seen at heading stage with a value of 0.21 and RMSE of 0.65t/ha, under no till mode. This low correlation could be caused by color changes from green to yellowish due to canopy senescence (Chung et al., 2017). For lentil, the high correlations between are observed at R3 (early pod), and R1 (early bloom) stages, with a coefficients of 0.85 and 0.98, under zero till and conventional, respectively. The RMSE was 0.17t/ha. However, a low correlations are seen at the V5 (the first multifoliate leaf has unfolded at the fifth node) stage, with values of 0.31 and 0.37 under no till and conventional till, respectively. This low weak correlation can be

attributed to the confusion of the application between weeds and crops canopy, especially under conventional till, when no weeds control had been made under this till mode.

Table 1. Pearson correlation coefficients and root mean square error (RMSE) between fractional green canopy cover (FGCC) and biomass (BIO), at each measurement stage

		No till		Conventional till	
Crop	Stage	R	RMSE (t/ha)	R	RMSE (t/ha)
Triticale	elongation	0.99	0.1	0.89	0.06
	booting	0.91	0.18	0.71	0.54
	heading	0.21	0.65	0.80	0.4
Lentil	V5	0.31	0.04	0.37	0.07
	R1	0.09	0.08	0.98	0.17
	R3	0.85	0.17	0.42	0.16

V5: the first multifoliate leaf has unfolded at the fifth node; R1: early bloom, one open flower at any node; R3: early pod, pod on nodes 10-13 of the basal primary branch visible.

These results are in accordance with other previous studies. Goodwin et al. (2018) found a good correlation between FGCC and wheat grain yield, with R^2 of 0.45. They mentioned that FGCC measurement is time sensitive and should be conducted at early stages of plant development. Jáuregui et al. (2018) found a positive linear relationship between FGCC and biomass of lucerne, with goodness of fit 0.77 and 0.86 for spring-summer and autumn-winter biomass, respectively. Shepherd et al. (2018) found a linear relationship between canopy cover measured with Canopeo and light interception taken by the line quantum sensor (R^2 = 0.94). (Jia et al., 2014), indicated that canopy cover and aboveground biomass of cotton were closely related (R^2 = 0.74-0.94). (Tomasel et al., 2001), found a high correlation between pixel count and green biomass (r = 0.95). Paruelo et al. (2000) reported that the correlation between FGCC and green grass biomass was 0.87. Louhaichi et al. (2010) and Pask et al. (2012) found a linear relation between digital ground cover and wheat biomass (r^2 = 0.63). The study of Lee & Lee (2013) showed a high correlation between canopy cover and dry weight of wheat (r=0.81). Bumgarner et al. (2012) reported that the correlation coefficients between direct measures of lettuce biomass and WinCAM estimates of canopy cover were 0.71 to 0.95. According to (Büchi et al., 2018), a high correlation was found between visual assessment of canopy cover and Canopeo® image analysis of lentil (0.90), field pea (0.73), and faba bean (0.81). Firatligil-Durmuş et al. (2008), reported that image processing provide a rapid a non-invasive methodology to estimate lentil geometric features and engineering parameters. However, Prabhakara et al. (2015) reported that index saturation, chlorosis, and frost damage may lead to inaccurate estimates of aboveground biomass when using vegetation indices to measure greenness of crops. Another limitation of Canopeo® that can't distinguish between crops and weeds canopy (Jáuregui et al., 2018).

Conclusion

Based on our results, it can be concluded that digital image analysis using Canopeo® is suitable to assess triticale and lentil biomass, it is rapid, easy, and could replace the destructive biomass sampling. However, the measurements are time sensitive. Images should be collected at early stages for triticale, to be more precise and that under the two till modes. However for lentil, the photos should be taken at late stage under no till mode, and at early stages under conventional till mode. The main limitation of Canopeo® application that can't differentiate between crops and weeds canopy.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPHELS journal belongs to the author.

Acknowledgements or Notes

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