Grassland at the heart of circular and sustainable food systems

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Impact of trees on the growth of the herbaceous layer of Sahelian savannah. A UAV based approach

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Abstract

Sahelian savannah is composed of an annual herbaceous layer and a sparse tree community. The trees have a strong impact on the biomass and the species composition of the herbaceous layer due to microclimate and increase in fertility. In this work, we evaluated the impacts of distance of the tree on the herbaceous layers. We used an RGB UAV to produce a biomass map and then evaluated the distance of the tree impacts. In 2020 in a rangeland in northern Senegal, three grass measurements were made every second day during the growth season combined with a UAV flight made with a parrot Anafi drone. At each date we produced a biomass map and evaluated the distance of the tree impact using geostatic method. We obtained a calibration between UAV and field measurement with an R^2 equal to 0.64. The impacts of the tree ranged from 5 m at the beginning of the wet season to 15 m at the end of the wet season. This work shows the impact of tree distance on the grass layer in a savannah. The evaluation of this impact could be helpful for the management of the tree layers to increase the quantity of grass for the pastoralism.

Keywords: UAV, Savannah, tree impacts, biomass, grass

Introduction

In the Sahel region, the natural vegetation is the main source of food for livestock and plays an essential role for the local population (Ndiaye *et al.*, 2014). The ecosystem is a savannah composed of tree communities and annual herbaceous species. The trees improve the physical conditions of the environment and have a positive impact on the development and structure of the herbaceous layer (Akpo *et al.*, 1997; Elie *et al.*, 2003; Grouzis *et al.*, 1991). However, little is known about the distance of trees impact in these ecosystems. This study uses a drone and geostatistical approach to investigate the distance of influence of trees on the growth of the herbaceous layer in the Sahelian savannah.

Material and methods

Data were collected on a 1 ha plot during the 2020 rainy season (19 July 2020 to 17 September 2020). A drone flight and measurement of biomass in three plots each of 1 m^2, distributed respectively under the crown of a tree, at the edge of the crown, and at a distance from the edge of the crown equal to the height of the tree, were carried out every two days. These plots were rotated among the trees in the field until all four azimuths of trees were covered. The tree species in the field are *Balanites aegyptiaca* and *Vachellia tortilis*. They are between 2.3 and 8.8 m in height with an aerial cover of 6.4%. The drone flights were done at 60 m altitude, with a speed of 2 m s^{-1}, and 90% of overlap rate between images, on a double grid of 100×100 m and the angle of inclination of the camera fixed at 80°. The drone images were processed with PIX4DMapper software using the 3Dmaps analysis (Bossoukpe *et al.*, 2021a,b). Stepwise regression was used for the calibration between the 3D mapping data (Red (R), Green (G), Blue (B), DSM and vegetation indices; Table 1) and field measurements with the R software using Stepwise regression. Biomass maps were produced after calibration using QGIS.

Next, the variogram was calculated on the biomass maps to investigate the spatial variability of biomass around trees. The effect of tree distance (from the crown) refers to a parameter named 'Range' which was geostatistically analysed in R, using the libraries gstat and sp.

Table 1. Vegetation indices.

Acronym	Name	Formula	Source
VARI	visible atmospherically resistant index	(Green – Red) / (Green + Red - Blue)	Gitelson *et al.*, 2002
EXG	excess of green	Green – 0.39 × Red – 0.61 × Blue	Woebbecke *et al.*, 1995
GLI	green leaf index	(2 × Green – Red – Blue) / (2 × Green + Red + Blue)	Louhaichi, Borman and Johnson, 2001)
NDGRI	normalized difference green red index	(Red – Green) / (Red + Green)	Escadafal and Huete, 1991
NDBRI	normalized difference blue red index	(Red – Blue) / (Red + Blue)	Bossoukpe *et al.*, 2021a,b
NDBGI	normalized difference blue green index	(Green – Blue) / (Green + Blue)	Shimada *et al.*, 2012

$$\text{Range} = \sum_{i=0}^{nst} C_i . \Gamma_i \text{ (h)}$$

T_i(h) are the pool of i=0,nst structures, where the 0^{th} nested structure is the nugget effect by convention, is the contribution of the i^{th} structure, and each structural variogram (i=1,...,nst) is defined by seven parameters - three angles and three ranges (that define anisotropy) and a shape (often spherical, exponential or Gaussian).

Results and discussion

The results of the calibration show that the predictive variables of the biomass variation are the red, green, blue (statistically non-significant) spectra and the NDBRI index. Except the blue reflectance (P=0.07), results show the Red (P=3.1e^{-9}), Green (P=8.9e^{-7}) and NDBRI (P=0.02) contributed significantly to the predictive equation. The model obtained from the stepwise is significant with P=3.95e^{-13}, and R^2=0.64 according to the following predictive equation for biomass variation:

DM = -0.0054(Red) + 0.0047(Green) + 0.0032(Blue) + 0.78(NDBRI)-0.29.

The importance of vegetation indices to study biomass has been demonstrated (Lussem *et al.*, 2018). Establishing relationships between RGB reflectance, vegetation indices, and DSM data by using empirical linear methods to predict biomass variation reduces errors in establishing the predictive equation for RGB mosaic calibration.

This study incorporates a temporal dimension of tree impact. Performing variograms shows that the effect of the tree is not oriented and the distance of the impact of the trees on the grass varies during the season. The tree positively influences the variation of the herbaceous layer up to a minimum distance of 5 meters in August and a maximum of 15 m from the crown (Figure 1). These results are consistent with those of Roupsard *et al.* (2020) who used spectral indices (NDVI and MSAVI2) taken by drone and geostatistics to assess the distance of influence of *Faidherbia albida* on millet crop yield. Their results show that *Faidherbia albida* no longer has an effect on the millet crop beyond a distance of 17 m from the crown. The effect of the tree outside the crown may be explained by its ability to improve the soil quality by providing litter and root residues that help maintain soil organic matter levels and improve fertility (Young, 1995) at the plot or cropping system level.

Conclusions

The acquisition of multispectral images by drone associated with appropriate processing methods allows us to study the variation of the herbaceous layer and the interaction between woody and herbaceous species. This study shows the importance of the impact of the trees in Sahelian savannahs, and can help in the management of tree density in pastoral rangelands to positively affect the availability of fodder for livestock and improve the resilience of ecosystems to disturbances, particularly climatic disturbances.

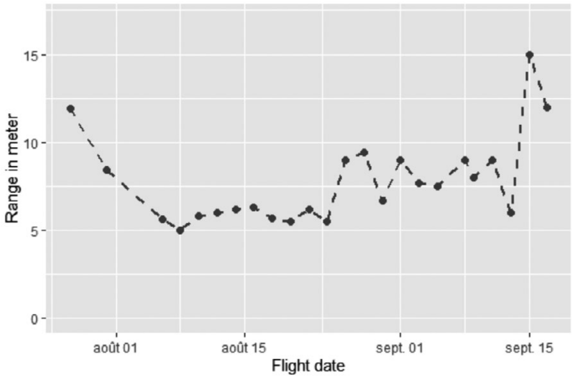

Figure 1. Variation in tree influence distance (Range) from the crown edge on the plot over the season.

However, these results could be improved by considering, in the study, the specificities related to each tree such as specific diversity, height and age.

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