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Assessment of the Faidherbia albida effect on millet yield using UAV images analysis and geostatistical techniques

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Agroforestry, the association between trees/shrubs and crops, a widespread practice in West Africa, is presented as a lever for ecological intensification to optimize cereal yields in the face of strong population growth and the fight against climate change. Within the framework of the EU-DESIRA SustainSAHEL project, we aim to develop techniques to spatially assess the effect of trees on millet yields on an intra-field scale using imagery from an UAV equipped with a multispectral camera combined with geostatistical approaches. Indeed, recent advances in earth observation technologies position the UAV as an effective tool for evaluating the agronomic performance of agroforestry systems and for taking into account the intra-field variability of yields caused by environmental conditions, agricultural practices or the presence of trees (Roupsard and al., 2020 ; Leroux and al., 2022). The objective of this study was to estimate millet yields intra-field variability using UAV and up-to-date geostatistical approaches.

The study was carried out over the 2018-2022 cropping seasons in one representative Faidherbia parkland of the groundnut basin of Senegal. To that end, a Random Forest (RF) algorithm was first calibrated to estimate millet yield at sub-plot scale using a thresholding classification to eliminate non-vegetation elements and also to integrate texture data, in

order to take into account the spatial relationships between pairs of pixels. Millet yields data and vegetation and textural index from aerial images at a flight height of 25 meters acquired in farmers' plots were used to calibrate the RF model. The RF model was used to upscale yield at the whole field scale thus allowing to obtain a map of millet yield. Then Voronoï diagram, with Faidherbia as a reference, was applied to each yield map, considering each Voronoï region as a zone of influence of its included Faidherbia. We then applied a transformation and rotation matrix to overlay all the zones of influence of a population of 50 Faidherbia by putting all the trees at the same geographical position. Finally, we build an atlas, which is an average structure representative of a population and which makes possible to detect the patterns and properties of the evolution of the population considered, to evaluate the distance and directional effect of Faidherbia on vegetation index of the population and then on millet yield.

The RF model is able to explain between 70 and 90 % of the millet yield variability. Then the analysis has shown that the tree has an influence on the millet stand density with a distance-decay effect from the tree. This stand density is about 60 % around the tree and 30 % at 15m from the tree.

Key words : Agroforestry, Uav, Machine learning, Image analysis, Geostatistics, Atlas

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Corresponding supplementary materials formerly uploaded have been withdrawn.