Detecting Coffee Leaf Nitrogen with UAV-based Vegetation Indices and Machine Learning

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**Keyword:** Random Forest, Remotely Pilot Aircraft, Nitrogen Management and Coffee Crop

**Abstract:** The development of new approaches to determine the spatial variability of nitrogen (N) in coffee leaves is essential to increase productivity and reduce production costs and environmental impacts associated with excessive N applications. Therefore, this study evaluated the potential of vegetation indices (VI) based on UAV and machine learning to estimate N content in coffee leaves.

The study was carried out in a coffee plantation located in the municipality of Santo Antônio do Amparo, MG, Brazil. Ten sampling points were demarcated in this crop, consisting of 5 plants. The sampling points were classified as N deficient (<2.5%), N critical (2.5 to 3.0%) and N adequate (3.0 to 3.5%). The images were captured using a commercial RPA 3DR Solo, equipped with a Parrot Sequoia multispectral camera. Image processing was performed in Agisoft PhotoScan® Professional software and Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI) and Normalized Difference Red Edge Index (NDRE) vegetation indices were calculated in QGIS 3.16 software. The classification of N content in coffee leaves throughout the crop was performed using the RF machine learning method. The classification was done in R, using the R Random Forest package. For the training of the RF, the values ​​of the vegetation indices and of the N analyses were extracted in the plants of each sampling point. The RF performance was evaluated using the metrics global accuracy and kappa coefficient.

In general, the classification showed a high performance in the evaluation of N in the coffee leaves, with global accuracy and kappa coefficient values ranging from 0.81 to 0.91 and 0.70 to 0.86, respectively. The NDVI presented the best results among the evaluated indices, while the NDRE was the worst. In addition, it was possible to estimate the special distribution of N classes throughout the crop. The NDVI also presented the best class definitions, demonstrating that 22% of the crop had N deficiency, 52% critical N and 26% sufficient N.

This study showed that the RF machine learning method applied to vegetation indices from UAV multispectral images could provide a promising approach for mapping N status in coffee crops and localized application of fertilizers.