NDVI INDEX AND ITS CORRELATION WITH BIENNIAL COFFEE YIELD

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Abstract.

Precision agriculture (PA) has consolidated itself as an important tool in agricultural management, allowing greater productive efficiency, cost reduction, and environmental sustainability. Among PA tools, the use of vegetation indices stands out, as it allows inferences about crop biomass both spatially and temporally.

In this context, this study aimed to evaluate the relationship between the normalized difference vegetation index (NDVI) and the yield of Arabica coffee (Coffea arabica L.), considering the crop's biennial nature. The study was conducted at Mandaguari farm, located in Indianópolis, Minas Gerais, Brazil, during the 2023/24 and 2024/25 crop seasons, in an area of 27 ha cultivated with coffee, cultivar Topázio, under drip irrigation. The results are applicable to commercial coffee plantations, as they identify key periods linking phenological changes to crop yield, supporting decision-making in precision agriculture.

A regular sampling grid of 50 points was established to obtain yield data. Yield was determined by manual harvesting of four plants per point, followed by drying to approximately 11.7% moisture, processing, and weighing. Surface maps were generated based on semivariogram modeling and kriging interpolation.

NDVI values were obtained monthly from Planet satellite images, covering the period from August 2023 to June 2025. Image analysis consisted of extracting pixel information in vector format. The data were subjected to descriptive, correlation, and geostatistical analyses.

The results showed the biennial variation in yield, with an average of 61 bags ha^{-1} in the 2023/24 season and 37 bags ha^{-1} in the 2024/25 season. The relationship between yield and NDVI varied throughout the crop cycle, with the strongest correlations observed in December ($r = 0.48$ in 2023/24 and $r = 0.32$ in 2024/25), while March presented a moderate negative correlation in 2023/24 ($r = -0.41$) and a weak correlation in 2024/25 ($r = 0.07$).

These results reflect the physiological dynamics of the crop. In December, plants are in an intense vegetative growth stage, with high photosynthetic activity and formation of productive structures, resulting in a positive relationship with yield. In contrast, in March, the beginning of the fruit filling stage leads to reduced vegetative vigor and lower photosynthetic activity, weakening the relationship between NDVI and yield. The relatively low correlation values reflect the complexity of commercial coffee fields, where multiple factors influence yield, resulting in relationships that represent general trends rather than strong linear associations. Additionally, pixel-level correlations may not fully capture visually observed spatial patterns, which can lead to apparent discrepancies between statistical and spatial analyses.

Thus, NDVI can be considered a useful tool to estimate the productive potential of coffee crops, provided that the timing of image acquisition is taken into account, being more effective during periods of greater vegetative activity.

Keywords.
Coffea arabica, Precision agriculture, Vegetation index, Spatial variability, Biennial bearing

Introduction

In coffee farming (*Coffea arabica* L.), crop management and yield estimation present a complex physiological challenge inherent to the crop: biennial bearing. This alternation between years of high and low fruit load impacts the photosynthetic rate, the vegetative development of the plants, and the formation of new reproductive structures. The canopy spectral response obtained from images is a strategic ally in monitoring phenological changes throughout the crop cycle (Bernardes et al., 2012). Precision agriculture (PA) and its associated technologies, such as the use of vegetation indices, including the normalized difference vegetation index (NDVI), allow inferences about crop vigor and its spatial and temporal variability (Rouse et al., 1973).

Given the complexity of the relationship between vegetative vigor and yield, monitoring the phenological dynamics is essential for decision-making. Therefore, this study aimed to evaluate the spatial-temporal relationship between the NDVI and Arabica coffee yield, considering the biennial nature of the crop.

Materials and Methods

The study was conducted at the Mandaguari farm, in the municipality of Indianópolis, state of Minas Gerais, Brazil, during the 2023/24 and 2024/25 crop seasons. The experimental area comprised 27 ha cultivated with coffee (*Coffea arabica* L.), cultivar Topázio, under a drip irrigation system. Yield data collection followed a regular georeferenced sampling grid of 50 points. Harvesting was performed manually by collecting fruits from four plants within a 5 m radius for each sampling point. The fruits were dried to an approximate moisture content of 11.7%, processed, and weighed to determine the final yield.

Spectral data were acquired using Planet® satellite imagery. Normalized difference vegetation index (NDVI) values were extracted monthly for the period from August 2023 to June 2025.

Based on the yield data and the vegetation index, descriptive statistical and linear correlation analyses were performed. Spatially, the presence of spatial variability in the data was analyzed using semivariogram modeling and kriging interpolation, to finally generate surface maps.

Results and Discussion

The biennial variation in yield was evidenced, with an average of 61 bags ha^{-1} recorded in the high-yield year (2023/24 season) and an average of 37 bags ha^{-1} in the low-yield year (2024/25 season). The data allowed observing the relationship between the spatial variation of yield and the spatial-temporal NDVI data throughout the phenological cycle (Fig. 1). December stood out, registering the highest positive correlations (r = 0.48 in the 2023/24 season; r = 0.32 in the 2024/25 season). The highest negative correlations were observed in March for the 2023/24 season (r = -0.41), which did not occur in the 2024/25 season (r = 0.07).

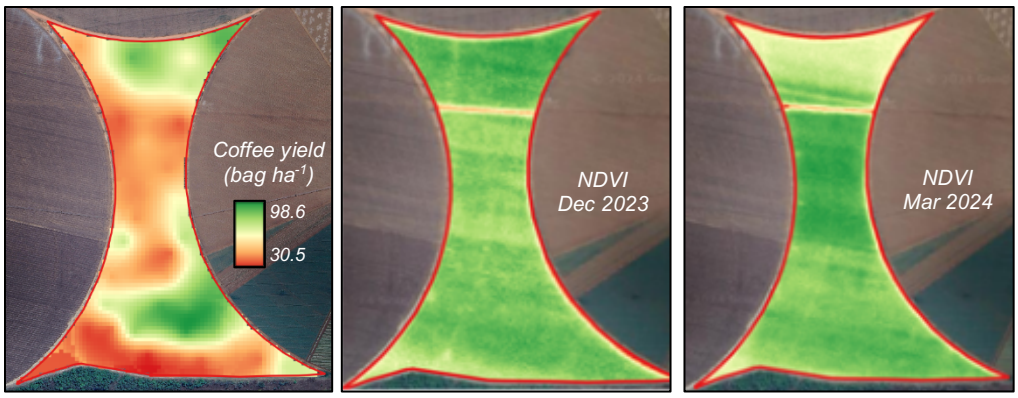

Fig. 1 Spatial distribution maps of coffee yield and NDVI in December 2023 and March 2024

The results reflect the physiological dynamics of the coffee crop. In December, the response is due to intense vegetative growth, with high photosynthetic activity and the formation of productive structures. This justifies the positive relationship between the higher NDVI spectral response and the final coffee yield (Lima et al., 2014). In March, the fruit filling stage begins (Camargo & Camargo, 2001), acting as a strong metabolic sink and causing a temporary reduction in vegetative vigor and leaf photosynthetic activity. This is reflected in the lower NDVI values. The observed correlations reflect, in this way, the complexity of factors that can be present in yield responses.

Conclusion

The normalized difference vegetation index (NDVI) is a viable tool for estimating the productive potential of coffee crops, assisting in the identification of optimal productive periods considering the crop's biennial bearing. The results reinforce the importance of temporal planning based on precision agriculture as a management and decision-making strategy in commercial coffee plantations.

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