Spatial nutritional variation of soil and coffee plants in a small farm in Caconde, SP

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Abstract

As a way to contribute to the producer for soil and plant management, this work aims at the spatial analysis of soil fertility and plant nutrition of a small property cultivated with coffee in the implementation phase, in the municipality of Caconde/SP. The interpolation maps indicate nutritional differences in soil and plants within and between plots and therefore, can support fertilization management and future investigations correlating with coffee productivity.

Keywords: Coffee farming; management; Interpolation.

1. Introduction

Brazil has been, for decades, the largest producer and second-largest consumer of coffee in the world (Suplicy, 2013; Brasil [...], 2023). Thus, it is essential to strive for increased bean quality and productivity to maintain market competitiveness and to sustain the growing consumer market (Usina da Comunicação, 2025). One of the obstacles to achieving these objectives is the lack of technical expertise among producers, some of whom do not know how to manage fertility in their plots and are unaware of the ideal fertilization levels for their properties in order to optimize productive and qualitative indices. Through the spatial analysis of soil and plants in the coffee plantation plots, it is possible to verify the nutritional difference caused in different coffee cultivars, in order to clarify the owner's doubts and create data for future nutritional and productivity studies.

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As a way to contribute to the producer for soil and plant management, this work aims at the spatial analysis of soil fertility and plant nutrition of a small property cultivated with coffee in the implementation phase since 2022, in the municipality of Caconde/SP, which is being monitored by the Embrapa team.

2. Methods

The work was developed on a small coffee farm, named Progresso, in Caconde, SP (Figure 1). The predominant soil in the region is Red-Yellow Latosol, with a humid subtropical climate (Instituto de Pesquisas Florestais, 2014). Soil and plant samples were collected from three plots: A – Planting 2023, Catuaí 144/62 variety; B – Planting 2024, Catuaí 137 variety; C – Planting 2023, Catuaí 62 variety. In a total of 26 georeferenced points samples were collected in January 2025 for soil from a depth of 0-20 cm and analyzed for soil fertility, and leaf samples were collected for average nutritional analysis of each of the three plots A, B, and C (Figure 1). The data were organized in a geographic information system (GIS) for the soil fertility attributes Ca, Mg, K, P, Na, SB, in mmolc/dm³, OM in g/dm³, pH ($CaCl_2$) and Aluminum Saturation. And for plant nutrition, data for Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, and Sulfur were obtained, all in g/kg.

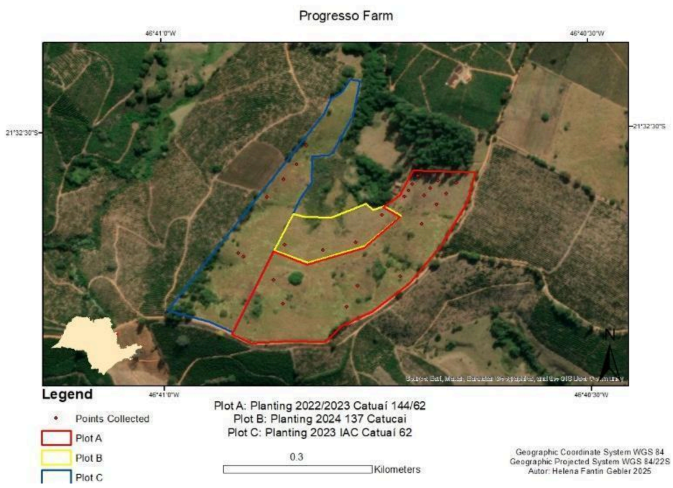


Figure 1. Soil and plant sampling area, divided into plots A, B, and C, at Progresso Farm, Caconde, SP.

The data were subjected to descriptive statistical analysis for initial exploration. Due to the limited number of sampling points, it was not possible to identify spatial dependence using Geostatistics. Therefore, data interpolation was performed using IDW (Inverse Distance Weighting). With the interpolated values, maps of value ranges were constructed based on the geographic coordinates using the ArcGis Pro software.

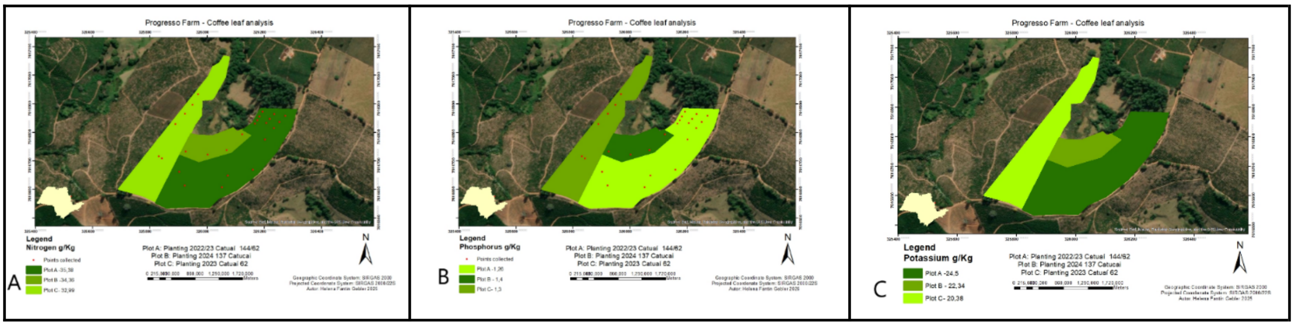
3. Results and Discussion

For the initial exploratory data analysis, descriptive statistics (Table 1) were calculated for the soil data analyzed at more than one point per area (Plot A, B, and C).

Table 1. Descriptive statistics of the macronutrient of coffee soil analysis and mean from Plot A, B and C.

Macro-nutrients	Mean A	Mean B	Mean C	Variance	SD	Min	Max	symmetry	Kurto-ses	Grand Mean
Al saturation	23.28	30.14	10.70	55.45	7.446	4.00	29.00	0.707	-0.0557	21.37
Ca	12.20	16.00	16.88	58.28	7.63	4.00	30.00	0.52	-0.41	14.07
Mg	4.6	7.75	7.33	9.81	3.13	1.00	14.00	0.71	0.01	5.90
K	4.2	3.75	3.95	1.68	1.30	2.60	8.80	1.82	5.09	4.09
Na	0.15	0.15	0.14	0.00	0.07	0.10	0.40	1.84	4.93	0.15
SB	21.02	27.67	28.32	104.80	10.24	8.60	46.60	0.65	-0.03	24.20
P	20.63	21.50	25.56	493.56	22.22	7.00	119.0	3.29	12.94	22.28
MO	31.87	30.25	31.44	27.69	5.26	23.00	41.00	0.29	-1.12	31.52
pH	4.13	4.40	4.50	0.07	0.26	3.90	4.80	0.34	-1.00	4.28

Through the elaboration of foliar and soil analysis maps, it is possible to observe a pattern of variation in soil fertility and plant nutrition among the plots. In plots A and part of C, a higher concentration of foliar macronutrients is observed, with the exception of phosphorus (Figure 2).



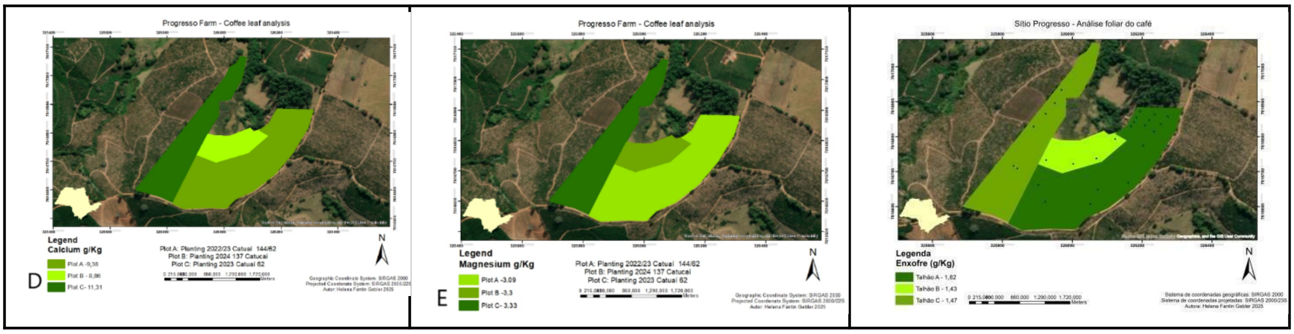


Figure 2. Macronutrient maps of coffee leaf analysis: A) Nitrogen, B) Phosphorus, C) Potassium, D) Calcium, E) Magnesium and F) Sulfur.

In the left and lower direction of the area (plots A and part of C), a predominance of higher levels of soil macronutrients is also observed (Figure 3). A more detailed investigation in these plots, with monitoring of a productive cycle, correlating with productivity, could provide explanations for this spatial variation among plots.

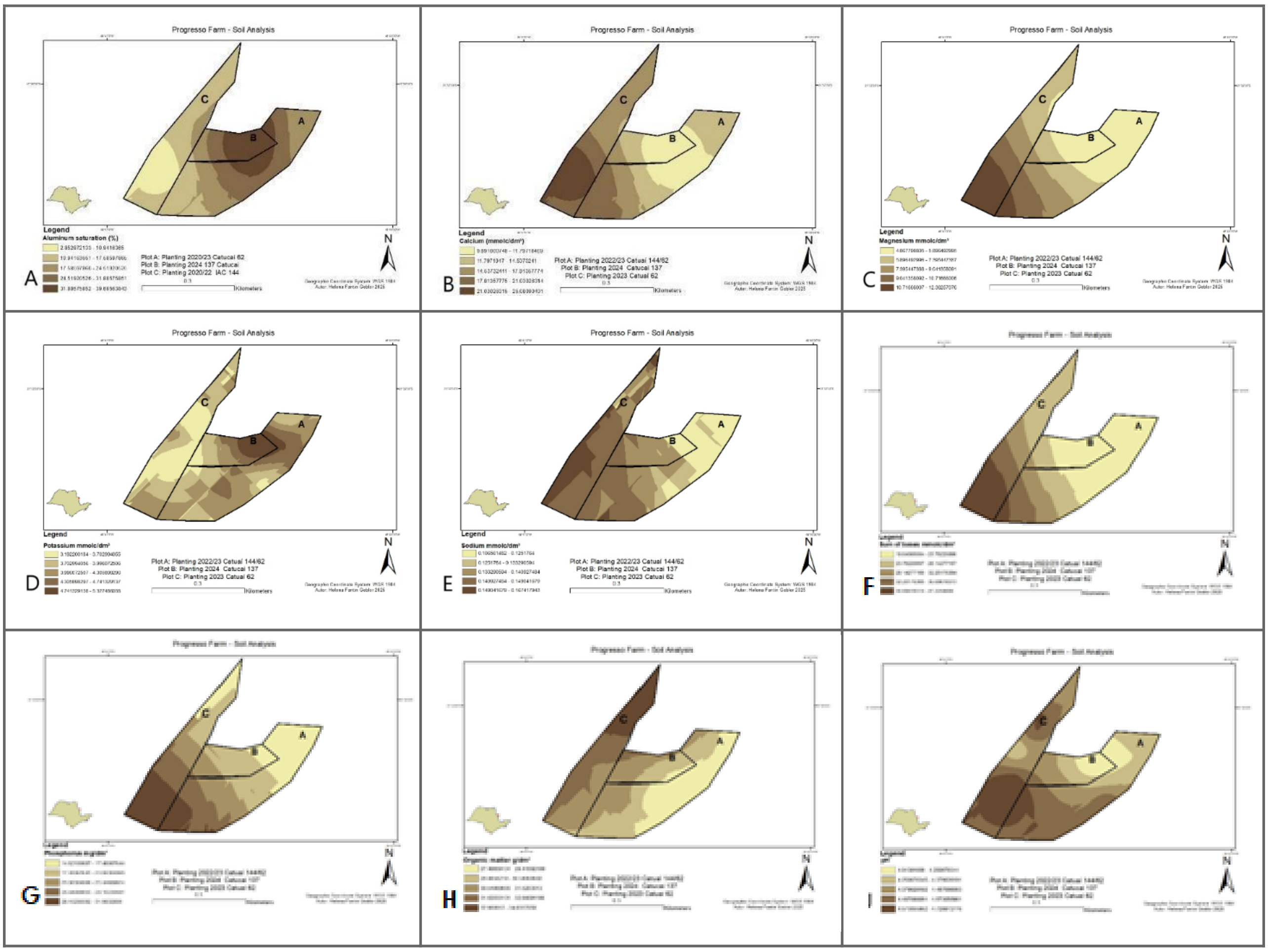


Figure 3. Macronutrient maps of coffee soil analysis: A) Aluminum saturation, B) Calcium, C) Magnesium, D) Potassium, E) Sodium, F) Sum of bases, G) Phosphorus, H) Organic matter, I) pH.

4. Conclusion

The spatial analysis of soil and foliar fertility reveals that there are standardized spatial variations within each of the three investigated plots. The maps generated in this research can serve as support for the identification of variability patches and may assist in fertilization and other management practices. Monitoring future productive cycles of this small agricultural property may provide indications of correlations between soil and foliar analyses with the production of the analyzed plots.

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