# CHARACTERIZATION OF SOILS IN COFFEE PRODUCTIVE AREAS IN THE PROVINCES OF COLON AND PANAMÁ OESTE-REPUBLIC OF PANAMA


## ABSTRACT

Planting robusta coffee is gaining greater interest among Panamanian farmers as an alternative for soil conservation. The objective of this study was to characterize the properties of the soils of coffee producing farms in the provinces of Colón and Panamá Oeste for the preparation of regionalized fertilization cards according to the edaphoclimatic characteristics of each area. On 15 farms in the province of Colón and 20 in Panama Oeste, samples were taken at two depths (0-20 and 20-40 cm) to understand their properties and initiate a sustainable fertilization program that contributes to improving productivity. Digital maps were created using the Q-Gis v.2.2 program and regionalized fertilization cards for each zone. The soils of the province of Colón 47% presented a high percentage of aluminum saturation, average pH of 4.6, low levels of organic matter and phosphorus, and 53% low in potassium. 80% are high in magnesium, 40% in calcium. Imbalances were found in the Ca/Mg and Ca + Mg/K ratios, which causes nutritional problems. In Panama Oeste, 30% presented a high percentage of aluminum saturation, average pH of 5.3 and 1.4% organic matter, 100% are low in phosphorus, 90% low in potassium, medium and high levels of magnesium and calcium. A positive and statistically significant correlation was found between % clay, organic matter, pH and calcium. It is expected with this characterization and regionalized fertilization cards to improve soil properties in a sustainable manner.



*Keywords:*arabica, coffee, digital maps, fertilization, robusta, soil properties


## 1. INTRODUCTION

Coffee in Panama has been cultivated since Spanish colonial times, the Coffea arabica cultivar (Típica cultivar) ar Panama through Portobelo, province of Colón in the year 1780 (1).

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**Comment [ZA2]:** Add the scientific name

The planting of crops such as robusta and Arabica coffee (MIDA 96) is gaining more and more interest among Panamanian producers, as an alternative for the recovery of the agricultural sector and to confront the effects of climate change, the high cost of inputs, the fluctuation of product prices in the market and the shortage of labor, among others.

Most of the soils for central provinces of Panama are soils where low organic matter content, acidic pH, high levels of aluminum toxicity and low base content (K, Ca and Mg) predominate, this impacts the yields of coffee plots. According to Ministry of Agriculture (MIDA) (2) data of coffee production in Panama Oeste (1,700 ha, 1425 producers), Coclé (4,600 ha, 2,185 producers), Herrera (44.75 ha, 143 producers), Los Santos (6 ha, 30 producers), Colón (1,550 ha, 2005 producers), represents 53.3% of the total planted in the country in an area of 7900.75 ha of a total of 14,826 ha planted nationwide, where 5,788 producers and their families are dedicated to this task .

According to harvest data from MIDA (3) the yield of coffee plantations in the province of Colon is around 0.48 ton/ha and in Panama Oeste around 0.44 Ton/ha. Considered very low yields that can be improved with good management and balanced fertilization.

Previously, researchers from the Panama Agricultural Innovation Institute (IDIAP) developed soil fertility maps at the national level based on soil analysis results (4), however, specifically studies to select the best site that favors the coffee cultivation has not been done in the country.

The objective of the work was to characterize the properties of the soils of coffee-producing farms in the provinces of Colón and Panamá Oeste that allow the preparation of regionalized fertilization cards according to the edaphoclimatic characteristics of each area.

## 2. MATERIAL AND METHODS

In 15 plots of the districts of Colón (Ciricito township) and Chagres (Guabo and La Encantada townships) of the province of Colón and 20 plots of the Capira districts (Trinidad, Cirí Grande, Cirí de los Soto and Cacao townships) In Panama Oeste province (Figure 1), soil samples were taken at a depths of 0-20 cm to know the properties of the soils and thus initiate a sustainable fertilization program that contributes to improving productivity.

The selection of the farms was made considering that they were farms producing coffee under a shade system. Maps of texture levels, pH, organic matter, percentage of aluminum saturation, cationic exchange capacity, macroand micronutrients of the districts where the selected farms are located were prepared, using the Q-Gis v.3.32.1 program.

In addition, recommended fertilization charts were prepared for each area according to its edaphoclimatic characteristics. Descriptive statistics analysis, Pearson correlation analysis and principal component analysis were carried out to know which elements are influencing the quality of soils for coffee cultivation (5).

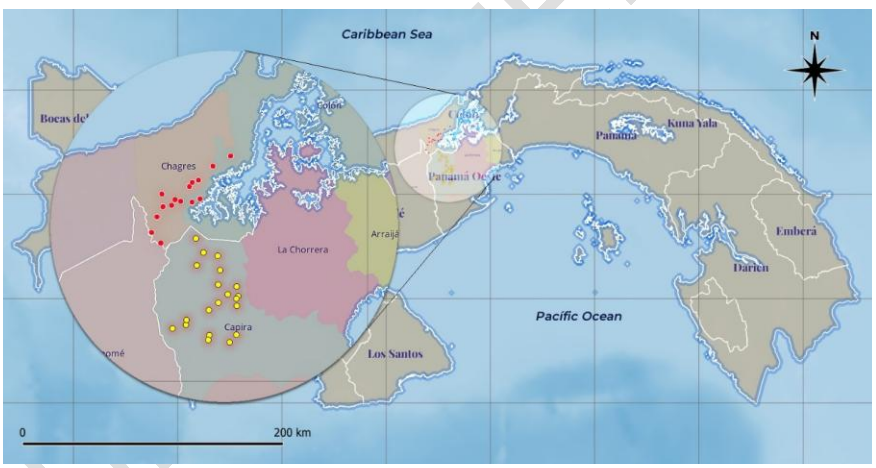


**Fig 1. Location of the sites where samples were taken on productive farms in Colon and Panama Oeste, Republic of Panama**

## 3. RESULTS AND DISCUSSION

Tables 1 and 2 present the correlations with high statistical significance ($p < 0.05$) in soils from Colón and Panama Oeste, respectively. All those properties related to the Al content and the pH of the soil, negatively affecting it, are highlighted. It is also striking in Colon that the copper content affects the apparent density and negatively correlates with the % porosity.

Furthermore, in Panama Oeste soils a high negative correlation is observed between phosphorus content and % clay, indicating that there is an important influence of phosphorus fixation by clays in these soils, also between magnesium and CEC, which denotes a high magnesium concentration in this area. These results coincide with those found by Torrente and Ladino (6) in soils from southern Colombia.

Tables 1 shows a negative correlation (-52) between pH and SOC in Colon soils. These soils have acidic pH so as the SOC content rises they should improve their pH levels. Likewise, high negative correlations were observed between pH and % Al saturation and between Ca with % Al saturation. A more alkaline pH or close to it favors high Ca concentrations and low % Al saturation. Positive and statistically significant correlations were obtained for Fe and Al concentrations and for bulk density with Fe..

**Table 1. Pearson correlations between properties of Colon soils (0-20 cm)**

| Variable (1) | Variable (2) | n | Pearson | p-value |
|---|---|---|---|---|
| pH | Dap | 15 | -0.57 | 0.0254 |
| pH | % Porosity | 15 | 0.57 | 0.0254 |
| pH | % Organic matter | 15 | -0.53 | 0.0413 |
| pH | % SOC | 15 | -0.54 | 0.0389 |
| Mg | % Organic matter | 15 | -0.56 | 0.0304 |
| Mg | % SOC | 15 | -0.56 | 0.0300 |
| Al | pH | 15 | -0.84 | 0.0001 |
| % Al saturation | pH | 15 | -0.81 | 0.0003 |
| % Al saturation | Ca | 15 | -0.52 | 0.0479 |
| % Al saturation | Al | 15 | 0,86 | 0.0000 |
| CEC | Bulk density | 15 | 0,56 | 0.0307 |
| CEC | % Porosity | 15 | -0.56 | 0.0307 |
| CEC | Ca | 15 | 0.71 | 0.0030 |
| CEC | Mg | 15 | 0.57 | 0.0251 |
| % Base saturation | pH | 15 | 0.81 | 0.0003 |
| % Base saturation | Ca | 15 | 0.52 | 0.0480 |
| % Base saturation | Al | 15 | -0.86 | 0.0000 |
| Fe | Bulk density | 15 | 0.57 | 0.0278 |
| Fe | % Porosity | 15 | -0.57 | 0.0278 |
| Fe | pH | 15 | -0.57 | 0.0265 |
| Fe | Al | 15 | 0.71 | 0.0032 |
| Zn | Fe | 15 | 0.56 | 0.0292 |
| Cu | Bulk density | 15 | 0.80 | 0.0003 |
| Cu | % Porosity | 15 | -0.80 | 0.0003 |

| | | | | |
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| % Base saturation | Al | 15 | -0.86 | 0.0000 |
| Fe | Bulk density | 15 | 0.57 | 0.0278 |
| Fe | % Porosity | 15 | -0.57 | 0.0278 |
| Fe | pH | 15 | -0.57 | 0.0265 |
| Fe | Al | 15 | 0.71 | 0.0032 |
| Zn | Fe | 15 | 0.56 | 0.0292 |
| Cu | Bulkdensity | 15 | 0.80 | 0.0003 |
| Cu | % Porosity | 15 | -0.80 | 0.0003 |

SOC: soil organic carbon; CEC: cationic exchange capacity

**Table 2. Pearson correlations between properties of Panama Oeste soils (0-20 cm)**

| Variable (1) | Variable (2) | n | Pearson | p-Value |
|---|---|---|---|---|
| % Organic matter | Bulk density | 20 | -0,63 | 0,0027 |
| % Organic matter | % Porosity | 20 | 0,63 | 0,0027 |
| % SOC | Bulk density | 20 | -0,63 | 0,0026 |
| % SOC | % Porosity | 20 | 0,63 | 0,0026 |
| P | %clay | 20 | -0,71 | 0,0005 |
| Al | pH | 20 | -0,49 | 0,0276 |
| % Al saturation | pH | 20 | -0,51 | 0,0207 |
| % Al saturation | Ca | 20 | -0,45 | 0,0475 |
| % Al saturation | Al | 20 | 0,98 | 0,0000 |
| CEC | pH | 20 | 0,47 | 0,0379 |
| % Base saturation | pH | 20 | 0,51 | 0,0207 |
| % Basesaturation | Ca | 20 | 0,45 | 0,0477 |
| % Basesaturation | Al | 20 | -0,98 | 0,0000 |

Figure 2 shows the result of the principal component analysis for the Colón soils that are very influenced by the pH and % base saturation, to the right, negatively (left side) the influence of % Al saturation is observed. Upwards, high levels of CEC stand out and downwards there is a greater influence of the clay content in the soils.

The results indicate that the soils of La Encantada (3), Guabo (5), Santa Fe de Guabo (13), to a lesser extent the soils of Plátano-El Guabo (7), El Bijao-La Encantada (12) are very influenced by the % base saturation, % silt and to a lesser extent by the % sand, concentration of calcium, magnesium, potassium. On the other hand, the soils of Ciricito (1), Héctor Gallego (4), Las Cruces-La Encantada (11), are influenced by the aluminum content and with less influence by the apparent density, contents of iron, copper, zinc and the CEC. The soils of Los Cedros-Ciricito (6), Guabo (15) and to a lesser extent La Encantada (14), are very dependent on the % saturation of aluminum and manganese and to a lesser extent on the % clay and % organic carbon. ground. The soils El Pepino-Guabo (2), Los Cedros (8) and to a lesser extent La Encantada (9), have a high influence of phosphorus content and especially pH, with porosity being less important.

In Figure 3, for soils from Panama Oeste, better pH levels, high Ca and Mg content in these soils stand out to the right, which leads to the CEC appearing with a high influence. Towards the left it is observed that the % Al saturation dominates and the low values of organic matter in the soil. Towards the top, micronutrients such as Cu and Zn stand out and towards the bottom, the clay content of the soil has a lot of influence. These results coincide with those obtained by Silva-Parra et al (5) for soils in coffee plantations in Mexico.

In this area, the soil of Ciri Grande (6) appears to be very dependent on pH, % base saturation, calcium and phosphorus content, to a lesser extent % sand and zinc content, similar to those obtained by Castro-Tanzi et al. (7). The soils of Trinidad (7, 14, 15), Cacao (17, 18) and to a lesser extent 20, also Cacao, are influenced by the concentration of magnesium. CEC, and with less influence of the apparent density and the % of silt. Likewise, the soils of Ciri Grande (2), Ciri de Los Soto (8), Trinidad (12, 13), and to a lesser extent the soils of Ciri Grande (1, 3) and Ciri de Los Soto (10), receive a lot of influence of iron content, manganese, % organic matter, % organic carbon with less influence of copper content and porosity. The Ciri de Los Soto soils (9), Trinidad (11, 16) and to a lesser extent the Ciri Grande soils (4 and 5), have a high influence of % aluminum saturation and % clay.

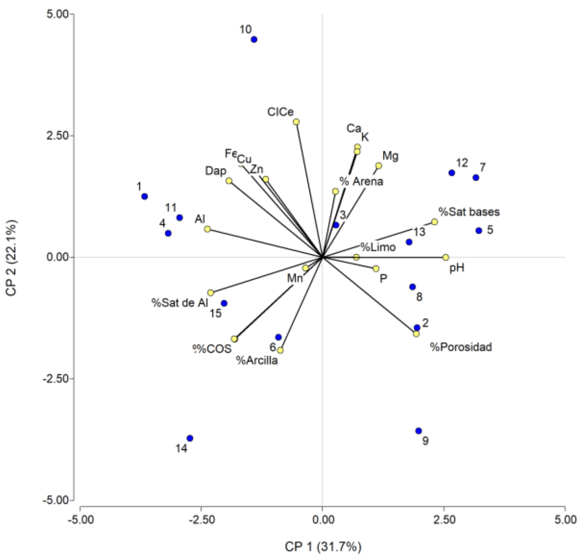


**Fig 2. Analysis of principal components of Colon soils planted with coffee.**

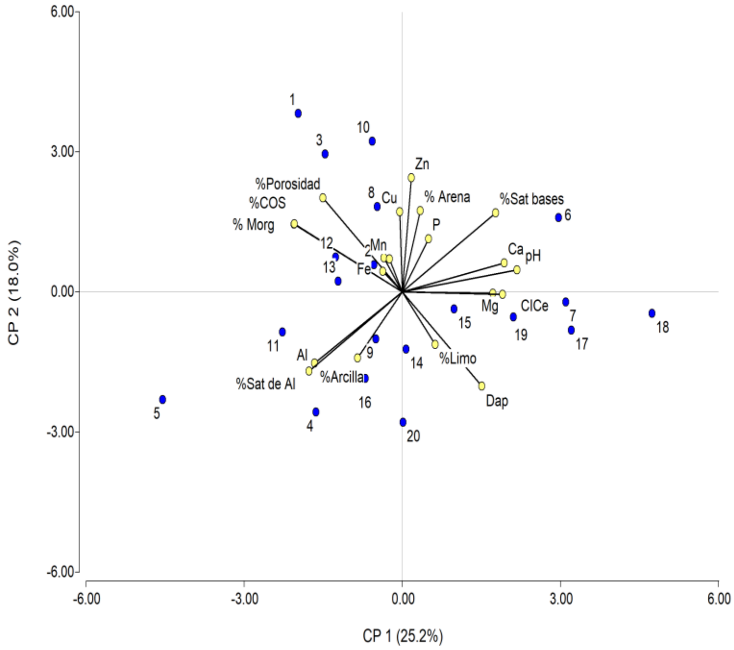


**Fig 3.Analysis of principal components of Panama Oeste soils planted with coffee.**

Maps of properties were prepared, such as aluminum levels in Colón soils (Figure 4) and organic matter content in Panama Oeste (Capira) soils (Figures 5).

Considering the analysis results of the soil samples, the climate, and the height of the site, regionalized fertilization cards were prepared for the sampled areas in the two provinces. These recommendations include doses of organic fertilizer, bioles, phosphate rock, application of low doses of chemical fertilizer, agricultural lime for soils with high % Al saturation and use of urea in low doses, applied at the beginning and end of the rainy season in Panama (April-May and October-November respectively)  At the same time, maps of properties were prepared, such as for example: aluminum levels in Colón soils (Figure 4) and organic matter content in Panama Oeste soils (Figure 5), which reflect the results shown in the principal component analyses.

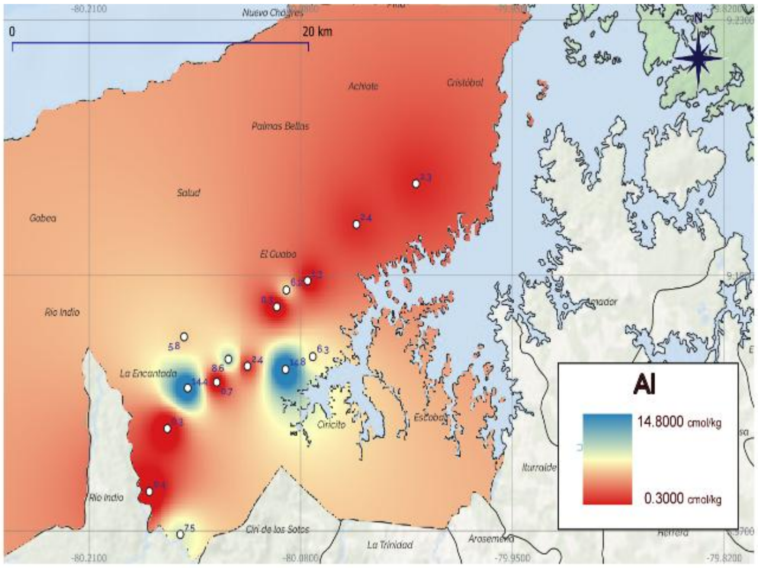


**Fig 4. Aluminum levels in soils of Colon province**

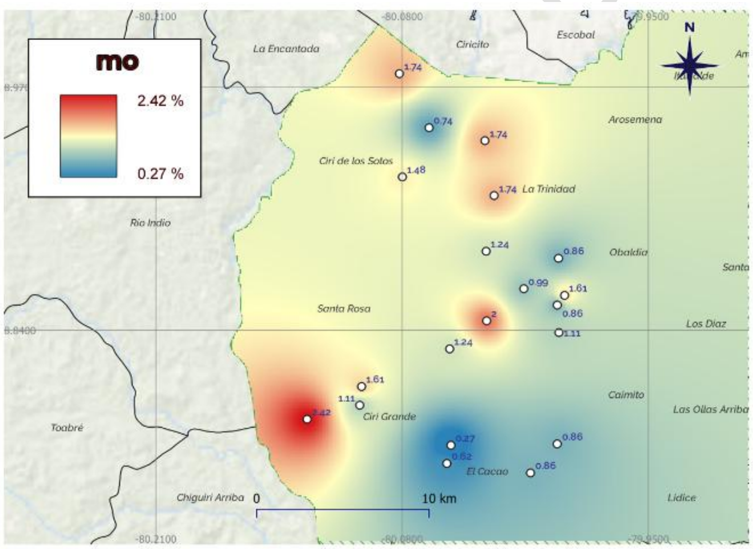


**Fig 5. Organic matter levels in soils of Panama Oeste province**

## 4. CONCLUSIONS

The soils studied in the coffee producing areas of the provinces of Colón and Panama Oeste have generally shown very acidic pH, low content of organic matter, high percentage of aluminum saturation, some areas with high calcium and magnesium content, problems of compaction and consequently low porosity, making the circulation of water and air difficult for the plantations. Fertilization recommendation cards have been prepared

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for these two provinces and they take into account this entire situation and physical problems found in the soils. Much emphasis is also placed on organic fertilization of plantations as a complement to traditional fertilization, seeking more balanced nutrition.

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