# Utilising soil nutrient analysis from Nicaragua as a local cocoa grower's guide

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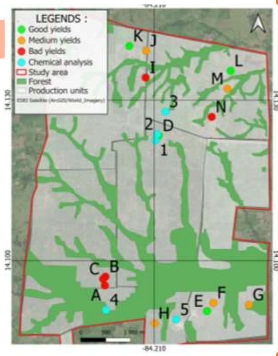
## The Context

**Mission : Diagnosis of soil quality in a caco plantation in Nicaragua**

The study area is located in Nicaragua, in the Autonomous Region of the Northern Caribbean Coast (RACCN). With annual rainfall of 2 500-3200mm and temperatures ranging from 18 to 37°C, the area has a tropical climate. Soil sampling was carried out on a cocoa farm, Cacao Oro, covering an area of 2000 hectares. Initially a grazing area, the plantation was established in 2014 on degraded soils, notably due to compaction caused by livestock farming. 2 800 000 cocoa trees of 19 different varieties were planted, along with 250 000 trees to reforest the area. However, in 2020, a hurricane destroyed most of the cocoa trees. Although the trees have been replanted, the farm is currently entering production. Current yields average 800kg/ha. However, the aim is to achieve production of 1,5t/ha. To achieve this, in addition to the genetic work carried out on the cocoa trees and the conservation zones set up to preserve existing biodiversity, constant soil improvement work is necessary. With the aim of gaining a better understanding of soil issues on the farm, the physical properties of 14 soil samples (numbered A to N) were analyzed (density, infiltration time and presence of earthworms), and 5 samples (marked 1 to 5) were chemically analyzed to determine their nitrogen, phosphorus and potassium content. Sample location can be found on Figure 1.




*Figue 1: Location for smapling in a cocoa plantion in Nicaragua*

## The Methodolgy

### Physical and chemical Analysis :

**Physical Soil Properties ( samples A to N)cf. Figure 2:**
The physical characteristics of the soils were analyzed by measuring bulk density, infiltration time, earthworm count, and soil texture.

**Bulk Density:** A tube with a 7.5 cm diameter was inserted into the ground to a depth of 7.5 cm. Once the cylinder was fully inserted, it was removed using a spade. The soil was dried for three days in the sun. The bulk density was determined by weighing the soil mass divideddd by the known volume.

**Infiltration Time of Water into Soil:** A cylinder with a diameter of 15 cm and a height of 15 cm was inserted to a depth of 7.5 cm. A plastic film was placed over the surface of the soil inside the tube, and then 444 mL of water was added. The plastic film was carefully removed, allowing the water to come into contact with the soil. The time it took for the water to be completely absorbed by the soil was recorded.

**Earthworm Count:** A hole measuring 30 x 30 x 30 cm was dug, and the extracted soil was placed on a plastic sheet to prevent the worms from escaping. All earthworms within this volume of soil were counted.

**Chemical soil properties (Samples 1 to 5) cf. Figure 3, Table 1:**

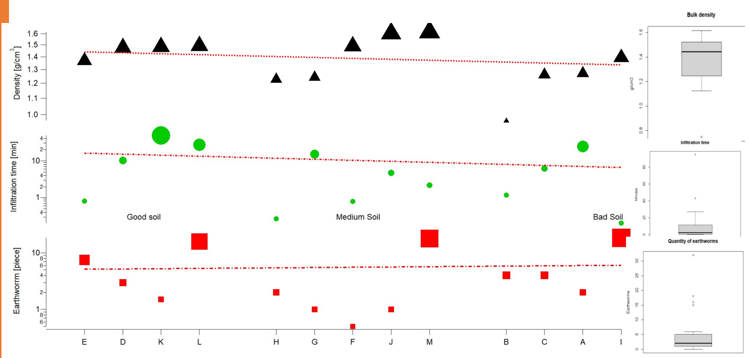
**Soil Texture Study:** A sedimentation test was conducted to assess particle size distribution. Different sediment layers allowed the identification of minerals and organic matter. Macroscopic fragments were removed to avoid skewing the results. Samples were alternated with water in a graduated cylinder and shaken to create a homogeneous solution. The results were observed after 24 hours of sedimentation.

**Kjeldahl Method for Nitrogen Extraction:** The samples were pre-treated with salicylic and sulfuric acids to oxidize the organic matter. After oxidation, the nitrogen was distilled and captured in an acidic solution. The ammonia was then released using a sodium solution and reacted with boric acid to form borate. The amount of nitrogen was determined by titration with sulfuric acid.

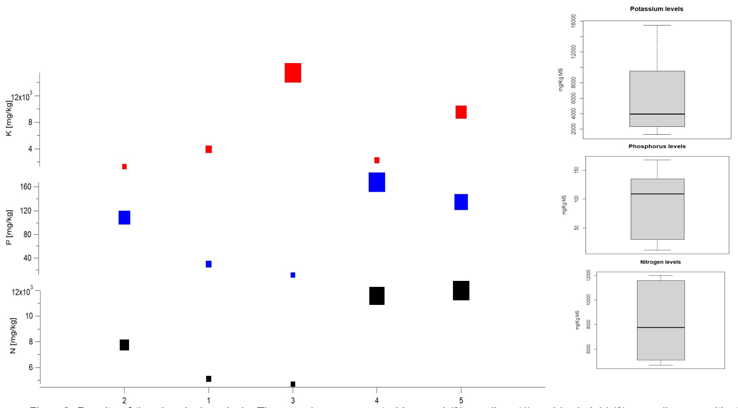
**Potassium Quantification by Flame Photometry:** Soil samples were treated with nitric and hydrochloric acids and heated for 30 minutes. After cooling and filtration, potassium concentrations were measured using a flame photometer. A calibration curve was prepared with six potassium solutions of different known concentrations.

**Spectrophotometry:** Phosphorus was measured by mixing the dry soil samples with ammonium sulfate and filtering the solution. Standard phosphorus solutions were prepared for spectrophotometer calibration. The solution was then mixed with ammonium molybdate, sulfuric acid and ascorbic acid for colorimetric analysis.

## The Results




*Figue 2: Results of the physical analysis:* The samples are « arbitraty » sperated by good (E,D,K,L) medium (H,G,F,J,M) and bad yield(B,C,A,I), Dot size reflects the level, Linear regression line sit drawn as a guide for the eye, Top : Bullk density, Middle: Infiltration Time, Bottom: Earthworm count; Boxplots are provided on the right in order to ilustrate the large spread of the results regardless the origin of the soil,




*Figue 3: Results of the chemical analysis:* The samples are sperated by good (2), medium (1) and bad yield (3) as well as uncultivated (4) and forest soil (5), Dot size reflects the level. Top: potassium concentration Middle: Phosphorus concentration, Bottom: Nitrogen concentration; Boxplots are provided on the right in order to ilustrate the spread of the results,

| Zone | Clay (%) | Silt (%) | Sand (%) | Texture |
|---|---|---|---|---|
| *Good yield (2)* | 21.6 | 15.6 | 62.6 | Sandy Loam |
| *medium yield(1)* | 26.6 | 10 | 63.3 | Clay Loam |
| *bad yield (3)* | 2.8 | 1 | 96.1 | Sand |
| *forest soil (5)* | 15.6 | 15.6 | 68.7 | Sandy Loam |
| *uncultivated (4)* | 25 | 12.5 | 62.5 | Clay Loam |

*Table 1: Results of the chemical analysis soil classification:* The samples are sperated by good (2), medium (1) and bad yield (3) as well as uncultivated (4) and forest soil (5).

## Discussion

The physical characteristics of the soils were carried out with the local means; yield determination, which is normally based on tree count, is appreciated by the plantation; therefore no real yield was determined. This arbitrary separation between good bad and medium yield does not provide clear differences in physical analysis as one might expect. Furthermore it has to bee stated that the plantation was replanted due to a meteorological event recently. There is however a tendency which is plotted into figure 2 where it can be seen that Bad yield providing soil is rather decreasing in density (it is supposed that water retention capacity for carbon rich soils is higher and also infiltration time (which cannot be explained with compacity only).
Since chemical soil analysis from expert companies is rather costly it was decided not to analyze the collected samples further.
The chemical analysis that was carried out was undertaken by a group of students at ISTOM in their PIDEX exercise, while the samples were collected during the summertime together with the samples A to N.
The chemical analysis shows however clear differences. The bad yield providing soil (3) has the highest potassium level which might be du to the fact that the plantation is former grassland for cattle production.
The Nitrogen count for unexploited (4) and and forest (5) soil is highest for the 5 sample. Since the Phosphorous count is also high this may be the reason why those soils are promising high yields since the $N/PO_2O_5$ ratio should be rather 0,5/1 for total phosphorous for optimal growth conditions of coca as provided by Snoeck *et al.*, 2016.

## Difficulties

The mission at Cacao Oro in Nicaragua faced significant challenges due to economic, logistical, and climatic constraints. The company's remote location made acquiring specialized equipment difficult, and some tests, such as soil respiration and chemical analysis, couldn't be performed immediately due to cost and availability (but where later perfumed in part at ISTOM). Additionally, the rainy season interfered with soil sampling, which had to be done 48 hours after the last rainfall. The frequent rain slowed down the process, reducing the number of samples from 18 to 14, with only two repetitions per sample. While anticipating the rainy season, its impact goes underestimated.
Transportation within the 3000-hectare farm was another obstacle, as walking with equipment was not feasible for distant sampling points. The limited availability of vehicles meant some areas had to be reached on foot, which was time-consuming and exhausting, yielding fewer samples.

## Conclusion

The physical characteristics of soil always goes with chemical analysis, otherwise one might miss out important insight. However whatever the soil, the plant has its final word whether the environment il suitable or not. Both physical and chemical analysis require preparation as well as materials. It is not always straight forward to have both at hands furthermore in developing countries cost effective analysis offer stays at a superficial level. We showed that both physical and chemical analysis could be carried out at a low cost. However further chemical determinations such as carbon and mineral count need to be taken into account for further studies.

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