SOILS: WHERE FOOD BEGINS

# Soil fertility status and oil palm productivity in southwest Cameroon

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# Title:

# Soil fertility status and oil palm productivity in southwest Cameroon

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# Presentation outline

- Introduction
- Materials and methods
- Results and discussion
- Concluding statements
- References

# I-Introduction

- **1.1. Rationale and problem statement**

- The African oil palm (*Elaeis guineensis* Jacq.) is the most productive oil crop in oil yield per hectare and resource use efficiency.

- Palm oil is an international commodity used for food, household and industrial purposes, and its demand is very high.

- In the best-managed plantations, the average yield of palm oil is about 4.2 t $ha^{-1}$ $yr^{-1}$, and can exceed 6.0 t $ha^{-1}$ $yr^{-1}$ (Fairhurst and Mutert, 1999).

- With a potential to produce about **25 t $ha^{-1}$** of fresh fruit bunch (FFB) (Feintrenie, 2012), actual yields range from **0.29 – 21.2 t FFB $ha^{-1}$ (mean = 7.70 ± 0.23 t FFB $ha^{-1}$) with a very high coefficient of variation (CV > 57%)** (Kome *et al.*, 2020).

# 1.2. The situation of oil palm production in Cameroon

Even though the harvested area over the past decades has increased, Cameroon has recorded low and variable oil palm yields and this situation has rendered her a major importer of crude palm oil, with importation increasing from **16,000 to 95,000 t between 2016 and 2017, while 100,000 t were imported in 2018 and 90,000 t in 2019.**

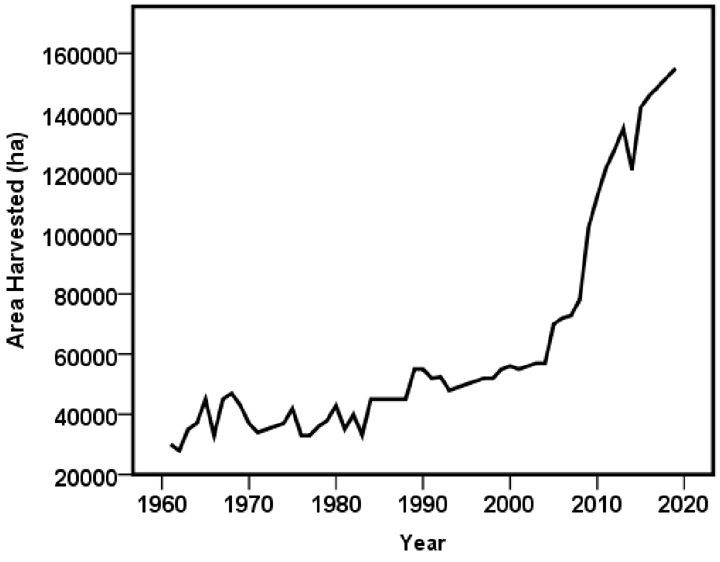



**Figure 1.**
**Harvested area under oil palm plantations in Cameroon from 1961–2019.**
**Source: Faostats (2020)**

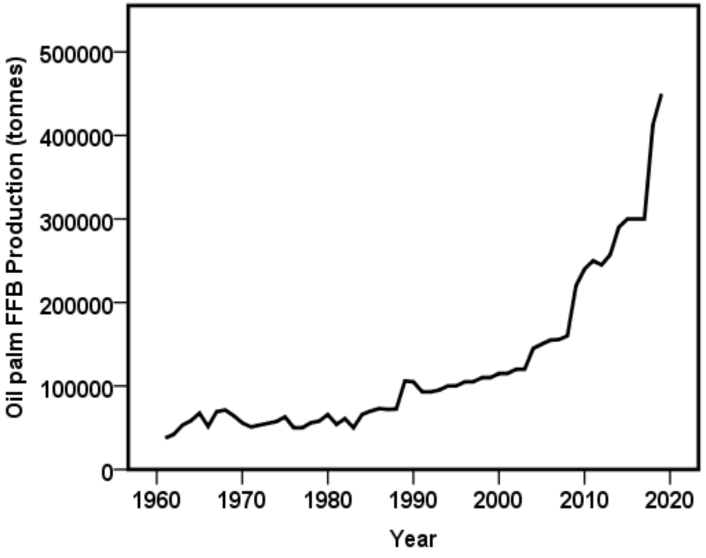



**Figure 2.**
**Oil palm FFB production in Cameroon from 1961–2019.**
**Source: Faostats (2020)**

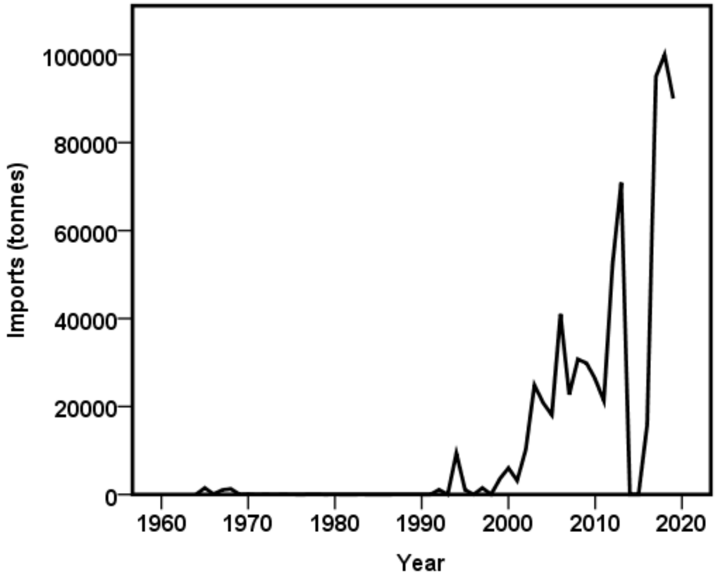



**Figure 3.**
**Importation of Crude Palm Oil in Cameroon from 1964-2019.**
**Source: Faostats (2020)**

# 1.3. Objectives of the study

- **Main objective:**
- To identify factors responsible for low and variable oil palm yields and to contribute information necessary to guide oil palm intensification and sustainable production.
- **Specific objectives:**
- To assess the soil fertility status and variability under oil palm plantations
- To evaluate the suitability of soils under oil palm in order to identify major limiting factors.

# II-Materials and methods

- **2.1. Description of study area**

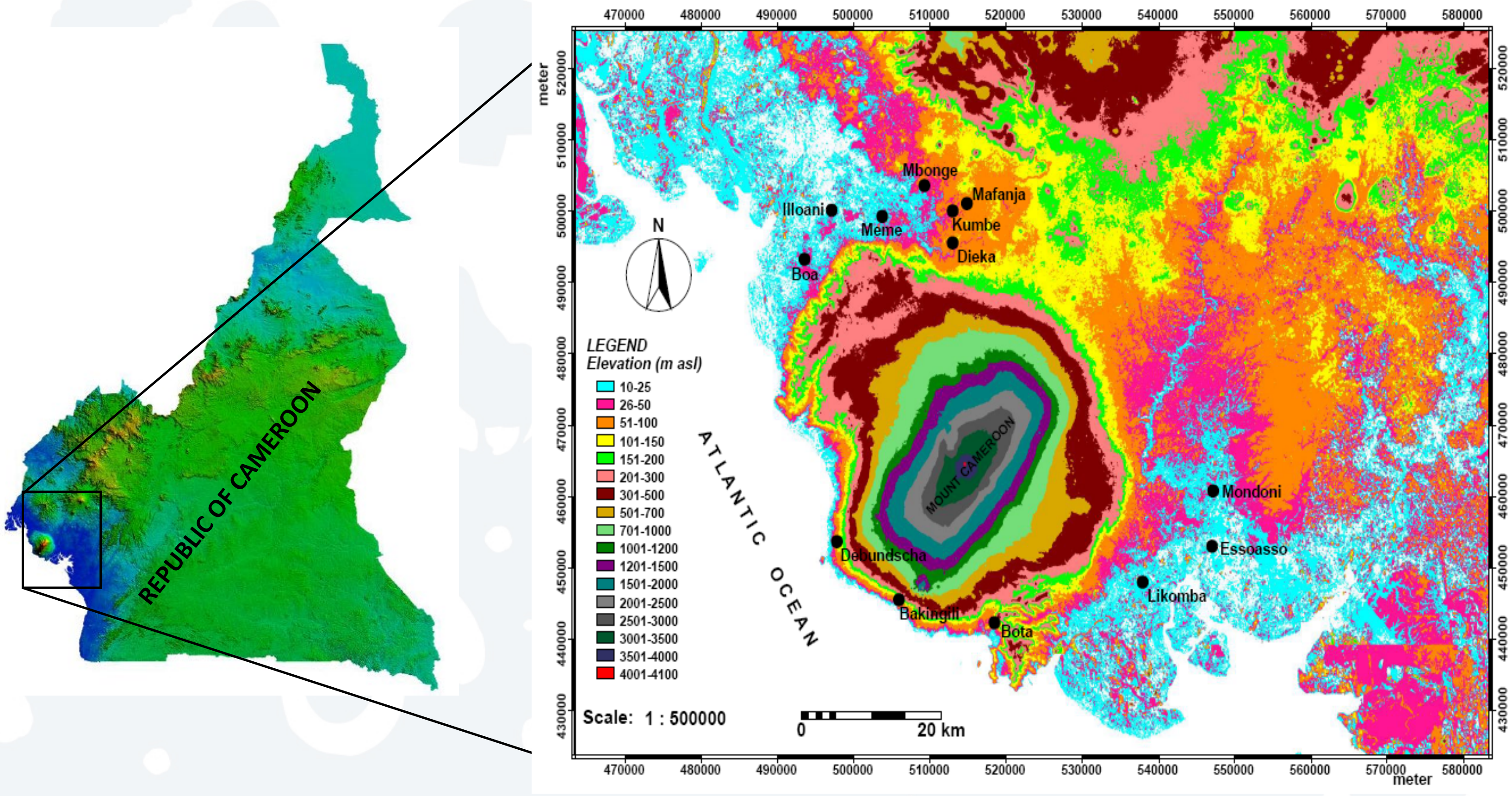



Figure 4. Location of study area

The study was carried out in the coastal lowland plains of southwest Cameroon, which is a representative of the oil palm belt of Cameroon.

Soil parent materials include basaltic lavas, recent alluvial deposits, volcanic ash deposits and granites.

Reference soil groups include: Andosols, Leptosols Nitisols, Ferralsols.

Climate is equatorial, precisely the Cameroon type which is quite hot and humid, with two distinct seasons – one wet (rainy) season (March to October) and a comparatively short dry season (November to February).

Rainfall is very high ranging from 2000 – 10,000 mm annually.

Temperatures are high, ranging from 23 – 26°C.

Atmospheric humidity is high (> 70%).

# II-Materials and methods

## 2.2. Field Methods

**Field work mainly involved soil description, soil sampling, and climate and yield data collection, following standard procedures.**

| Soil description and sampling | Climate data | Oil palm yield data |
| --- | --- | --- |
| • Soil profiles (n = 13)<br>• Surface soils (0 – 30 cm), n = 42<br>• Subsurface soils (30–60 cm), n = 42 | • Rainfall (mm)<br>• Temperature (°C)<br>• Relative humidity (%)<br>• Period: 1965 - 2017 | • FFB yield (t/ha/yr)<br>• Period of record: 2005 - 2017 from six large oil palm estates. |

Figure 5. Field methodology

# 2.3. Laboratory Methods

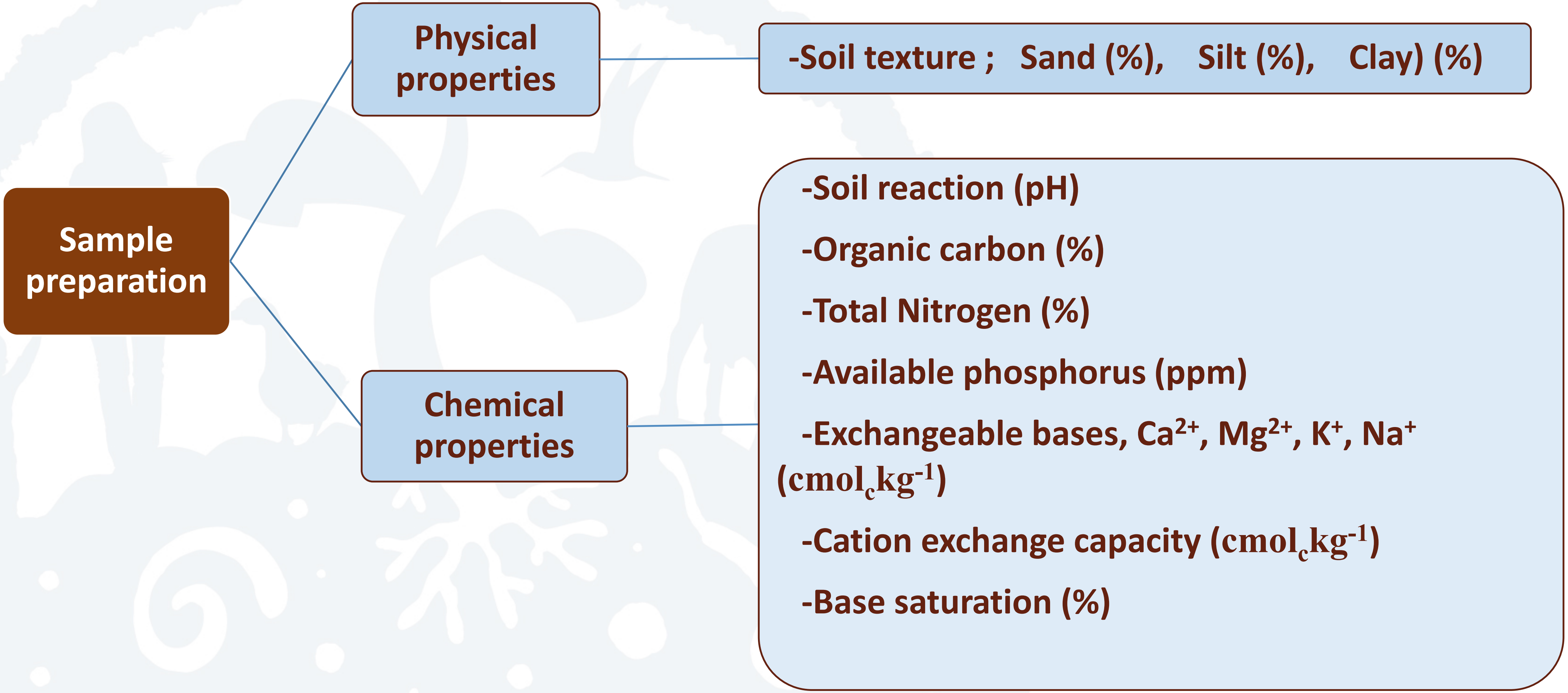



Figure 6. Standard laboratory methods according to Pauwels *et al*. (1992)

# 2.4. Analysis of soil variability and contributing factors

-Coefficient of variation (CV) (Rizwan *et al*., 2016)

$$CV = \frac{\text{Standard deviation}}{\text{Mean}} \times 100$$

| | |
|---|---|
| *CV < 15% ;* | *Low variability* |
| *15 ≤ CV ≤ 35% ;* | *Moderate variability* |
| *CV > 35% ;* | *High variability* |

- Principal Components Analysis (PCA)

- Shapiro-Wilks test

- Cluster analysis

# 2.5. Soil fertility assessment of oil palm plantations

To assess the fertility status of the soils, limits for various soil properties were set out (Table 1) and used as criteria for rating the fertility status of the soils.

Table 1. Critical soil fertility levels for oil palm growth

| Soil property | Unit | Very low | Low | Moderate | High | Very High |
|---|---|---|---|---|---|---|
| pH-$H_2O$ | – | < 3.5 | 3.5 - 4.0 | 4.0 - 4.2 | 4.2 - 5.5 | > 5.5 |
| Organic C | % | < 0.8 | 0.8 - 1.2 | 1.2 - 1.5 | 1.5 - 2.5 | > 2.5 |
| Total N | % | 0.08 | 0.08 - 0.12 | 0.12 - 0.15 | 0.15 - 0.25 | > 0.25 |
| Available P | ppm | < 10 | 10 - 25 | 25 – 40 | 40 - 60 | > 60 |
| Exchangeable $K^+$ | $cmol_c kg^{-1}$ | < 0.08 | 0.08 - 0.20 | 0.2 0- 0.25 | 0.25 - 0.30 | > 0.30 |
| Exchangeable $Mg^{2+}$ | $cmol_c kg^{-1}$ | < 0.08 | 0.08 - 0.20 | 0.20 - 0.25 | 0.25 - 0.30 | > 0.30 |
| CEC | $cmol_c kg^{-1}$ | < 6 | 6 - 12 | 12 - 15 | 15 - 18 | > 18 |

Source: Adapted from Goh and Chew (1997); Goh (2004)

## 2.6. Procedure for land suitability evaluation

**STEP 1 – Placement of soil profiles (up to 100 cm depth) and climatic variables in suitability classes by matching their characteristics/properties with the requirements for oil palm.**

**STEP 2 – Rating of each limiting characteristics using a parametric method (Square Root Method)**

$$IP = A \, x \, \sqrt{\frac{B}{100} x \frac{C}{100} x \frac{D}{100} x \ldots}$$

*Where, A = overall lowest characteristic rating; B, C, D, etc., are the lowest characteristics ratings for each land quality group [(c), (t), (s), (w), (f)]*

**STEP 3 – Calculation of productivity (land) indices; (Sys *et al*., 1993; Ogunkunle, 1993)**
***(1) Potential (IPp) and (2) Actual or Current productivity index (IPc)***

**STEP 4 – Classification of land indices (IP values) into suitability classes**
**S1-Highly suitable (100–75); S2-Moderately suitable (74–50); S3-Marginally suitable (49 – 25); and N-Not suitable (24 – 0)**

# III - Results and discussion

## 3.1. Variability of soil properties and factors accounting for variation

More than 80% of soil properties (Sand, Silt, Clay, Ca, Mg, Na, K, CEC, BS, OC, TN, and P) were highly variable with CV > 35%.

Four factors could explain > 81% of the variation observed;
(a) Base status (exchangeable $K^+$ and $Mg^{2+}$, cation exchange capacity and base saturation),
(b) Soil acidity (pH-$H_2O$),
(c) Soil organic matter (SOM) and
(d) Available phosphorus.

## Table 2. Rotated Component Matrix and communalities of soil properties (0 – 30 cm)

| Soil properties | Components (factors) | | | | Communalities |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| Sand (%) | -0,832 | -0,060 | -0,233 | -0,372 | 0,888 |
| Silt (%) | 0,780 | 0,087 | 0,332 | 0,088 | 0,735 |
| Clay (%) | 0,722 | 0,000 | 0,090 | 0,527 | 0,807 |
| pH-$H_2O$ | -0,245 | 0,897 | 0,145 | 0,146 | 0,908 |
| pH-KCl | -0,172 | 0,866 | -0,233 | -0,119 | 0,848 |
| $Ca^{2+}$ ($cmol_c kg^{-1}$) | 0,582 | 0,645 | 0,276 | -0,208 | 0,875 |
| $Mg^{2+}$ ($cmol_c kg^{-1}$) | 0,875 | 0,027 | 0,091 | -0,047 | 0,776 |
| $Na^+$ ($cmol_c kg^{-1}$) | 0,397 | 0,032 | 0,716 | -0,264 | 0,740 |
| $K^+$ ($cmol_c kg^{-1}$) | 0,086 | -0,068 | 0,814 | 0,168 | 0,703 |
| ∑Bases ($cmol_c kg^{-1}$) | 0,811 | 0,419 | 0,295 | -0,097 | 0,930 |
| CEC ($cmol_c kg^{-1}$) | 0,897 | -0,191 | -0,114 | 0,039 | 0,855 |
| BS (%) | 0,247 | 0,653 | 0,559 | -0,198 | 0,839 |
| OC (g/kg) | 0,785 | -0,224 | -0,082 | 0,207 | 0,717 |
| TN (g/kg) | 0,804 | -0,266 | 0,016 | -0,289 | 0,801 |
| C/N | 0,091 | -0,096 | -0,207 | 0,884 | 0,842 |
| Avail. P (mg/Kg) | -0,112 | 0,146 | 0,794 | -0,214 | 0,711 |
| Variance explained (%) | 37.42 | 17.37 | 16.25 | 10.03 | Total = 81.08% |

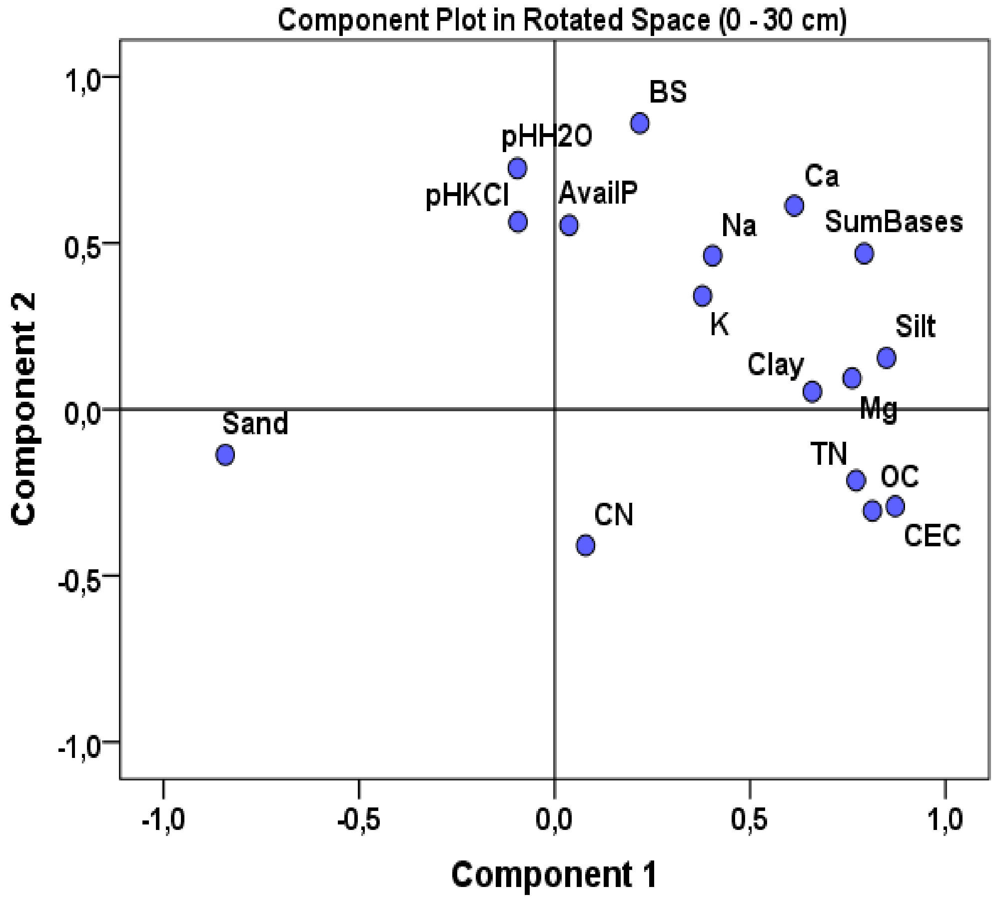



Figure 7. PCA component plots (0-30 cm)

# Table 3. Rotated Component Matrix and communalities of soil properties (30 – 60 cm)

| Soil properties | Components (factors) | | | | | Communalities |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Sand (%) | -0,697 | 0,326 | -0,410 | -0,284 | 0,226 | 0,892 |
| Silt (%) | 0,639 | -0,010 | 0,522 | 0,227 | -0,132 | 0,750 |
| Clay (%) | 0,671 | -0,096 | 0,334 | 0,268 | -0,405 | 0,807 |
| pH-$H_2O$ | 0,060 | 0,926 | 0,089 | -0,238 | -0,121 | 0,941 |
| pH-KCl | -0,013 | 0,923 | -0,084 | -0,060 | -0,104 | 0,873 |
| $Ca^{2+}$ ($cmol_c kg^{-1}$) | 0,562 | 0,466 | 0,345 | 0,229 | 0,317 | 0,805 |
| $Mg^{2+}$ ($cmol_c kg^{-1}$) | 0,880 | 0,240 | 0,010 | 0,005 | 0,175 | 0,863 |
| $Na^+$ ($cmol_c kg^{-1}$) | 0,417 | 0,124 | 0,646 | 0,014 | 0,229 | 0,660 |
| $K^+$ ($cmol_c kg^{-1}$) | 0,063 | 0,006 | 0,872 | 0,033 | 0,002 | 0,766 |
| ∑Bases ($cmol_c kg^{-1}$) | 0,797 | 0,406 | 0,228 | 0,130 | 0,273 | 0,943 |
| CEC ($cmol_c kg^{-1}$) | 0,874 | -0,128 | -0,060 | 0,237 | -0,044 | 0,842 |
| BS (%) | 0,213 | 0,629 | 0,434 | -0,043 | 0,455 | 0,839 |
| OC (g/kg) | 0,210 | -0,065 | 0,053 | 0,906 | -0,279 | 0,950 |
| TN (g/kg) | 0,263 | -0,193 | 0,050 | 0,891 | 0,212 | 0,948 |
| C/N | -0,119 | 0,329 | 0,041 | 0,056 | -0,871 | 0,885 |
| Avail. P (mg/Kg) | -0,160 | 0,252 | 0,440 | 0,004 | 0,580 | 0,620 |
| Variance explained (%) | 26.33 | 18.16 | 14.43 | 12.56 | 12.14 | Total = 83.64% |

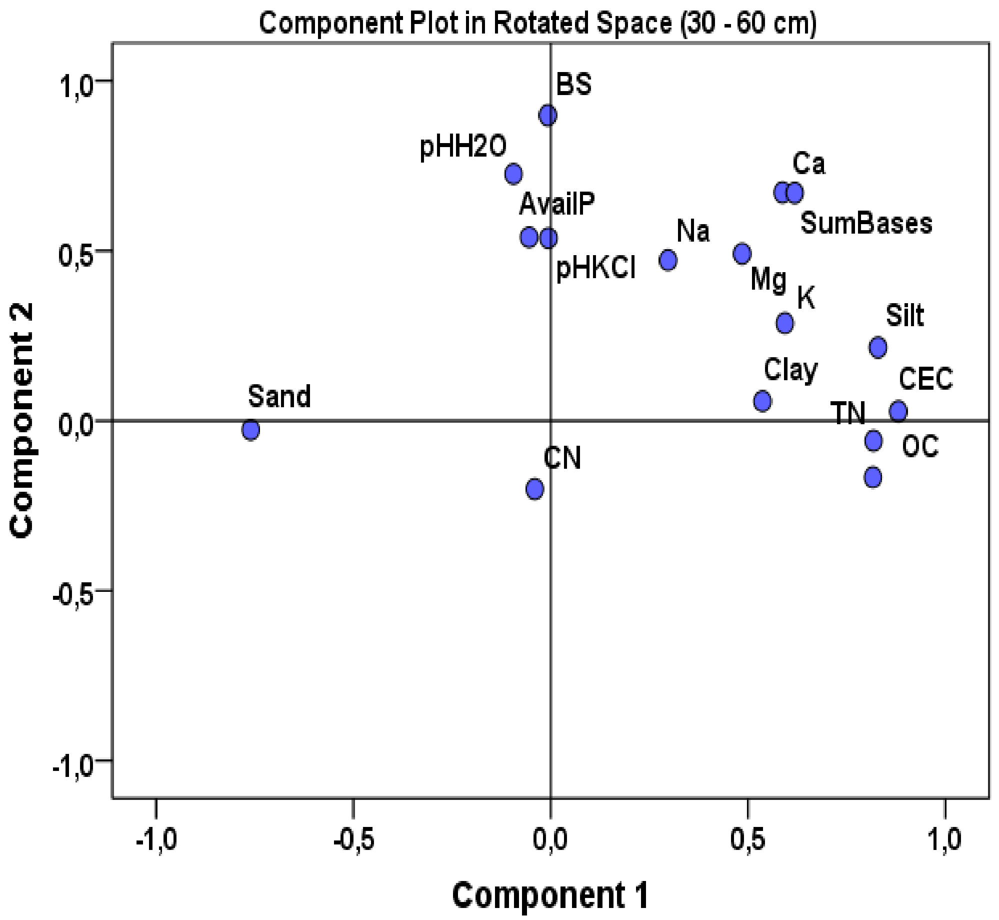



Figure 8. PCA component plots (30-60 cm)

# 3.2. Soil nutrient status in oil palm plantations

## Table 4. Percentages of soils with different critical soil fertility levels

| Soil property | Very low | Low | Moderate | High | Very High |
|---|---|---|---|---|---|
| | | | % | | |
| | | | Surface soils (0 – 30 cm), (n = 42) | | |
| pH-$H_2O$ | 0,0 | 2,4 | 0,0 | 78,6 | 19,0 |
| Organic C | 21,4 | 31,0 | 11,9 | 28,6 | 7,1 |
| Total N | 9,5 | 19,0 | 31,0 | 33,3 | 7,1 |
| Available P | 73,8 | 23,8 | 2,4 | 0,0 | 0,0 |
| Exchangeable K | 2,4 | 28,6 | 26,2 | 19,0 | 23,8 |
| Exchangeable Mg | 4,8 | 2,4 | 7,1 | 2,4 | 83,3 |
| | | | Subsurface soils (30 – 60 cm), (n = 42) | | |
| pH-$H_2O$ | 0,0 | 2,4 | 2,4 | 78,6 | 16,7 |
| Organic C | 69,0 | 21,4 | 2,4 | 4,8 | 2,4 |
| Total N | 64,3 | 26,2 | 0,0 | 7,1 | 2,4 |
| Available P | 81,0 | 16,7 | 2,4 | 0,0 | 0,0 |
| Exchangeable K | 4,8 | 28,6 | 40,5 | 9,5 | 16,7 |
| Exchangeable Mg | 4,8 | 9,5 | 0,0 | 2,4 | 83,3 |

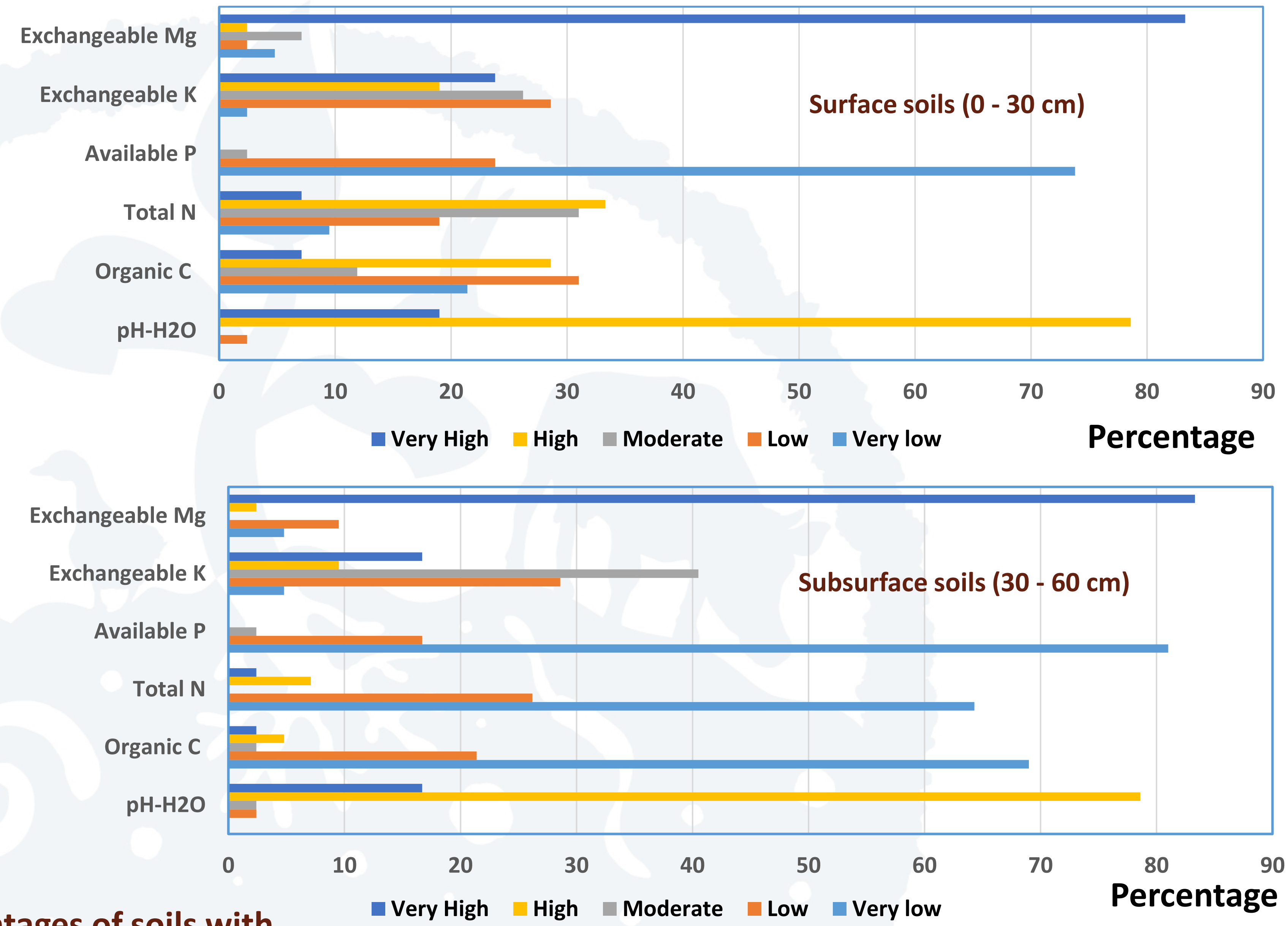
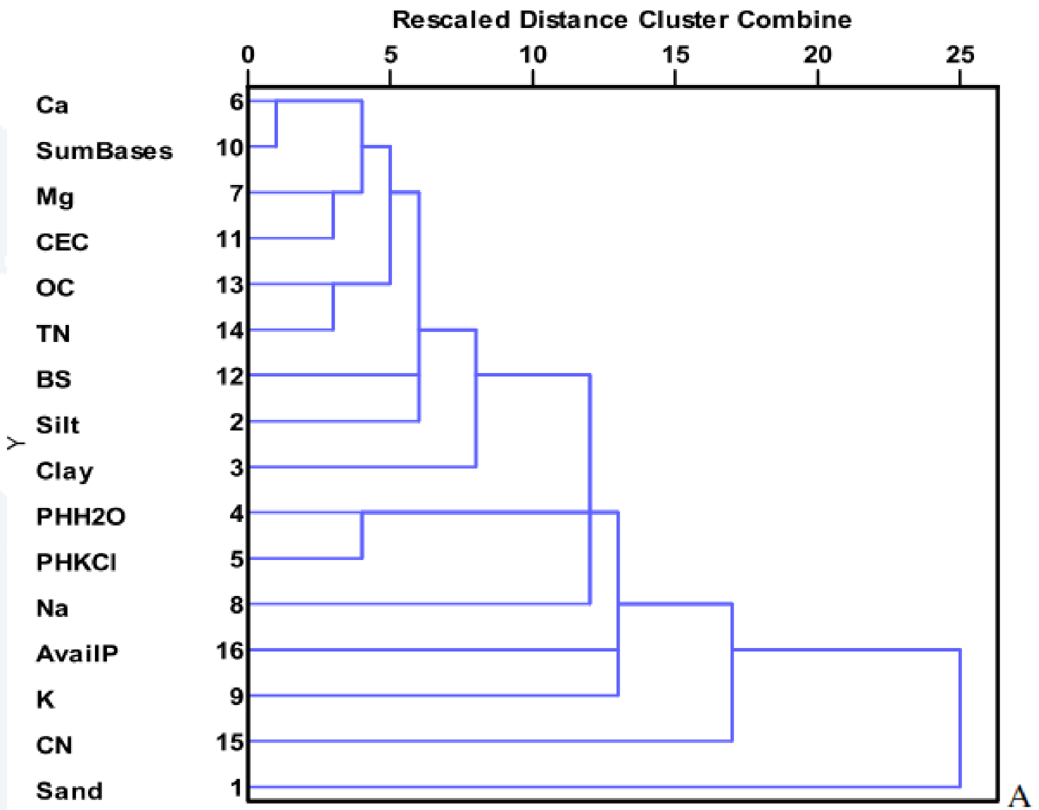



**Figure 9. Percentages of soils with different critical soil fertility levels**



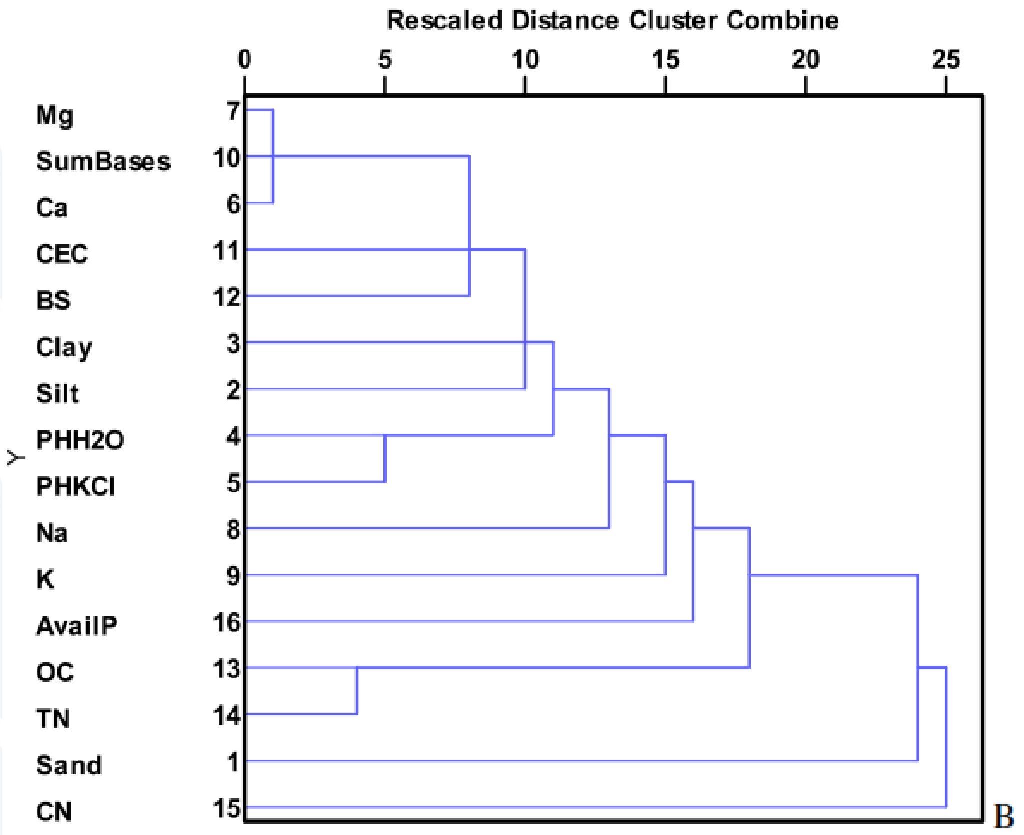




**Figure 10. Dendrogram of soil properties. A; surface (0 – 30 cm) soil properties. B;subsurface (30–60 cm) soil properties.**

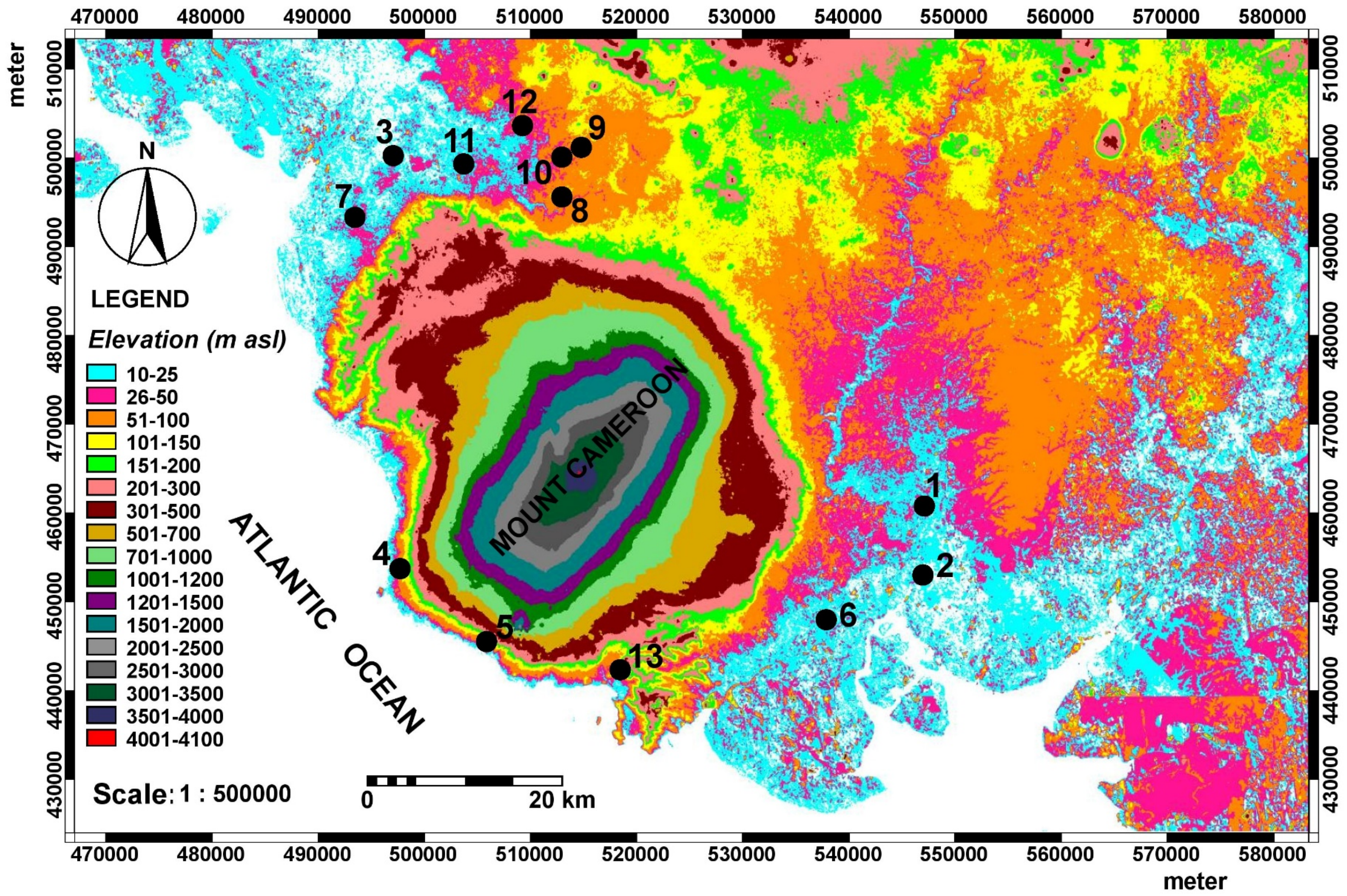
## 3.3.Land suitability for oil palm in coastal plains of southwest Cameroon

Land suitability evaluation indicated that soil physical characteristics, mainly soil texture (dominantly clayey) and poor drainage constitute limitations to oil palm productivity, meanwhile soil chemical properties, **especially the K mole fraction**, appear to be the major constraint to optimal oil palm productivity. Current climatic conditions do not pose a limitation to oil palm growth.

| Land suitability | Sites | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| **IPp** | 45(S3) | 62(S2) | 23(N) | 50(S2) | 46(S3) | 38(S3) | 32(S3) | 39(S3) | 32(S3) | 32(S3) | 31(S3) | 48(S3) | 52(S2) |
| **IPc** | 18(N) | 25(S3) | 15(N) | 20(N) | 26(S3) | 21(N) | 18(N) | 22(N) | 22(N) | 22(N) | 21(N) | 19(N) | 21(N) |

**Table 5. Land productivity indices of some major oil palm producing sites in southwest Cameroon**

***IPp* = Potential productivity index ;   *IPc* = Current or actual productivity index**




Current (actual) productivity

1 – Mondoni (N)
2 - Essoasso (S3)
3 - Illoani (N)
4 - Debundsha (N)
5 – Bakingili (S3)
6 – Likomba (N)
7 – Boa (N)
8 – Dieka (N)
9 – Mafanja (N)
10 - Kumbe (N)
11 - Meme (N)
12 - Mbonge (N)
13 – Bota (N)

Figure 11. Sites with different actual productivity indices in southwest Cameroon

- Soil fertility appears to be the major constraint for optimal oil palm production. Specifically, cation exchange capacity, base saturation, organic carbon and soil pH pose slight to moderate limitations, while K mole fraction is the most serious constraint, and is the most limiting factor in all the sites. Based on the suitability evaluation, about 70% of the soils are potentially marginally suitable (S3), 23% are moderately suitable (S2) and 7% are not suitable (N).

- Based on the initial nutrient status of the different soils, they are expected to respond differently to varying rates of N, P, K and Mg fertilization. The fertilizer (NPK 10-10-30 + 1.5 Mg + 0.3 B) rates range from 226 kg $ha^{-1}$ to 1332 kg $ha^{-1}$ with a mean value of 924 ± 49 kg $ha^{-1}$ and standard deviation of 296 kg $ha^{-1}$.

# Concluding statements and perspectives

- This study revealed that the main soil properties necessitating management vis-à-vis oil palm growth and productivity are base status (exchangeable K and Mg, CEC and base saturation), soil pH, soil organic matter and available P content.

- The high variability of soil properties observed informs on the necessity for site-specific soil fertility management.

- Based on the critical soil fertility levels for oil palm growth, recommended management practices to sustain productivity include adequate use of chemical fertilizers (N, P, K, Mg), the use of legume cover crops for improving on N status and addition of soil organic matter through proper residue management.

- Further studies on soil potassium fractions (forms) and dynamics in oil palm agro ecosystems shall be carried out to better understand its effect on oil palm productivity.

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# Thank you !