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# Evaluation of Physical and Chemical Soil Fertility in Cocoa-Based Agro Systems in the Kokumbo Sub-Prefecture (Central Côte d'Ivoire)

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**Abstract** **Original Research Article**

This study was carried out in the Kokumbo sub-prefecture in central Côte d'Ivoire to assess the impact of cocoa-based agrosystems on the physical and chemical characteristics of cocoa soils. This region was chosen for the study because it still houses traditional agroforestry plantations based on cocoa trees and still in production. Soil pits were opened following the toposequence in each type of agroforest for the determination of the physical characteristics of the study site. For the determination of soil chemical parameters, the basic sampling was carried out at the auger at two levels of horizon: 0-20 cm and 20 - 40 cm in zigzag, following the longest diagonal for laboratory analysis. The results obtained showed that regardless of the full sun, mixed or complex forest agrosystem, the values of the fertility parameters obtained indicate overall a very satisfactory soil fertility level. Moreover, the mixed cocoa-based agro-forestry system appears to be more interesting in improving the soil structure and enrichment of available mineral elements and could be recommended to cocoa producers in the area of study.

**Keywords:** Agrosystems based on cocoa trees, physical and chemical soil fertility, Kokumbo, Côte d'Ivoire.



## INTRODUCTION

Low crop yields in sub-Saharan African countries are generally due to the natural nutrient poverty of soils and the low use of inputs, coupled with the excessive presence of varieties traditional low performance, sensitive to disease and adverse weather conditions [1-3]. Also, the fertility of the soils under the old cocoa trees is experiencing a progressive deterioration of nutrients, notably, organic carbon, nitrogen, phosphorus and potassium because the exports of these mineral elements through the fruits of cocoa (cocoa bud and beans) are not compensated [4-7]. These constraints explain the excessive acreage in Africa to improve productivity and offset low yields [2]. Cocoa (Theobroma cacao L.) whose cultural requirements correspond to the edaphic and climatic conditions of the intertropical zone is not exempt from this reality although this culture can adapt to a greater variability of biophysical environments, soil types and climates [8-10]. It is grown in the field under different cropping systems, including full sun, shading and intermediate systems. Research has provided farmers with the opportunity to conduct cocoa in pure or light shade with chemical input applications [11]. However, the forest is and still is the ideal cultural precedent to guarantee a good vegetative development and a good productivity of a cocoa plantation. Indeed, according to [12], the cocoa tree considered a shade plant has a high productivity when it is totally exposed to light. This perpetual search for maximizing cocoa production has led producers to new fronts of forest clearing, thus constituting one of the main causes of forest cover degradation in the tropical world [13]. Forest cover degradation and biodiversity is due to anthropogenic activities in general and in particular to the establishment of more than 38% of the forest area destroyed [14]. This expansion of cacaoculture has led to a change in cropping practices that has led to the shift from pluristratified (complex) agroforestry systems to crops under moderate shade or full sun. Despite its negative impact on forest cover, several authors [15-17] showed the benefits and benefits of adopting agroforestry practices in cocoa farming. Paradoxically, the forest-savannah contact zone in central Côte d'Ivoire, once considered unfavourable to the cultivation of cocoa because of the instability of the transient soils between the tropical ferruginous soils of the north (lixisols) and ferralsols from the south [18] and the scarcity of forest areas ([19] has long been an area of average cocoa production, notably the department of Toumodi. The work carried out by [20, 21] showed that different agroforestry systems based on cocoa trees persist in the department of Toumodi and more particularly in the sub-prefecture of Kokumbo. However, very little published work in this area of Côte d'Ivoire deals with the impact of cocoa-based agroforestry systems on the fertility and quality of cocoa soil and on the yield of commercial cocoa. The evaluation of the impact of these agrosystems on the physical and chemical characteristics of the soils will allow the necessary amendments to be made with a view to sustaining these systems and sustaining the cultivation of cocoa in this area.

## MATERIAL AND METHODS

### Characteristics of the study area

The study was carried out in the Kokumbo sub-prefecture in the region of Aries in Côte d'Ivoire. This region was chosen for the study because it still houses traditional agroforestry plantations based on cocoa trees and still in production, like other producing regions where agroforestry systems have almost disappeared. It is located in central Côte d'Ivoire between north latitudes 6°19'37.81'' and 6°34'51.18'' and west longitudes 5°19'58.35'' and 5°20'02.54'' (Figure 1).

From a geology point of view, the region is located in a broad band of metamorphic Birrimien, direction NNE-SSW, framed by newer granitoids, belonging to Ebony orogenesis (Yao-Kouamé, 2007) and marked by a combination of granitic and sedimentary zones. It mainly contains biotite granites, micaschists and chloritoschites, metavolcanites and conglomerates. There are also rock outcrops in balls or slabs and lateral battleships that supplant the shale formations.

The floors are ferralitic, strongly or moderately desaturated. Their fertility potential depends mainly on the percentage of coarse elements and the texture of the higher horizons [22]. The region belongs to the mesophilic sector of the Guinean domain [23] and is part of the forest-savanna transition zone. It is under the influence of a tropical, bimodal climate, characterized by two rain seasons of unequal importance, separated by two small dry seasons. Monthly rainfall is around 1,090 mm annually, while temperatures are characterized by uniformity and low amplitude of 27.14°C.

The vegetation consists of a mosaic of Guinean savannahs and dense semi-deciduous humid forests [24] on lowlands and a low system of wrinkles and hills. There are also some plains and many hills of granite structure [25]. The river system department is dominated mainly by the Bandama in the West and the N'Zi in the South-East, as well as several rivers.

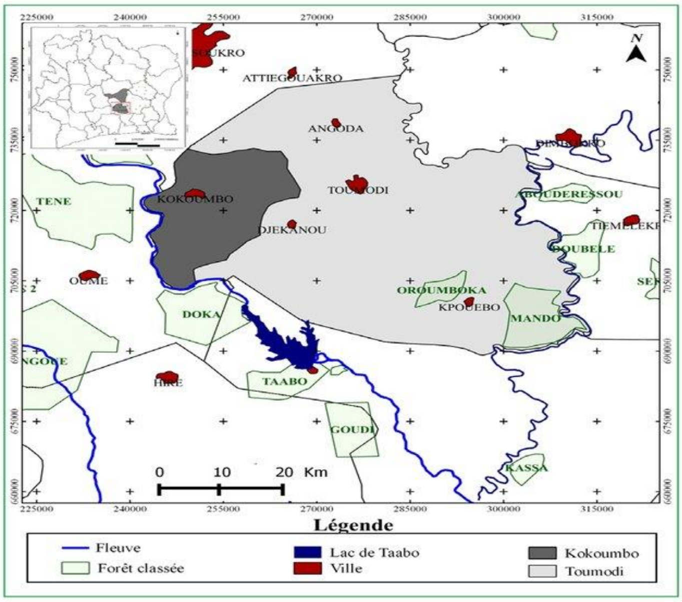


**Fig-1: Location of the sub-prefecture of Kokoumbo in the department of Toumodi in the centre of Côte d'Ivoire**

## MATERIAL

### Plant material

The plant material consists on the one hand of cocoa «*Theobroma cacao*» not selected commonly called "all-coming" and the improved variety selected by the research and on the other hand, by the plant species constituting the agroforests.

### Field equipment and soil analysis

**Global Positioning System Field equipment consists of**

- (GPS), for topographical surveys and surveys of geographical coordinates;
- machetes, shovels, picks, for cleaning the plot and opening the soil profiles;

- Edelman type soil auger, 7 cm in diameter, for the sampling of soil cores;
- plastic bags, for the packaging of samples of soil collected;
- electric agitators, precision electronic balance, sieve, electric grinder, burette, centrifuge, for the measurements and preparation of the composite soil sample for particle size and chemical analysis;
- pH-meter, for pH determination;
- Ventilated oven with hot air (105°C), oven, Kjeldhal distiller, graduated test piece, flask, graduated and graduated pipettes and sieve for chemical analysis of soil samples.

## STATISTICAL ANALYSIS

Field data and analysis results were captured and codified using the Microsoft Excel 2010 spreadsheet. They were subjected to statistical analyses using SAS V9.1 software. Which allowed the mean particle size and physico-chemical soil data from each study site to be compared by variance analysis (ANOVA) at the $\alpha = 0.05$ threshold. When a significant difference was noted between the factors considered for a given trait, the Newman-Keuls test was performed.

## METHODS

**Methods**

The methodology adopted in the field consisted of a survey of the sites in order to select the most representative plantations of the various agroforestry systems of the area. The choice of these cocoa plantations was guided by the agroforestry typology as defined by the work of [20]. For the determination of the physical characteristics of the study site, soil pits were opened following the toposequence in each type of agroforest. Thus, three soil pits were opened by agroforest. The depth of the pits was defined according to the penetration of the roots of the cocoa tree. The description of the crop profile revealed the main characteristics of the various layers of land per basic plot.

For the determination of soil chemical parameters, the basic sampling was carried out at the auger at two levels of horizon: 0-20 cm and 20 - 40 cm in zigzag, following the longest diagonal. For the same plot, 2 composite samples of 20 elemental samples were constructed according to the depth of collection for laboratory analysis. A total of 18 soil samples were collected, bagged and carefully labelled for chemical analysis at the soil and plant laboratory of the Institut National Polytechnique Félix Houphouët-Boigny (INP-HB) in Yamoussoukro.

**Laboratory analysis**

The laboratory analyses concerned the determination of the physical and chemical properties of the soil after drying the composite samples.

**The determination of the physical properties of the soil covered**

- analysis of the particle size of the fraction of the composite sample taken from the site; using the sieve method [26] ;
- determination of coarse elements;
- Floor texture by tactile method.

**The determination of soil chemical parameters concerned**

- the pH of the soil water which was determined by the electrometric method at pH-meter, with a glass electrode, on a water suspension - sieved soil, in a soil/solution ratio of 1/2,5;
- The total organic carbon (C) of the soil was determined by the Walkley and Black method (1934). The organic matter content (MO) was determined by the relationship: MO (%) = total carbon 1.72;
- total nitrogen was determined by the Kjeldahl method;
- the assimilable phosphorus (P2o5ass), was determined by the Olsen-Dabin method described by [27] ;
- Cationic exchange capacity (CEC) and exchangeable bases ($Ca^{2+}$, $Mg^{2+}$, and $K^+$) were extracted by rinsing an ammonium acetate solution ($NH_4C_2H_3O_2$, 1N) at pH 7.

## RESULTS

**Evolution of soil size according to agrosystems under cocoa trees**

A significant difference between the soil characteristics of full sun, mixed and complex agrosystems, in particular, at the level of fine silt, total silt and coarse sand was observed (Table 1). More specifically, a statistically higher mean fine silt value (41.82%) was recorded in full sunlight compared to complex agrosystems (34.68%) and mixed agrosystems (30.95%) in descending order. A similar and similar average value was found for total silt. On the other hand, for coarse sand, the highest value was recorded in mixed agrosystems (15.87%) and the lowest in full sun (8.95%) with a statistically intermediate value in complex agrosystems (11.59%).

Considering the average values of the different parameters by horizons of the different agrosystems, no statistically significant difference between the mean values of the grain size parameters determined by the agrosystems, whatever their depth; except for coarse silt in full sun agrosystem which displays significant values for horizon 0-20 cm (10.22%) which is double that of horizon 20-40 cm (5.42%).

With regard to the texture of the different horizons, and hence the overall soil texture of the cocoa agro-systems, the chemical analyses showed that the soils at the study site are of silty-sandy-clay if we refer to the percentages of the total clay, silt and sand whatever the agrosystem (full sun, complex or mixed) and the horizons (0-20 cm or 20 cm-40 cm) considered.

**Table-1: Particle size of Cocoa Growing Soils in the Study Area**

| | **Particle size of soils (%)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Full sun culture system** | | | **Mixed agroforestry system** | | | **Complex agroforestry system** | | |
| Parameters | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm |
| Clay | 17,37A | 14,25a | 20,50a | 29,63A | 29,02a | 30,25a | 24,22A | 21,77a | 26,67a |
| Fine silt | 41,82B | 40,65a | 43,00a | 30,95B | 32,00a | 29,90a | 34,68AB | 33,87a | 35,50a |
| Coarse silt | 7,82A | 10,22a | 5,42b | 7,22A | 6,12a | 8,32a | 8,73A | 8,90a | 8,57a |
| Total silt | 49,42A | 46,95a | 51,28a | 38,17B | 38,25a | 38,08a | 43,42AB | 42,77a | 44,07a |
| Clay + Silt | 67,02A | 69,54a | 67,62a | 67,81A | 67,26a | 69,10a | 67,63A | 64,54a | 70,73a |
| fine sand | 24,02A | 24,77a | 23,27a | 16,31A | 18,00a | 14,62a | 20,77A | 24,36a | 17,18a |
| Coarse sand | 8,95B | 10,10a | 7,80a | 15,87A | 14,85a | 16,90a | 11,59AB | 11,10a | 12,08a |
| Total sand | 32,97A | 30,55a | 35,40a | 32,19A | 32,74a | 31,64a | 32,36A | 36,45a | 28,28a |

The values followed on the same line by the same letter are not statistically different at the threshold of α = 0.05 for the capitals between the agrosystems and for the lower case between horizons of an agrosystem respectively.

**Evolution of soil chemical parameters in relation to agrosystems under cocoa trees**

**Soil acidity**

The statistical analysis showed that there was no statistically significant difference between the pH(water) and pH(kcl) of the soils of the different agrosystems (Table 2). In addition, the pH values of the soils regardless of the agrosystem and the level of the depth considered varied between 6.70 and 7.00 for the actual acidity of the soil, determined by the pH(water) and between 5.65 and 6.37 for potential acidity, determined by pH(kcl). These pH values, which were lower overall than the actual acidity ((pH(water) = 7), indicated a soil under low acid cocoa. The difference in mean Δph between pH(water) and pH(kcl) of the soil was statistically significant by agrosystem and horizon level. In fact, the deviation Δph varying between 0.50 and 1.13 indicated a slight variation in acidity (Δph = 0.50) at the level of the horizon 0-20 cm and a high potential acidity (Δph 1) at the level of the horizon 20-40 cm for all soils under cocoa trees of agrosystems.

**Table-2: Acidity of Soil under Cocoa in the Study Area**

| | **Full sun culture system** | | | **Mixed agroforestry system** | | | **Complex agroforestry system** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameters | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | *Norms** |
| pH (eau) | 6,70A | 6,70a | 6,70a | 6,80A | 6,85a | 6,75a | 6,90A | 7,00a | 6,80a | *6-7* |
| pH (kcl) | 5,92A | 6,20a | 5,65a | 5,90A | 6,20a | 5,70a | 6,02A | 6,37a | 5,67a | *5-6* |
| ΔpH | 0,77A | 0,50b | 1,05a | 0,85A | 0,65b | 1,05a | 0,88A | 0,63b | 1,13a | *0,5-1* |

The values followed on the same line by the same letter are not statistically different at the threshold of α = 0.05 for the capitals between the agrosystems and for the lower case between horizons of an agrosystem respectively.

**Organic matter content and assimilable phosphorus of the studied soil**

No significant differences were observed between the agrosystems for the organic matter and phosphorus levels considered (Table 3). However, there is significant variability in mean values of organic matter levels and mixed agrosystem phosphorus content in the 0-20 cm and 20-40 cm horizons, respectively. In fact, the respective levels of organic matter (19.90%); carbon (11.52%); total nitrogen (0.87%) and assimilable phosphorus (107.25 ppm) were elevated at the surface layer 0-20 cm as at the layer 20-40 cm in mixed agrosystem. On the other hand, the ratio C/N is 13.86 was higher at the 20-40 cm layer than at the 0-20 cm layer. For the full sun and complex agrosystems, no significant difference was observed at any level of the considered layer. However, the highest mean values were noted with the mixed agri-system for these parameters.

**Table-3: Organic matter and assimilable phosphorus content of soil under cocoa Trees**

| | Soil organic matter | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Full sun culture system | | | Mixed agroforestry system | | | Complex agroforestry system | | | |
| Parameters | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | *Norms** |
| M.org. (%) | 12,77A | 15,86a | 9,69a | 18,89A | 19,90a | 17,88b | 15,54A | 19,23a | 11,86a | *3,6-6,5* |
| Carb (%) | 7,43A | 9,22a | 5,63a | 10,98A | 11,52a | 10,37b | 9,04A | 11,18a | 6,89a | *6,2-11,2* |
| Ntotal (%) | 0,57A | 0,71a | 0,43a | 0,81A | 0,87a | 0,75b | 0,67A | 0,83a | 0,51a | *0,1-0,15* |
| C/N | 12,45A | 12,91a | 11,99a | 13,54A | 13,23b | 13,86a | 13,35A | 13,46a | 13,24a | *11-15* |
| Pass (ppm) | 116,70A | 103,45a | 129,95a | 105,20A | 107,25a | 99,15b | 126,18A | 101,43a | 150,93a | *50-100* |

The values followed by the same letter are not statistically different at the threshold of α = 0.05 on a line for capital letters between agrosystems and for lower case letters between horizons of an agrosystem respectively

**Exchangeable cations and cation exchange capacity of the soils studied**

At the level of chemical analysis no significant difference in the mean values of the exchangeable cation contents was observed between the different agrosystems on the one hand, and on the other hand, over horizons 0-20 cm and 20-40 cm whatever the agrosystem, except for magnesium which has shown significant average values particularly in mixed agrosystems and full sun over the horizons considered (Table 4). In addition, the sum of exchangeable cations indicated significant mean values (P 0.05) in mixed agrosystem in horizons 0-20 cm and 20-40 cm with a higher mean value in horizon 0-20 cm. Similarly, the CEC only displayed a significant mean value for the full sun agrosystem. Indeed, the CEC had a higher average value in the 0-20 cm horizon than in the 20-40 cm horizon. It was also noted that overall, the highest mean values were for the mixed agrosystem although no statistical differences were observed between these parameters.

**Table-4: Exchangeable cation contents and exchange capacity**

| | Exchangeable cations and cation exchange capacity | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Full sun culture system | | | Mixed agroforestry system | | | Complex agroforestry system | | | |
| Parameters ($cmol^{+}.kg^{-1}$) | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | *Norms* |
| Ca | 5,22A | 4,93a | 5,51a | 6,01A | 6,31a | 5,14a | 5,60A | 6,41a | 4,79a | *5-8* |
| Mg | 2,51A | 2,96a | 2,07b | 3,40A | 3,87a | 2,92b | 2,83A | 3,37a | 2,28a | *1,5-3* |
| K | 0,08A | 0,09a | 0,07a | 0,09A | 0,11a | 0,07a | 0,09A | 0,11a | 0,08a | *0,15-0,25* |
| Na | 0,15A | 0,18a | 0,11a | 0,11A | 0,13a | 0,10a | 0,12A | 0,13a | 0,11a | *0,3-0,7* |
| S | 7,96A | 8,17a | 7,75a | 9,62A | 10,43a | 8,81b | 8,64A | 10,02a | 7,27a | *7,5-15* |
| CEC | 25,45A | 28,00a | 22,90b | 28,55A | 30,60a | 26,50a | 25,93A | 23,53a | 25,33a | *10-20* |
| V (%) | 31,66A | 29,37a | 33,94a | 33,70A | 34,17a | 33,23a | 33,24A | 38,30a | 28,17a | *60-90* |

The values followed by the same letter are not statistically different at the threshold of α = 0.05 on a line for capital letters between agrosystems and for lower case letters between horizons of an agrosystem respectively

**Saturation rate in exchangeable bases**

In the analysis, no significant difference in the average values of the saturation rates in exchangeable bases was observed between the different agrosystems as well as in horizons 0-20 cm and 20-40 cm, except for magnesium which displayed significant mean values, in mixed and full sun agrosystems in the 0-20 cm (12.68%) and 20-40 cm (10.98%) mixed agrosystem and in the 0-20 cm horizons (10.57%) and 20-40 cm (9.03%) in full sun culture (Table 5). In addition, the comparison of the mean values of the magnesium saturation rates indicated a higher rate in the horizon 0-20 cm than in the horizon 20-40 cm in mixed agroforestry systems as well as in the full sun system.

**Table-5: Exchangeable base saturation rates of the soil absorbing complex**

| | Exchangeable base saturation rates of the soil absorbing complex | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Full sun culture system | | | Mixed agroforestry system | | | Complex agroforestry system | | | |
| Nutrients (%) | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | Global soil | Horizon 0 -20 cm | Horizon 20 -40 cm | *Norms ** |
| $Ca^{2+}$ | 20,92A | 17,74a | 24,09a | 21,12A | 20,64a | 21,59a | 21,65A | 24,46a | 18,74a | *60-70* |
| $Mg^{2+}$ | 9,80A | 10,57a | 9,03b | 11,84A | 12,68a | 10,98b | 10,72A | 12,81a | 8,63a | *10-12* |
| $K^{+}$ | 0,32A | 0,33a | 0,30a | 0,32A | 0,38a | 0,27a | 0,38A | 0,42a | 0,34a | *2,5-3,5* |
| $Na^{+}$ | 0,57A | 0,66a | 0,48a | 0,41A | 0,44a | 0,38a | 0,48A | 0,50a | 0,46a | *< 1* |

The values followed by the same letter are not statistically different at the threshold of α = 0.05 on a line for capital letters between agrosystems and for lower case letters between horizons of an agrosystem respectively

**Ratio between the cations of the soils studied**

Mean values of cation ratios did not show a significant difference between the agrosystems on the one hand, and on the other hand, in the 0-20 cm and 20-40 cm horizons regardless of the agrosystem, except for the ratio Ca2+/Mg2+ which displayed particularly significant mean values, in mixed agrosystems and full sun respectively, in horizons 0-20 cm (1.63) and 20-40 cm (1.76) in mixed agroforestry systems and in horizons 0-20 cm (1.67) and 20-40 cm (2.66) in full sun system (Table 6).

**Table-6: Ratio of $Ca^{2+}$, $Mg^{2+}$ and $K^{+}$ cations of soils**

| | Cation ratio (cmol.kg-1) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Full sun culture system | | | Mixed agroforestry system | | | Complex agroforestry system | | | |
| Nutrients | Global soil | Horizon 0-20 cm | Horizon 20-40 cm | Global soil | Horizon 0-20 cm | Horizon 20-40 cm | Global soil | Horizon 0-20 cm | Horizon 20-40 cm | *Norms ** |
| $Ca^{2+}/Mg^{2+}$ | 2,07A | 1,67b | 2,66a | 1,76A | 1,63b | 1,76a | 1,98A | 1,90a | 2,10a | *2-9* |
| $K^{+}/Mg^{2+}$ | 0,03A | 0,03a | 0,03a | 0,03A | 0,03a | 0,02a | 0,07A | 0,03a | 0,04a | *0,05-0,1* |
| $Ca^{2+}+Mg^{2+}/K^{+}$ | 96,62A | 37,82a | 35,08a | 43,78A | 41,49a | 46,85a | 37,04A | 37,05a | 33,29a | *12-15* |

The values followed by the same letter are not statistically different at the threshold of α = 0.05 on a line for capital letters between agrosystems and for lower case letters between horizons of an agrosystem respectively

## DISCUSSION

**Effect of cocoa-based agroforestry systems on the physical fertility of cocoa soils**

The study showed that the different cocoa-based agrosystems had no significant effect on the physical parameters of the soils. These soils have sometimes presented morphophedological constraints along the landscapes which are summarized in a superficial induration, the abundance of coarse elements with a silty-sandy texture. The predominance of battleship soils in the landscape was also highlighted by [28] in the north of Côte d'Ivoire, an area with very contrasting seasons. The results obtained are also consistent with those of [29] in the South-West, in the regions of Méagui and San-Pédro. The main morphological stress of cocoa-based agroforest soils in the study area was the abundance of coarse elements with a rate that could be estimated at more than 50%. The abundance of these coarse elements (gravel, pebbles, etc.) was associated with the presence of battleship. The work of [30] also revealed that the presence of battleships and coarse elements on some topographical positions of the soils. The silt-sandy texture and hydromorphic properties also characterize these soils. Soil morphological stresses to cacaoculture were demonstrated by [29] in the Central West and South West of Côte d'Ivoire. These morpho-soil constraints have an impact on cacaoculture insofar as the depth of the soil is fundamental to the establishment of this crop. According to the work of [29], a soil depth of less than 100 cm is not conducive to cacaoculture because its durability is not guaranteed because of the development of the pivotal root. Coarse elements have shares similar to those of depth according to [31]. The immediate consequence of the action of induration at less than 100 cm of depth and of the high rate of coarse elements is the water deficit which would cause the mortality of cocoa feet according to the work of [32] made in Togo on indurated soils and high gravillonnaire.

**Effect of cocoa-based agroforestry systems on the chemical fertility of cocoa soils**

The study showed that the soils of the different cocoa-based agrosystems have well satisfactory overall soil fertility values when taking into account the normative values referred by [33-36, 30]. In fact, according to these authors, soils under cocoa trees require chemical properties in terms of actual acidity pHeau (6-7), organic matter content (3.6-6.5 p.c.), carbon content (6.2-11.2 p.c.) and nitrogen content respectively. (0,1-0,15 b.w.), C/N (11-15), assimilable phosphorus (50-100 ppm), potassium (0,15-0,25 cmol.kg-1), calcium (5-8 cmol.kg-1), magnesium (1,5-3 cmol.kg-1), sodium (0,3-0,7 cmol.kg-1), sum of exchangeable bases (7,5-15 cmol.kg-1) and cation exchange capacity from 10 to 20 cmol.kg-1. Similarly, important balances between the different minerals were also respected, including the optimal balances of Ca/Mg (2-9), K/Mg (0.05-0.1) and Ca+Mg/K (12-15). Diagnostic studies of soils under cocoa trees carried out elsewhere in Côte d'Ivoire showing soil fertility in relation to cocoa farming requirements have been proven and corroborate the work of [37]. Correlations between the significantly positive or negative physical, chemical and physical-chemical parameters obtained justify the satisfactory fertility of the soils of cocoa-based agroforests. This good mineral availability of the soils of agroforests to cacaoculture would be related to the presence and density of the associated arboristic species in the plantations of cocoa trees by shading effect, which would avoid possible soil degradation in favour of mineral enrichment. So there is some linkage between the mineral needs of a cocoa tree and how it is set up by agroforestry systems. The influence of the soil's mineral wealth on cocoa production depends on the degree of permanent shade of the agroforest [8, 38].

## CONCLUSION

The study concerning the evaluation of soil characteristics under cocoa-growing agrosystems has shown that agroforests are conservative of a certain level of ecological biodiversity conducive to maintaining good soil fertility. They conserve and maintain the physico-chemical parameters of soils under cocoa trees, especially mixed and complex agroforests. In terms of the fertility of the soils of agroforests, the values of the fertility parameters obtained indicate globally a level of fertility of the soils well satisfactory and this regardless of the agrosystem forest full sun, mixed or complex. Moreover, the mixed cocoa-based agro-forestry system appears to be more interesting in improving the soil structure and enrichment of available mineral elements and could be recommended to cocoa producers in the area of study.

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