Agronomic diagnosis of soil quality in the experimental plot at the Jean Lorougnon Guede University for the implementation of an irrigated agroforestry system

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Abstract— **The aim of the study was to determine the agronomic potential of the soil in the Jean Lorougnon Guédé University (JLoGU) experimental plot for the establishment of a productive and sustainable forest agro-system. The study was carried out in May 2022 during the rainy season on one of the experimental plots at the Jean Lorougnon Guédé University in Daloa. The experiment consisted in first opening soil pits (100 x 80 x 120 cm) on the plot area, after having determined the azimuthal direction, at the preferential positions of the toposequence (Plateau, Versant and bas de versant), then describing them and finally taking soil samples from the horizons (superficial A and underlying B) to determine the physical parameters in the laboratory. The results showed morphopedologically that the soil has a thick superficial A horizon (22 to 32 cm) and a deep underlying B horizon (98 to 88 cm) from plateau to lower slope. An endoplinthic ferralsol (Plateau), a plinthic leptosol (Versant) and a pseudogleyic ferralsol (bas de versant) were respectively determined along the toposequence. Physically, the texture was silty-clayey-sandy, bulk density (1.35-1.50 g/cm3) and useful reserve (>100mm) were satisfactory for good soil water circulation. Chemically, the soil had a slightly acidic pH (pH=6.7), with average organic matter (OM=2.01%) and carbon (C=1.17%) contents. Nitrogen (N=0.09%) and assimilable phosphorus (Pass=5.52ppm) levels were low. However, good mineralization was noted (C/N= 12.30), with exchangeable cations and CEC well supplied. In terms of suitability for cultivation, the plot presented no major constraints on the practice of agriculture or the establishment of an agroforest. In conclusion, the morpho-pedological characteristics and physico-chemical properties of the soil were favourable for sustainable farming of both perennial and annual crops.**

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Index Terms— **Soil, Physical properties, Cultivation aptitude, Jean Lorougnon Guede University (Côte d'Ivoire).**

I. INTRODUCTION

Because of its complexity and multiple functions, soil can be defined in several ways, depending on the field of application. In its traditional sense, soil is the natural medium in which plants attach their roots and draw most of their food for growth and development [1]. Its morphological organization and physical and chemical characteristics ensure the plant's stability and survival by holding it in the soil and supplying it with water and mineral elements. It is therefore a medium of stability and life, rich in physico-chemical properties essential to the plant. In agronomic terms, soil refers to the surface layer of the earth, known as the "topsoil", with an acceptable depth, which farmers work and maintain to grow crops [2]. Farmers often have a general knowledge of the technical itineraries of the plants to be cultivated, but few have any knowledge of the agronomic quality of the soil, in particular its physical and chemical fertility, before planting crops. This has often led to the early decline of long- or short-rooted crops, not only because of the physical constraints of the soil [3], but also because of the soil's availability of plant nutrients [4]. However, good crop growth, development and sustainable production depend on good agronomic diagnosis and good morphopedological and physico-chemical knowledge of the soil [5]. This morphopedological and physico-chemical knowledge of the soil can only be obtained, firstly, by describing the soil profile, secondly, by determining properties in the field, which provide information on the level of physical soil fertility, and thirdly, by laboratory analysis of soil samples, which provide information on the level of chemical soil fertility. Key indicators of physical soil fertility, based on the morphological characteristics of the different horizons, the proportions of solid soil particles (clays, silts and sands), bulk density and useful soil reserve, have been reported in a number of studies, including those by Kouamé and al. [3], Ouattar [6] and Adéchina and al. [7]. Likewise, chemical soil fertility indicators reported by several researchers [8]-[9]-[10]-[11] include soil acidity, major element and trace element content. With a view to sustaining crops, maintaining production and/or optimizing yields while preserving forest cover, several researchers agree on sustainable agricultural practices, in particular, agroforestry, which is defined as a complex agricultural system integrating trees into farms [12]-[13]-[14] so as to sustainably reconcile agricultural production, soil fertility and environmental protection [15]-[16]-[17]. With this in mind, a project to set up an agroforestry system integrating, perennial crops, food crops and forest trees was initiated on one of the experimental plots at Jean Lorougnon Guédé University. But well before implementing this innovative project, an agronomic diagnosis of the soil quality of the plot in question was needed to ensure the sustainability of the planned cropping systems. This is the purpose of the study entitled "Agronomic diagnosis of soil quality in the Jean Lorougnon Guédé University experimental plot for the implementation of an agroforestry system". Its aim is to determine the agronomic potential of the soil quality of the Jean Lorougnon Guédé University experimental plot for the implementation of a productive and sustainable agroforestry system.

II. METHODOLOGY

- **Description of the study area**

The study was carried out in May 2022 during the rainy season on one of the experimental plots at the Jean Lorougnon Guédé University (JLoGU) in Daloa (Fig.1). The town of Daloa is the capital of the Haut-Sassandra administrative region and the rural development hub of west- central Côte d'Ivoire located between 6° and 7° North latitude and 7° and 8° West longitude [18].The climate is transitional humid tropical with bimodal rainfall varying between 1200 and 1600 mm/year [19].The average annual temperature is between 24 and 25°C and the average relative humidity is around 70% [20]. Vegetation cover is highly heterogeneous, varying gradually from semi-deciduous rainforest to pre-forest savannah. The region's soils are based on vast granitic massifs, metamorphic and schistose rocks. They are represented as a Distric plinthic ferralsol complex, which overall present good agricultural suitability for all crop types [21].

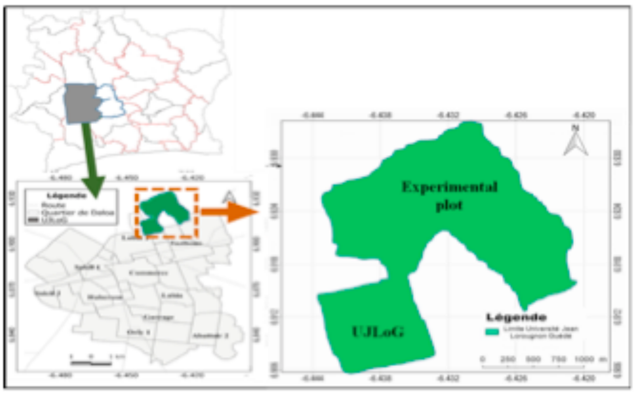

Figure 1: Location of JLoGU's experimental plot

- **Soil survey**

The soil survey was carried out using the toposequence method [22]-[23]. This method involves studying successive soils from the plateau to the lower slopes of a morpho-pedological landscape. The soil survey work on the site began with the determination, using a compass, of an azimuthal, northerly direction along which a layon was opened up.

- **Opening and description of soil pits**

Depending on the toposequence, soil pits measuring 100 x 80 x 120 cm were opened manually in the preferred positions of plateau, slope and lower slope (Fig. 2). These pits were described in accordance with the criteria defined by the CPCS [24] and inspired by the method of Boulet *and al.* [25], the approach of the Office de Recherche Scientifique et Technique d'Outre-Mer [26] associated with the simplified guide for soil description [27]-[28]-[29] and by the soil pit description sheet of the STIPA model [30] adapted to the WRB system [31]. These criteria are based on, among other things, horizon thickness, color, organic matter, moisture, texture, structure, general cohesion, compactness, porosity, density, root size and abundance, coarse element content, hydromorphy, horizon types and soil type. In the field, these main morphological soil characteristics were determined using specific methods summarized in Table 1.

- **Characterization of soil physical properties**

Following the morphological description of the profile, soil samples were taken from the superficial A and underlying B soil horizons and cleared of plant debris and gravel for characterization of the soil's physical properties

Determining soil grain size

Soil particle size defines the proportions of primary solid soil particles. It is determined by measuring the size of solid soil particles that can pass through a sieve with different mesh sizes.

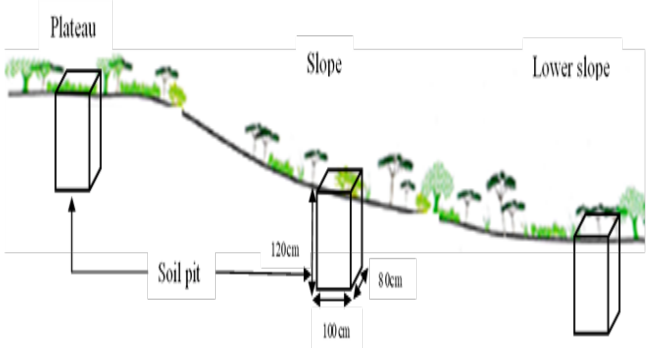

Figure 2: Opening of soil pits along the toposequence

Soil characteristics	Determination methods
Thickness	Measure horizon thickness using a tape measure
Color	Munsell code [32]
Organic matter	Visual assessment of humus content on the face of the soil profile
Hydromorphic stain	Hydromorphic stains visible to the naked eye on the face of the soil profile
Porosity	Assessment of pore abundance by naked eye on the face of the soil profile
Compactness	In situ knife penetration test [27]
Coarse elements	Estimating the proportion of gravel on the face of the soil profile by eye
Roots	Assessment of root abundance, size and orientation by naked eye on the face of the soil profile
Texture	Pudding test [33]
Structure	Observation of the arrangement of soil components

Table 1: Soil characteristics and profile description methods

So, after describing the soil profile, soil samples were taken from both the A and B horizons at each level of the toposequence (Plateau, slope and lower slope) to determine the different proportions of solid particles (clay, silt and sand) in the soil in the laboratory using the sieve method [34]. This method determines soil texture by separating granulometric fractions. The principle of this sieve method consists in separating a portion of dried soil sample by vibration, on a series of superimposed sieves of different porosities (45 µm, 63 µm, 106 µm, 150 µm, 180 µm, 500 µm, 2 mm and 2.36 mm). After mechanical agitation of the sieve, at a maximum speed of 2,000 rpm, for 25 minutes, the granulometric fractions are separated according to size, in particular, clay (< 45 µm), silt (45 to 60 µm), fine sand (106-500 µm) and coarse sand (>2 mm). The contents of each sieve are then weighed, and the sample fraction collected per sieve is related to the total sample quantity (as a percentage) according to the following equation:

$$\text{Particle size fraction (\%)} = \frac{\text{Sieve weight with fraction - Empty sieve weight}}{\text{Weight of total sample used}} \times 100 \quad (1)$$

Determining bulk density

Bulk density is the mass of soil present in a given volume, generally expressed in g/cm3. It reflects the overall compactness of the soil and, indirectly, the total porosity and capacity of water to circulate in the soil. Soil bulk density has been determined using the cylinder method [35]-[36]. The principle consists of mechanically driving a cylinder 5cm in diameter and 10cm long into the soil to a desired depth, and removing the cylinder with the soil it contains. The soil was oven-dried at 105°C for 48 hours, then weighed on a NHB-1500 g electronic precision balance. Apparent density was obtained using the following ratio:

da = Mass of dried soil /Volume of cylinder (g/cm3) (2)

Apparent density was calculated for horizons A and B, considering each level of the toposequence.

Estimating useful reserves

The useful water reserve (UWR) of the soil is the necessary quantity of water that a soil can absorb and return to the plant. It was determined from the equations of Rawls and Brakensiek [37], taking into account the values of field capacity (pF2.5) and soil moisture content at the wilting point (pF4.2). The useful water reserve (UWR) is obtained using the equation :

UWR = (Moisture pF2.5 - Moisture pF4.2) x z (3)

Where: z = horizon thickness in meters

The useful reserve was calculated for horizons A and B, considering each level of the toposequence.

- **Characterization of soil chemical properties**

Three soil samples were augered from the first 20 cm of the toposequence on the plot area, at the preferential positions of plateau, slope and lower slope of the interfluve. Soil samples taken at each level of the toposequence were mixed to obtain a composite sample, which was then air-dried under cover, sieved through a fine sieve and ground. A representative one-kilogram sample of crushed composite soil from each level (plateau, slope and lower slope) of the toposequence was packaged in specially designed black plastic films and sent to the Laboratoire des Végétaux et des Sols at the Institut National Polytechnique Houphouët-Boigny in Yamoussoukro, Côte d'Ivoire for analysis. These analyses concerned :

- pH_{water}: this was determined using the electronic glass pH meter method in a soil/solution ratio of 1/2.5 [38]. The principle consists in immersing the glass electrode of the pH meter in the soil mixture and taking the reading directly on the pH meter dial after stabilization to give the pH value ;
- total carbon content: total carbon content is determined using the Walkley and Black method described by Nelson and Sommers [39]. The principle involves cold oxidation of the total organic carbon present in the soil by a solution of potassium dichromate ($K_2Cr_2O_7$), in the presence of sulfuric acid (H_2SO_4). Excess dichromate is titrated in a strongly acidic environment, using a 0.5N ferrous sulfate solution ($FeSO_4$, $7H_20$). The proportion of total organic carbon was determined after turning the solution brown. The organic matter content was determined by multiplying the soil carbon percentage by a constant conversion factor equal to 1.724 through (%C x 1.724= MO) according to Bemmelen [40];

- total nitrogen content: the modified Kjeldahl method was used [41]. The principle consists in transforming organic nitrogen compounds into ammonium sulfate $SO_4(NH_4)2$ in an acidic environment, in the presence of concentrated sulfuric acid (H_2SO_2), at high temperature, and a mixture of catalysts (K_2SO_4 and $CuSO_4$). The ammonia thus formed is displaced from its combinations by concentrated soda ash (NaOH), distilled by steam distillation, collected in a boric acid solution (H_3BO_3) and assayed by titrated sulfuric acid.

- C/N ratio: calculated using the ratio of total carbon to total kjeldahl nitrogen;

- assimilable phosphorus content: this was determined using the Olsen-Dabin method described by Olsen and Sommers [42]. Assimilable soil phosphorus is extracted with a sodium bicarbonate solution ($NaHCO_3$; 0.5N), pH8.5 on an autoanalyzer, by measuring the intensity of the phosphomolybdic blue complex;

- Cation exchange capacity (CEC) and exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+): these were extracted by rinsing with an ammonium acetate solution ($NH_4C_2H_3O_2$, 1N) at pH_7. The principle of this method is based on the fact that the quantity of ammonium retained by the soil after washing out the excess ammonium acetate is expressed in cation exchange capacity (CEC). The ammonium retained is released by percolation, and determined by autoanalyzer. Exchangeable bases ($Ca^{2+}$and Mg^{2+}) were determined by atomic absorption spectrophotometry, and K^+ by flame photometry, in the percolate.

- **Determining the agronomic potential of the experimental plot's soil**

The agronomic potential of the soil defines a certain number of morphological and physico-chemical parameters that make it possible to cultivate the soil according to the requirements of the intended plant. It has been determined here from the agricultural limitation based on the useful soil depth, pHwater, gravel distribution on the face of the soil profile, soil texture, nutrient content (organic matter-MO, nitrogen-N, assimilable phosphorus-Pass, potassium-K, cation sum-S, saturation volume-V and cation exchange capacity-CEC [43]-[44]-[45] at each level of the toposequence (Table 2).

- **Statistical processing of data**

Data analysis was performed using descriptive statistics and analysis of variance (ANOVA) methods with SAS software version 9.4. Means were separated using the Newman and Keuls test at the 5% probability threshold.

III. RESULTS

- **Morphological characteristics of soil profiles**

The morphologically described open soil profiles along the entire toposequence (plateau, slope and lower slope) are shown in Fig.3. Two main horizons (superficial A horizon and underlying B horizon) of varying thickness were determined at each level of the toposequence. Overall, it can be seen that the dominant characteristics described are identical, with a few differences between horizons and levels of the toposequence. The A horizon is humus-rich, porous and loose, with numerous subhorizontally oriented roots and a lumpy structure, whatever the level of the toposequence. On the other hand, thickness, color, hydromorphy and grit tend to vary with toposequence level. More explicitly, the thickness of the A layer increases with the level of the toposequence. It is respectively 22 cm on the plateau, 25 cm on the slope and 28 cm at the bottom of the slope. Color also varies from dark brown (7.5YR, 3/2) on the plateau to brown (7.5YR, 5/3) on the slope and (7.5YR, 4/2) on the lower slope. No hydromorphic stains were observed on the plateau, slope or lower slope, and the structure is lumpy. The proportion of gravel in the soil decreases with the level of the toposequence. It is 15 to 20% on the plateau and 5 to 10% on the slopes and lower slopes. This is an A11 horizon.

- In terms of the characteristics of the B horizon, a similar description was noted, with similarities and dissimilarities. Layer B is thicker on the plateau (98 cm), on the slope (95 cm) and at the bottom of the slope (82 cm). In addition, the B horizon is not very humus-rich, porous or compact. A few roots can be observed on the plateau and slope, with rare roots at the bottom of the slope. The color is yellowish brown (10YR) at all levels of the toposequence. The structure is subangular polyhedral on the plateau and slope, and massive with polyhedral flow on the lower slope. The proportion of gravel is relatively higher on the plateau than on the lower slopes. Finally, this morpho-pedological description shows a soil more than 100 cm deep at all levels of the toposequence, with an endoplinthic ferralsol on the plateau, a plinthic leptosol on the slope and a pseudogleyic ferralsol at the foot of the slope. This is a B12 horizon. **Soil physical characteristics**

Soil particle size and texture

Table 3 shows the average content of the various solid soil particles (clay, silt and sand) and their texture according to the level of the toposequence, for both the superficial A horizon and the underlying B horizon. Analysis shows that there is a significant difference ($p<0.05$) between the average clay content of soil fractions in both the A horizon ($p=0.042$) and the B horizon ($p=0.059$). The granulometry of the A horizon indicates a low clay content at the bottom of the slope (15.75%), compared with the plateau (25.50%) and the slope (25.67%), which have statistically identical mean contents. On the other hand, silt and sand contents were not statistically different ($p> 0.05$) whatever the level of the toposequence. Silt content was statistically identical on the plateau (20.56%), slope (26.75%) and lower slope (20.53%).

A similar result was noted on the plateau (55.84%), slope (48.75%) and lower slope (65.75%) with sand. For the B horizon, the granulometric fractions are similar to those of the A horizon, with the same order of variation. Clay content was significant ($p< 0.05$), while silt and sand content were statistically identical at all levels of the toposequence. In terms of texture, although there were relative variations between toposequence levels, the overall texture recorded was silty-clay-sandy (SCS) in both the A and B horizons.

Soil bulk density

The average bulk densities calculated at each level of the toposequence in the superficial A and underlying B horizons are recorded in Table 4. It can be seen that there is no significant difference between the mean values of bulk density at any level of the toposequence, with an overall mean of between 1.35 and 1.50 g/cm3. Furthermore, bulk density increases relatively as one moves from the surface layer (A) to the underlying layer (B) within the same level of the toposequence. However, it was noted that the bulk density on the plateau (A horizon = 1.4 g/cm3; B horizon = 1.5 g/cm3) and at the bottom of the slope (A horizon = 1.4 g/cm3; B horizon = 1.5 g/cm3) are identical and the highest compared with that on the slope (A horizon = 1.3 g/cm3; B horizon = 1.4 g/cm3). Furthermore, the soil's bulk density meets the standard considered in tropical soils, which is between 1.30 and 1.70 g/cm3.

Table 2: Assessment criteria for soil agronomic potential

	Fertility level				
	High (no limitation)	Médium (medium limitation)	Low (low limitation)	Low (severe limitation)	Very low (very severe limitation)
Charactéristics	Degree 0	Degree 1	Degree 2	Degree 3	Degree 4
Soil depth (cm)	120-100	100-80	80-50	50-20	< 20
Chippings (% soil volume)	1-10	10-25	25-45	45-75	> 75
Soil texture	Sandy-clay	Clay-sansy	Silty	Sandy	Clay
pHwater	5,5-6,5	5,5-6,0	5,5-5,3	5,3-5,2	< 5,2
MO (%)	>2	2-1,5	1,5-1	1-0,5	< 0,5
N (%)	> 0,08	0,08-0,06	0,06-0,045	0,045-0,03	< 0,03
Pass ($cmol^+/kg$)	> 20	20-15	15-10	10-5	< 5
K^+ ($cmol^+/kg$)	> 0,4	0,4-0,3	0,3-0,2	0,2-0,1	< 0,1
Cations Sum-S ($cmol^+/kg$)	> 10	10-7,5	7,5-5	5-2	< 2
CEC ($cmol^+/kg$)	> 25	25-15	15-10	10-5	< 5
V (%)	> 60	60-50	50-30	30-15	< 15

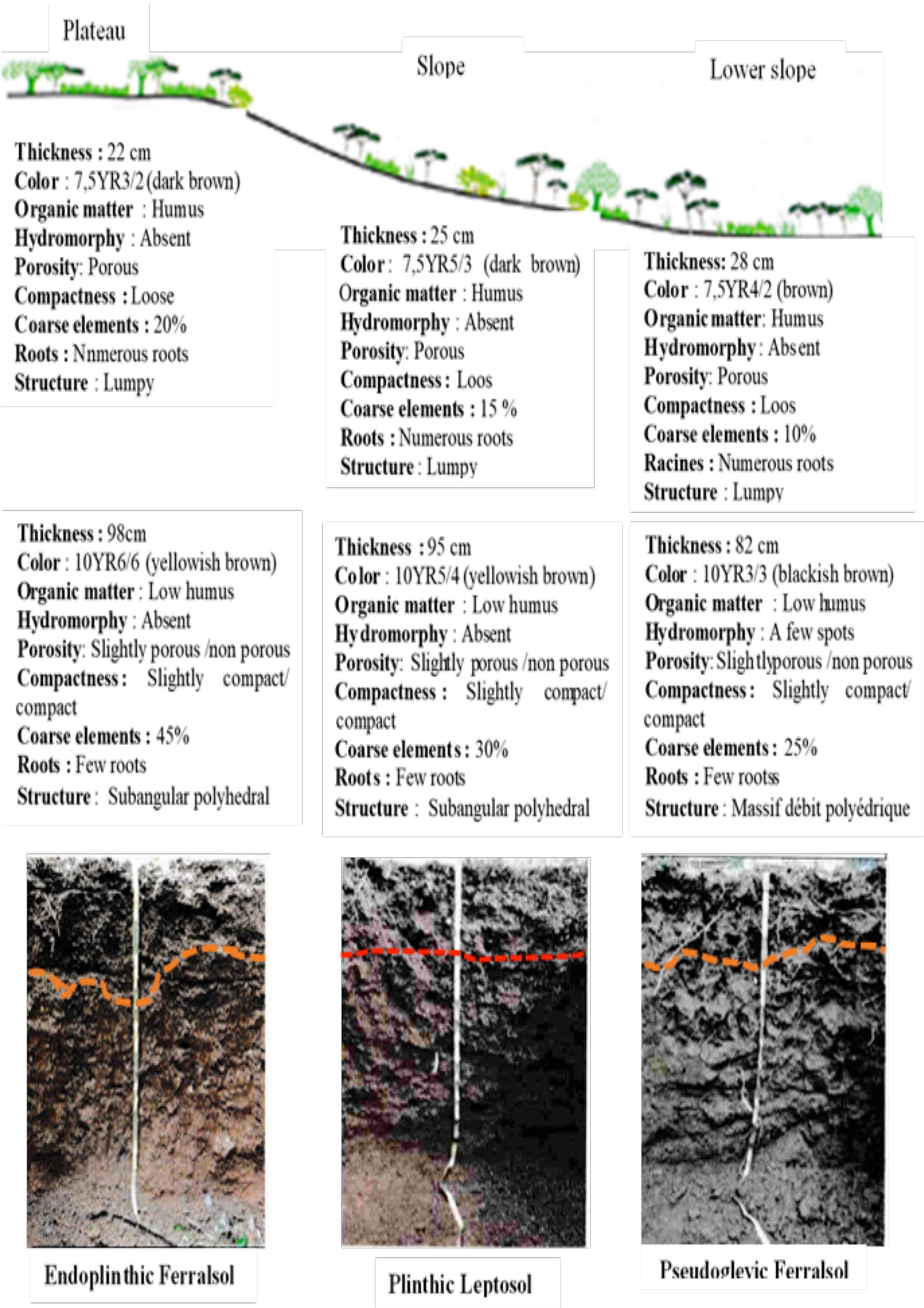

Figure 3: Morphological characteristics of soil profiles at different levels of the toposequence.

Table 3: Granulometric proportion of soil horizons according to toposequence

Topographic level	Granulometry of horizon A (%)				Granulometry of horizon B (%)			
	Clay	**Silt**	**Sand**	**Texture**	**Clay**	**Silt**	**Sand**	**Texture**
Plateau	25,50b	20,56a	55,94a	SCS	21,75b	21,84a	60,41a	SCS
Slope	25,67b	26,75a	48,75a	SCS	28,00a	26,38a	45,82a	SCS
Lower slope	15,75a	20,53a	65,75a	LS	19,94b	25,49a	56,26a	SCS
Mean	22,31	22,61	56,81	SS	23,23	24,57	51,16	SCS
Pr > F	0,042	0,601	0,622	-	0,059	0,646	0,755	-

Values followed by the same letter in the column are not statistically different at the threshold of α = 5%. SCS = silty-clay-sandy ; SS= silty-sandy

Table 4: Apparent density of soil horizons as a function of toposequence

Apparent density (g/cm^3)	Topographics levels			*Norms**
	Plateau	**Slope**	**Lower slope**	
da-Horizon A	1,4a	1,3a	1,4a	-
da-Horizon B	1,5a	1,4a	1,5a	-
Mean	1,45	1,35	1,45	*1,30-1,70*
Pr > F	0,588	0,685	0,156	-

*Values followed by the same letter are not statistically different at the α = 5% threshold; *Normative reference values (Bitom, 1988)*

Useful soil reserves (UWR)

The estimated useful reserves per horizon at each level of the toposequence are recorded in Table 5. There is no significant difference between the mean values of the useful reserves at any level of the toposequence, with an overall mean of over 100 mm. This may reflect the soil's capacity to retain and circulate water.

- **Soil chemical characteristics**

pHwater, organic matter, carbon, nitrogen and available phosphorus

Average values for pHwater, organic matter, carbon, nitrogen, carbon-to-nitrogen ratio and assimilable phosphorus from sample analysis are shown in Table 6. There is significant variability ($p < 0.05$) in the various chemical parameters at different levels of the toposequence. Explicitly, we note that

Useful reserve (mm/cm)	Topographics levels			Norms*
	Plateau	**Slope**	**Lower slope**	
UWR-Horizon A	126a	115a	114a	52,4-60,2
UWR-Horizon B	123a	111a	100a	37,7-73,4
Mean	124,5	113	107	47,7-66,46
Pr > F	0,641	0,512	0,438	-

Table 5: Useful reserve of soil horizons according to toposequence

*Values followed by the same letter are not statistically different at the α = 5% threshold; *Normative reference values (*Ben *et al.*, 2002)

-pH_{water}: comparison of its mean value, indicating the acidity of the toposequence levels, shows that the slope (pH=6.3) and lower slope (pH=6.5) had statistically identical and higher acidity levels than the plateau (pH=5.9). On the other hand, if we refer to the normative value and the general average of the pH-water rate (6.7), the UJLoG soil is not very acidic overall (6.5 < pH=6.7 < 7.5).

-Organic matter and carbon: organic matter and carbon showed significant average levels ($p < 0.05$) in relation to the different levels of the toposequence. Organic matter-MO and carbon-C had respectively higher and satisfied contents at the plateau (MO = 2.29%; C= 1.33%) compared with the slope (MO=1.89%; C=1.10%) and lower slope (MO=1.84%; C=1.07%) levels of the toposequence, which had intermediate, identical and unsatisfied contents compared with standards. However, the overall average of these parameters indicates that organic matter (2 < MO=2.01% < 3) and carbon (1.2 < C=1.17% < 1.7) contents are quite good. The soil is moderately rich in organic matter and carbon.

-Nitrogen: the levels of the toposequence (plateau, slope and lower slope) had no significant impact on nitrogen content ($p > 0.05$), which is low and very unsatisfactory, except for the plateau (N=0.10%), which appears to be within normal limits. This indicates that the soil in the UJLoG experimental plot is generally low in nitrogen (N=0.09% < 0.1).

-C/N ratio: the C/N ratio was not significantly affected by toposequence levels, although on average it indicated good mineralization (11<C/N=12.30<15) whatever the toposequence level.

-Pass: analysis of the table shows that assimilable phosphorus showed significant differences ($P< 0.05$) at toposequence level. A comparison of the averages shows a higher and statistically identical assimilable phosphorus content on the plateau (Pass=6.38 ppm) and slope (Pass=5.71 ppm) than at the bottom of the slope (Pass=4.46 ppm). However, no assimilable phosphorus content is satisfied if normality is taken into account. Overall, the soil is low in phosphorus (Pass=5.52ppm <10).

Exchangeable cation content, sum of exchangeable cations, cation exchange capacity and cation saturation rate.

Table 7 shows the respective contents of exchangeable cations, cation exchange capacity and cation saturation rate resulting from the analysis of the soil samples taken. Analysis of the table shows that exchangeable cations, cation exchange capacity and saturation rate are variably affected by the different levels of the toposequence. Specifically, we noted that potassium-K, sodium-Na and cation exchange capacity-CEC showed no significant values ($p > 0.05$) between the different levels (plateau, slope and lower slope) of the toposequence. However, it should be pointed out that the overall mean contents of potassium-K (K= 1.48 cmol/kg > 0.4), sodiun-Na (Na > 0.30 cmol/kg) and cation exchange capacity-CEC (10 < CEC= 16.83cmol/kg <20) were satisfactory compared with the norm. On the other hand, calcium-Ca, magnesium-Mg, sum of exchangeable cations-S and cation saturation-V were significantly affected by toposequence levels. Specifically, calcium-Ca and sum of exchangeable cations-S contents were statistically identical and highest on the plateau (Ca=6.59 cmol/kg; S=8.75 cmol/kg) and slope (Ca=5.15 cmol/kg; S= 7.34 cmol/kg) compared to the lower slope (Ca=3.17 cmol/kg; S=5.49 cmol/kg). A similar result was obtained with magnesium-Mg and saturation-V, with higher contents on the plateau (Mg=3.17 cmol/kg; V=51.07%), while the slope (Mg=0.43 cmol/kg; V= 42.98%) and lower slope (Mg=0.31 cmol/kg; V=33.93%) showed identical and intermediate contents. A comparison of the overall average levels with the normative levels shows that exchangeable cations, cation exchange capacity and saturation levels were all satisfied.

Table 6: Mean values for soil pH, organic matter, nitrogen and available phosphorus along the toposequence of the UJLoG Daloa experimental plot.

graphics levels	Soil chemical element contents					
	Iwater	IO (%)	C (%)	N(%)	C/N	Pass (ppm)
ıs	*6,5-7, 5*	*2 -3*	*1,2 -1,7*	*0,1-0,15*	*11-15*	*10-15*
Plateau	5,9b	2 ,29a	1,33a	0,10a	12,65a	6,38a
Slope	6,3a	1,89b	1,10b	0,09a	12,58a	5,71a
Lower slope	6,5a	1,84b	1,07b	0,08a	11,64a	4,46b
Mean	6,7	2,01	1,17	0,09	12,30	5,52
CV (%)	4,9	22,43	13,04	16,42	11,05	18,56
Pr > F	0,020	0,033	0,019	0,119	0,370	0,016

*Values followed by the same letter are not statistically different at the α = 5% threshold; *Normative reference values*

[1]	[2] Exchangeable cation content and cation exchange capacity						
3] Topographics levels	[4] K 5] cmol/kg	[6] Ca cmol/kg	[7] Mg cmol/kg	[8] Na cmol/kg	] S cmol/kg	[10] CEC cmol/kg	[11] V 12]%
[13] *Norms	*[14] 0,2-0,4*	*[15] 2,3-3,5*	*[16] 1-1,5*	*[17] 0,3-0,7*	*[18] 5-10*	*[19] 10-20*	*[20] 40-60*
[21] Plateau	[22] 1,55a	[23] 6,59a	[24] 3,17a	[25] 0,33a	[26] 8,75a	[27] 17,13a	[28] 51,07a
[29] Slope	[30] 1,45a	[31] 5,15a	[32] 0,43b	[33] 0,29a	[34] 7,34a	[35] 17,05a	[36] 42,98ab
[37] Lower slope	[38] 1,44a	[39] 3,17b	[40] 0,31b	[41] 0,27a	[42] 5,49b	[43] 16,30a	[44] 33,93b
[45] Mean	[46] 1,48	[47] 4,97	[48] 0,45	[49] 0,30	[50] 7,20	[51] 16,83	[52] 42,66
[53] CV (%)	[54] 11,49	[55] 23,69	[56] 30,49	[57] 21,54	[58] 18,34	[59] 3,01	[60] 18,98
[61] Pr > F	[62] 0,479	[63] 0,0006	[64] 0,0082	[65] 0,344	[66] 0,0024	[67] 0,022	[68] 0,008

Table 7: Exchangeable cation content and cation exchange capacity of the soil along the toposequence of the UJLoG Daloa experimental plot.

*Values followed by the same letter are not statistically different at the α = 5% threshold; *Normative reference values*

- **Agronomic potential of plot soil**

The agronomic potential or cultivation suitability of the soil was highlighted by the degrees of agricultural limitation presented in table 8, according to the topographical levels of the soil. An analysis of the table shows that, in terms of physical properties, no limitations were observed whatever the level of the toposequence, taking into account the depth of the surface layer (22-28cm), pHwater (5.9-6.5) and potassium content (1.44-1.55 cmol/kg). In terms of the distribution of rubble in the soil, the plateau and slope show a medium degree of limitation (10-20%), compared with 10% (no limitation) at the bottom of the slope. The silty-sandy-clay texture is not a limitation on the plateau and slope, whereas on the lower slope there is a medium limitation with the silty-sandy texture. Organic matter (2.29%) and nitrogen (0.10%) levels are not a limitation on the plateau, whereas they are moderately limited on the slope (OM = 1.89%; N = 0.09%) and lower slope (OM = 1.84%; N = 0.08%). Potassium is respectively unrestricted on the plateau (20.39 cmol/kg), moderately restricted (18.45 cmol/kg) on the slope and poorly restricted (14.24 cmol/kg) on the lower slope. The sum of exchangeable cations showed average limitation on the plateau (8.75 cmol/kg) and no limitation on the slope (42.98 cmol/kg) and lower slope (33.93 cmol/kg). Cation exchange capacity was moderately limited throughout the toposequence. Cation saturation volume showed average limitation on the plateau (51.07%) and low limitation on the slope (42.98%) and lower slope (33.93%).

Table 8: Soil suitability for cultivation assessed through the degree of agricultural limitation at the 0-20cm depth according to toposequence

Degree of agricultural limitation according to topographical levels						
Parameters	**Plateau**	**Degree of limitation**	**Slope**	**Degree of limitation**	**Lower slope**	**Degree of limitation**
Soil depth (cm)	**22**	**0**	**25**	**0**	**28**	**0**
Chippings (%)	**20**	**1**	**15**	**1**	**10**	**0**
Soil texture	**SCS**	**0**	**SCS**	**0**	**SS**	**1**
pHwater	**5,9**	**0**	**6,3**	**0**	**6,5**	**0**
MO(%)	**2,29**	**0**	**1,89**	**1**	**1,84**	**1**
N(%)	**0,10**	**0**	**0,09**	**1**	**0,08**	**1**
Pass (cmol/kg)	**20,39**	**0**	**18,45**	**1**	**14,24**	**2**
K (cmol/kg)	**1,55**	**0**	**1,45**	**0**	**1,44**	**0**
S (cmol/kg)	**8,75**	**1**	**42,98**	**0**	**33,93**	**0**
CEC (cmol/kg)	**17,13**	**1**	**17,05**	**1**	**16,30**	**1**
V (%)	**51,07**	**1**	**42,98**	**2**	**33,93**	**2**

Dégree of limitation : 0 = No limitation ; 1= Medium imitation; 2 = Low limitation (Boyer, 1982; Sys., 1978 ; 1993) SCS = silty-clay-sandy; SS= silty-sandy

IV. DISCUSSION

Morphological characteristics were described on the basis of soil profiles taken at different levels of the toposequence (plateau, slope and lower slope). At all levels of the toposequence, these profiles were more than 120 cm deep. This indicates that the soil in the experimental plot is deep. Soil depth is one of the most important morphological characteristics for identifying soil typology. Indeed, according to the work of Boyer [43] and Van Wambeke [46], a soil more than 100 cm deep that encounters no major constraints is classified as a ferralsol [31]. Because of their deep nature, Ferralsols are suitable for both long-rooted perennial crops and short-rooted annual crops [47].In terms of physical properties, the particle size fractions of the superficial A and underlying B horizons of the plot's soil have a relatively well-balanced, mainly silty-sandy-clay texture. In fact, all three grain fractions (clay, silt and sand) are generally well represented at all levels of the toposequence. This gives them good agronomic potential, according to Tossou et al. [48].

The silty-clay-sandy texture is indicative of a balanced texture that is favorable for cultivated plants. This would be an advantage for crop adaptation. This result confirms the work carried out by Buol et al. [49] and Pypers et al. [50], who showed that clay-sand soil texture is excellent and suitable for most crops to achieve good yields. Also, the soil in the experimental plot recorded an average bulk density of between 1.35 and 1.50g/cm3. These values correspond to the standard apparent density of ferrasols, varying between 1.30 and 1.70g/cm3 according to the work of Bitom [51]. This apparent soil density is due to the abundance of fine clay particles that compact and densify the material [52]. Furthermore, apparent density increases as one moves from the more superficial A horizon to the underlying B horizon. This result corroborates the work of Kouadio et al. [53], who claim that bulk density is lower in the upper horizons than in the lower horizons. The low bulk density in the (A) horizon at the surface means that porosity is higher in this horizon than in the deeper horizons [54]. The useful soil reserve recorded was also high (> 100 mm), constituting a good water reserve in the soil for hydromineral nutrition of the plant [55]. This good water retention capacity of the experimental plot's soil is thought to be the result of its granulometric composition and silt-clay-sand texture [56], and its lumpy structure with a sub-angular polyhedral tendency [57].These properties give the soil sufficient porosity to facilitate water circulation in the soil interstices, to store water for the roots [58] and also to absorb it by suction [59]. In short, the soil of the Jean Lorougnon Guédé University plot is morphologically and physically favorable to all types of crop, whether perennial or annual.

Analysis of the soil's chemical parameters revealed that the soil in the Jean Lorougnon Guédé University (JLoGU) experimental plot is low in acidity and moderately rich in nutrients, based on the quantitative nutrient content observed. The average organic matter content is globally satisfactory with reference to normality ($2 \leq$ MO% ≤ 3). This high organic matter content would be due to the fact that the plot has been fallow for over twenty years, and has therefore been able to produce abundant biomass on the soil [60]-[61]. This abundant organic matter is said to provide the soil with the nutrients needed by crops through humification and mineralization processes, thereby improving fertility [62]-[63]-[64]. This quality of organic matter has a positive impact on soil acidity through the low-acid pH-water rate [65]. Indeed, at average pH values ($pH \geq 5$), organic matter tends to develop more negative charges, which could lead to the attachment of exchangeable bases to the soil's absorbent complex [66]-[67], thus reducing the number of adsorbed H+ ions that are sources of soil acidity [68]. In addition, the organic matter rate also influenced the cation exchange capacity-CEC content, which fell within an acceptable range ($10 \leq 16.83$ cmol/kg ≤ 20. These results confirm the work of Alexandre et al. [69]; Koull and Halilat [70], who showed that CEC is intimately linked to the level of organic matter in the soil. Furthermore, it is important to emphasize that the CEC values obtained were average. It would therefore be opportune to develop cultivation techniques likely to maintain or improve the physico-chemical and biological properties of the soil for the burial of cultivated plants [71]. Analytical results also showed that the soil is moderately saturated in exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) with acceptable cation concentrations. This is linked to the quality of the clay-humus complex, which is rich in organic matter and, consequently, humus [72]. The richness of the clay-humus complex may also explain the soil's low acidity. The assimilable phosphorus content of the soil was also very low, especially on the slope and lower slope. This may be linked to the low levels of organic matter observed at these levels of the toposequence. Indeed, numerous authors, including Tumer [73] and Ballot et al. [74] have highlighted the importance of organic matter in the availability of assimilable phosphorus and in the reversible storage of nutrients via mineralization/immobilization by microorganisms [8]-[75]-[76]. Organic matter thus plays a decisive role in improving soil fertility [77].

Soil agronomic potential was observed respectively through profile depth, gravel content, texture, acidity and soil nutrient content. These parameters in no way constituted a major constraint to the establishment of an agroforestry system, given the degrees of agricultural limitation observed (no to low limitation) in Table 8, whatever the toposequence level.

This result can be explained by the accumulation of organic matter on the plateau following the decomposition of plant debris, which was more or less carried down the slope by run-off water. However, it should be pointed out that the agronomic potential of the plot is globally unbounded on the plateau, moderately bounded on the slope and weakly bounded on the lower slope, thus testifying to the degree of degradation of the plot's soil along the toposequence.

V. CONCLUSION

The aim of the study carried out on the experimental plot of the Jean Lorougnon Guédé University in Daloa was to make an agronomic assessment of the soil quality of the UJLoG experimental plot for the establishment of an agroforestry system integrating perennial and annual crops and forest trees. All the morphological characteristics and physical properties of the plot's soil were determined, revealing a ferralsol with no major constraints, a silty-clay-sandy texture, a lumpy structure, a convincing bulk density and a good useful reserve for plants. In addition, chemical analysis of the soil samples taken revealed a soil with low acidity and low to medium nutrient content at all levels of the toposequence. These different morphopedological, physical and chemical characteristics make the soil of the Jean Lourougnon Guédé University experimental plot well suited to the establishment of an agroforestry system integrating all types of crops. However, the soil is not very acidic and of low to medium fertility. In order to develop it as an agroforestry system, it would be advisable to develop cultivation techniques likely to improve soil fertility for the flourishing of cultivated plants.

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