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Morphopedological characteristics and physical potential of Zépréguhé Soils in Daloa Region, Centre West, Côte d'Ivoire

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Abstract

The morphopedological characterization of the soils of Zépréguhé (Centre-West of Côte d'Ivoire) only exists on a small scale, whereas this support is essential for the arboriculture on which the region depends. This study aims to establish the morphopedological and typological characteristics of the soils of the Daloa area and particularly the soils of the locality of Zépréguhé located between longitude 6°22'18'' West, latitude 6°54'09'' North and 250 m above sea level. The soil pits were opened over a toposequence 551 meters long and the profiles were described following the approach of the Office de Recherche Scientifique et Technique d'Outre-Mer (ORSTOM). This study carried out in April 2022 showed that the soil types in the area are rejuvenated reworked ferrallitic soils (Plinthic Lixisols) on the summits, hardened reworked ferralitic soils (Plinthic Lixisols) on the mid-slope, depleted reworked ferrallitic soils (Plinthic Arenosols) on the lower slope and hydromorphic soils depleted of alluvial input (Fluvisols) in the lowland. From the point of view of agricultural suitability, the soils on the summit physically present characteristics favorable as a whole to any kind of cultivation. The mid-slope soils would be favorable for low-rooting speculations, while the soils on the lower slope show potential characteristics favorable to all crops. Lowland soils present constraints related to shallow hydromorphy, dominance of sand and the very thin layer that can be exploited by plant roots.

Keywords: Morphopedological; Plinthic Lixisols; Arenosols; Fluvisols; Toposequence; Côte d'Ivoire

1. Introduction

The degradation of cultivated soils is one of the major constraints limiting agricultural productivity in sub-Saharan Africa [1]. Similarly, the lack of knowledge of the agronomic potential of soils very often limits good reasoning of mineral or organic fertilisation. This state of affairs is at the origin of yields that fall short of expectations. In fact, the soil is not in a stable equilibrium and is constantly subject to variations in condition due to variations in the climate and the atmosphere with which it is in contact through its upper part. Colour, proportions of mineral and organic matter, texture, structure, depth and behaviour after rainfall are characteristics that vary greatly from one soil to another, sometimes within the same plot. This variation positively or negatively impacts the various physico-chemical and

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biological properties of the soil that affect its fertility and producibility [2, 3]. In addition, the overexploitation of cultivable land and inadequate cultivation practices with the abusive use of inappropriate phytosanitary products accentuate the deterioration of soil quality, thus affecting its productivity and yield [4]. The soils of the Daloa region are not immune to this reality. Indeed, formerly known for their great agricultural aptitudes for all types of crops, the soils of the Central-Western region of Côte d'Ivoire are in constant decline in productivity [5] In such a context, it is more than necessary to update knowledge on soil characteristics at the regional scale for better planning of sustainable agriculture. It is with this in mind that this study was conducted. Specifically, it aims to determine the morphopedological and typological characteristics of the Zépréguhé soils of the Centre-West region of Côte d'Ivoire.

2. Material and methods

2.1. Study site

The study site adjoins the village of Zépréguhé in the Daloa region of central western Côte d'Ivoire (figure 1). The village is located at UTM coordinates, 6°22'18" W, 6°54'9" N and 250 m above sea level. The climate of the region is humid tropical characterized by four seasons including two rainy seasons and two dry seasons [6]. The rainy season is divided into a large rainy season (April to June) with frequent rainfall and numerous storms, and a small rainy season from September to October, with some small rainfall. The dry season is subdivided into a large dry period (November to March) marked by the northern trade winds (harmattan) and a small dry period from July to August, when the sky remains overcast. However, this distribution has been greatly disturbed in recent years. There is a single rainy season from April to October, followed by a dry season from November to March. These climatic deviations seriously disrupt the agricultural calendar and disorientate the rural population, with a negative impact on agricultural production, particularly on food crops. The region's rainfall regime is therefore bimodal. Annual rainfall varies between 1,200 and 1,600 mm and temperatures range between 24.65°C and 27.75°C on average. The vegetation consists mainly of forest and wooded savannah: dance forest in the southern and western parts of the territory, and wooded savannah in its northern and eastern parts. The soil is essentially of the reworked ferralitic soil group [7] the geological substratum of the Central West Region is granitic, giving rise to humus-rich soils with a sandy-clay texture. The hydrographic network of the area is dominated by the Sassandra River and its tributaries or confluents. The river called "Lobo", the main tributary of the Sassandra, is the second most important river. Large rivers such as the 'Dê' and the 'Gôre' complete the hydrographic network [8]. The relief is made up of a low-lying peneplain, comprising crystalline domes (300 – 400 m) in the northern part and low plateaus (200 – 3 00 m) in the south. The relief is more marked in the North-East, where a chain of hills unfolds, from Mount Goma to Mount Tangué, whose peaks reach 700 m in altitude. Finally, the region has shallow alluvial valleys with large alluvial lowlands suitable for irrigated crops [9].

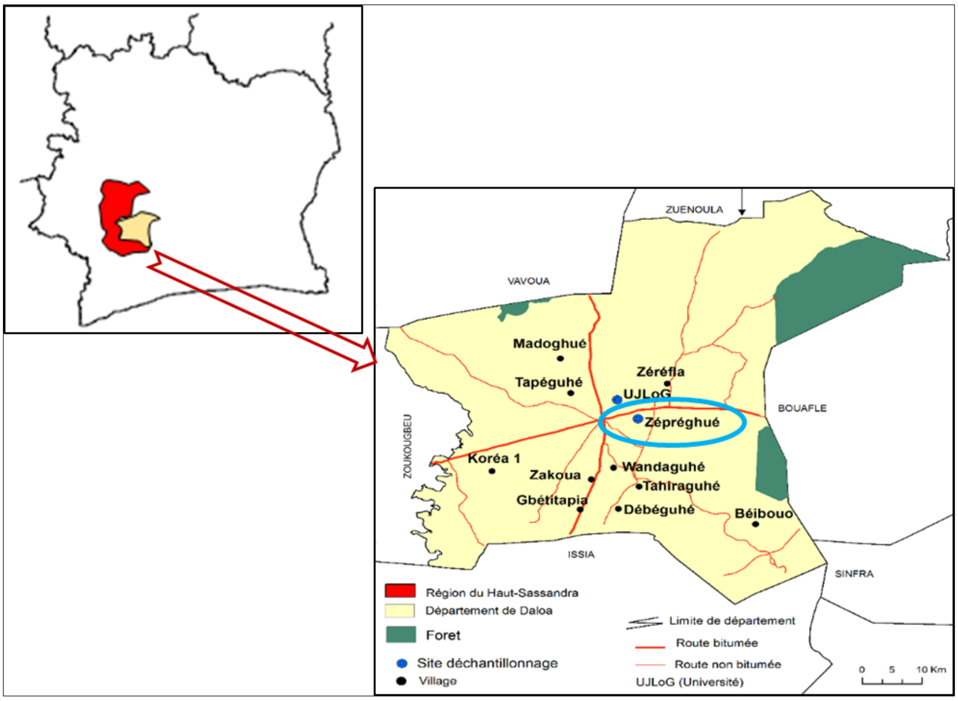

Figure 1 Location of Zépréguhé in the Daloa region

2.2. Soil survey

The soil survey was carried out using the toposequence method [10]. This method consists of studying the soils that follow one another from the top to the bottom of the slope of a morpho-pedological landscape.

2.2.1. Establishment of the toposequence

The longest representative slope in the area was opened up as a layon. The soil survey work on the site began with the determination of an azimuthal direction with the aid of a compass, according to which the layon was opened. The toposequence was oriented along the N. 153° direction and measured 551 metres in length. On this toposequence, soil pits of dimensions 100 × 80 × 120 cm were opened manually according to the preferred positions of top, mid-slope, bottom and bottomland and described hereafter based on criteria as defined by [11] and inspired by the method of [12] , the approach of the Office de Recherche Scientifique et Technique d'Outre-Mer [13] associated with the simplified guide for soil description [14, 15, 16] and the soil pit description sheet of the STIPA model [17] that we adapted to the WRB system [18]. Sampling was done horizon by horizon starting from the deep horizons to the surface horizons using a knife. This description of the soil profile, in accordance with these authors, takes into account the main characteristic elements of the soil, such as the thickness of the horizons, colour, organic matter, moisture, texture, structure, general cohesion, compactness, porosity, drainage, density and size and abundance of roots, the rate of coarse elements, hydromorphy, soil fauna, types of horizons and soil type.

2.2.2. Floristic description of the topographic segments of the toposequence

The vegetation surrounding each topographic segment of the toposequence was described by floristic identification according to the weed identification guide by [19] and [20] the cropping history was determined by observing the vegetation in place in order to characterise the arterial erosion, ploughing, depth of ploughing and anthropogenic colluvium and the previous crop.

2.2.3. Morphopedological characteristics observed

Macromorphological features were observed in the field and included colour, structure, texture, cohesion, porosity, layer boundaries and internal drainage. These elements were used to delineate the horizons or layers. Colour, determined using the Munsell code, provided information on the presence or absence of organic matter in the horizons. The structure was assessed according to the presence or absence of aggregates and was used to give indications on the architecture of the soil and therefore on the mode of arrangement of its components. The characterisation of the size of the mineral particles, or texture, was done in a tactile way. Thus, when the touch of the moistened sample is rough, it is in the category of sand. If the touch is soft, silky, it is called silt (diameter between 2 and 50 µm) and, when the touch is sticky, it is called clay (diameter < 2 µm). The void volume of soils or porosity, corresponding to the relative volume of the voids present, has been determined when a fine quantity of water poured onto a lump of earth can or cannot penetrate. Soils are said to be porous when water penetrates and non-porous when it does not penetrate the soil sample. The boundary between the layers was assessed according to whether it was clear, regular or diffuse. As for the internal drainage, it was determined according to the spots of hydromorphy or oxidation of rust discolouration or redox colouring of greenish-grey present on the horizons. These stains, being the mark of signs of excess water (hydromorphy) or not. Finally, the coarse element content was determined with the guide of the coarse element percentage estimation chart contained in the Munsell code. The biological activity in the horizons was determined by observation by separating the layers with differences (quantification of soil fauna or galleries of the same fauna). The presence or absence of roots and their orientation and size was observed and estimated. Compactness was tested by the resistance of the horizons to the penetration of the soil knife. Moisture was assessed by the dry or fresh state of the samples taken for this purpose.

2.2.4. Coding of the morpho-pedological characteristics of the soils described

Different codifications of the morphopedological characteristics were used for insertion in the tables of the results obtained. Thus, for:

- Colour: Br= Brown; Dbr= Dark brown; R= Reddish; Yr = Yellowish red; Dbl= Dark black; Bl = Black; Gr = Greenish; Ggr = Greenish grey with rusty spots; Gg = Greenish grey,
- organic matter: H = humus-bearing; PH = not very humus-bearing; NH = not humus-bearing,
- Texture: C = clayey; SC = sandy-clay; CSi = clayey-silt; CS = clay silty; SL = sandy loam; S = sandy; SC = sandy-clay,
- The structure: L = lumpy; Sp = subangular polyhedral; Fm = fissured mass; Pfm = polyhedral flow mass; P = particle,
- The transition between horizons: Pr = progressive, D = diffuse

- The hydromorphy: Hys = hydromorphy spots; AHys = absence of hydromorphy spots,
- The presence of roots and their orientation: NR = numerous millimetre roots with subhorizontal orientation; SR = some millimetre roots with subhorizontal orientation; AR = absence of roots;
- The porosity of the horizons: VP = very porous; P = porous; NVP = not very porous; NP = not porous,
- The compactness of the horizons: L = loose; NVC = not very compact; C = compact,
- The boundary between the horizons: R = regular; IR = irregular,
- The presence of biological activity in the horizons: Pr = present; Abs = no biological activity,
- The content of coarse elements: CE (%)
- Top. seg: topographic segments;Horiz :horizon, Trans :transition; Hydro: hydromorphy; Comp: compactness; BA: biological activity; OM : organic matter

3. Results

3.1. Floristics of the profile environment

The immediate environment of the profile (figure.2) is dominated at the top by a rubber tree field (*Hevea basiliens (Euphorbiaceae)*) whose undergrowth is mainly made up of *Panicum maximum (Poaceae)* at the mid-slope, the vegetation is made up of a fallow sorghum field (*Sorghum bicolor (Poaceae)*). A field of cassava (*Manihot esculenta (Euphorbiaceae)*) and sweet potato (*Lipomea batatas (Convolvulaceae)*) dominates the lower slope while the lowland is occupied by market gardening based on (*Solanum lycopersicum (Solanaceae)*), pawpaw (*Carica papaya (Caricaceae)*) and herbaceous plants consisting mainly of *Panicum maximum (Poaceae).*

3.2. Sequence of open profiles

Figure 2 shows the sequence of open profiles on the summit, mid-slope, lower slope and in the lowland respectively. The letters A and B followed by numbers represent the coding of the horizons. The surface and humus horizons are labelled A and the clay and accumulation horizons are labelled B.

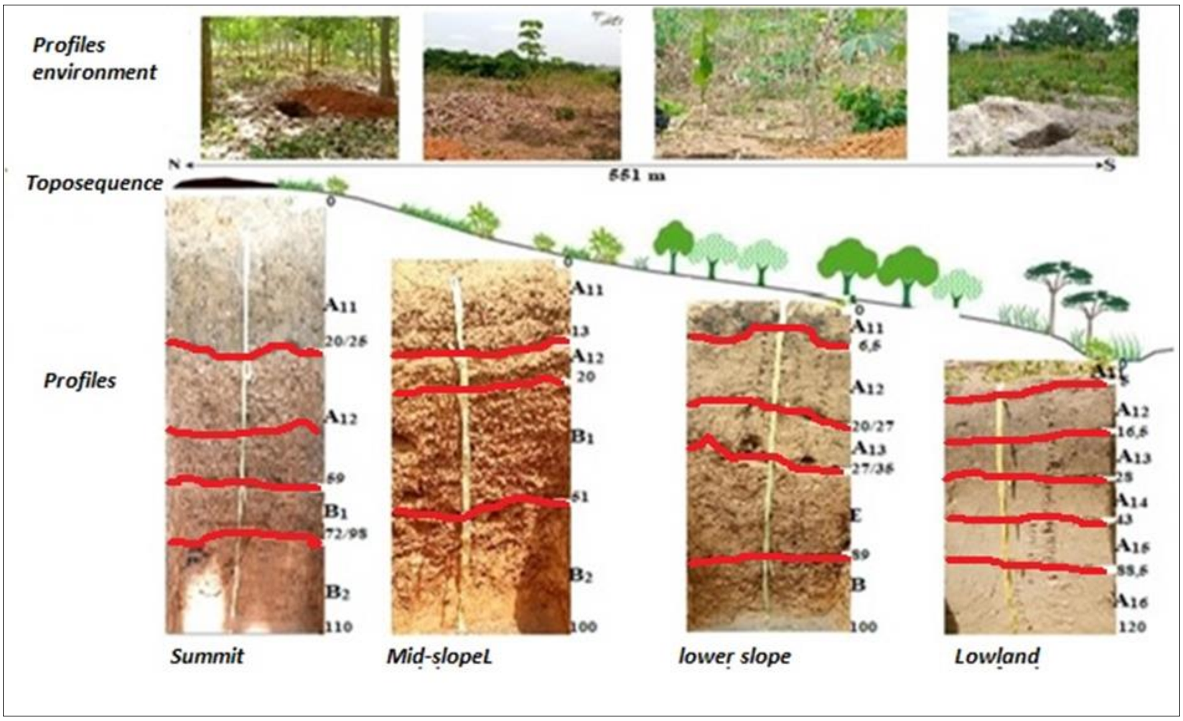

Figure 2 Diagram of the toposequence of the study area

3.3. Morphopedological characteristics of Zépréguhé soils

The results of the morphopedological characteristics of the Zépréguhé soils are recorded in table I. It describes the main visible characteristics of the different horizons from the most superficial horizons to the deeper underlying horizons by level (summit, mid-slope, lower slope and lowland) of the toposequence. Overall, it can be seen that certain characteristics are dominant and identical, with a few differences depending on the horizons and levels of the toposequence. The surface horizons are generally thicker, brown in colour, humus-bearing, porous, with a sandy-clay texture and gravelly structures, containing a sufficient number of millimetre to decimetre roots with a subhorizontal orientation. These characteristics decrease or diminish in intensity as we go deeper into the soil.

Table 1 Morphopedological characteristics of the profiles described

Seg.top	**Horiz**	***depth* (cm)**	**Color**	**OM**	**Texture**	**Structure**	**Trans**	**Hydro**	**Roots**	**Porosity**	**Comp**	**Limit**	**BA**	**CE (%)**	***Moist-ure***
summit	A_{11}	0 – 20 /25	Br (7,5YR5/2)	H	SC	L	Pr	AHys	NR	VP	NVC	IR	Pr	≤ 2	Fresh
	A_{12}	25 – 59	Br (7,5YR4/3)	PH	SC	L	Pr	AHys	SR	P	NVC	IR	Pr	40 – 50	Fresh
	B_1	59 – 72 /98	Yr (5YR4/6)	PH	SC	Fm	D	AHys	AR	NVP	C	IR	Abs	25 – 30	Fresh
	B_2	98 – 110	J (2,5YR4/6)	NH	SC	Fm	D	AHys	AR	NP	C	IR	Abs	10 – 15	Fresh
mid-slope,	A_{11}	0 – 13	Dbr (7,5YR2 3/3)	H	SL	L	D	AHys	NR	VP	NVC	IR	Pr	15 – 20	dry
	A_{12}	13 – 20	Dbr (7,5YR 4/6)	PH	SC	L	D	AHys	NR	P	NVC	IR	Pr	20	dry
	B_1	20 – 51	Yr (5YR 5/6)	NH	SC	Pfm	D	AHys	SR	NP	C	R	Abs	25 – 30	dry
	B_2	51 – 100	Yr (5YR 5/8)	NH	SC	Pfm	D	AHys	AR	NP	C	R	Abs	30	dry
lower slope	A_{11}	0 – 6 ,5	Br (7,5YR3/2)	H	SL	L	D	AHys	NR	P	L	IR	Pr	≤ 2	dry
	A_{12}	6 – 20/27	Br (7,5YR3/2)	H	SL	Sp	D	AHys	AR	P	C	IR	Pr	≤ 2	dry
	A_{13}	27 – 35	Dbr (7,5YR3/3)	H	SL	Sp	D	AHys	AR	P	C	IR	Pr	≤ 2	dry
	E	35 – 89	Br (7,5YR4/3)	PH	SC	Sp	D	AHys	AR	P	C	IR	Pr	≤ 2	dry
	B	89 – 100	Br (7,5YR4/4)	NH	CSi	Sp	D	AHys	AR	NP	C	IR	Abs	10 – 15	dry
lowland	A_{11}	0 – 5	Dbl (Gley1 3/N)	H	S	L	D	AHys	SR	VP	L	R	Pr	≤ 2	dry
	A_{12}	5 – 16 ,5	Bl (Gley1 4/N)	H	S	L	D	AHys	SR	P	L	R	Pr	≤ 2	Fresh
	A_{13}	16,5 – 28	Gr (Gley1 5/10Y)	PH	S	Sp	D	Hys	AR	NVP	NVC	R	Abs	≤ 2	Fresh
	A_{14}	28 – 43	Ggr (Gley1 6/10Y)	NH	S	P	D	Hys	AR	NVP	L	R	Abs	≤ 2	Fresh
	A_{15}	43 – 88	Gg (Gley1 6/10Y)	NH	S	P	D	AHys	AR	NVP	NVC	R	Abs	≤ 2	Fresh
	A_{16}	88,5 – 120	Gg (Gley1 6/10Y)	NH	S	P	D	AHys	AR	NVP	NVC	R	Abs	≤ 2	Fresh

3.4. Classification of Zépréguhé soils

Table 2 Soil classification of Zépréguhé

Profiles	**classifications**	
	CPCS [10]	**WRB [29]**
Summit	Reworked ferrallitic soil rejuvenated	Plinthic Lixisols
Mid-slope	Ferrallitic reworked indurated soil	Plinthic Lixisols
Lower slope	Depleted reworked ferrallitic soil	Plinthic Arenosols
Lowland	Depleted hydromorphic soil with alluvial input	Fluvisols

Table 2 shows the typology of soils along the toposequence. The name of the soil at each level of the toposequence reflects the processes or activities that take place in the different horizons. Thus, soils at the top of the toposequence are Plinthic Lixisols at the top and mid-slope respectively, while Plinthic Arenosols are observed at the bottom of the slope and Fluvisols in the lowland.

4. Discussion

The soils in the study area are generally derived from the weathering of migmatitic and granito- migmatitic rocks [21]. The profile observed in the upper slope soils is characterised by a high organic matter content in the first 20 cm of the soil and this organic matter progressively decreases until it disappears from 98 cm in depth. This high organic matter content in the first 20 cm can be explained by the occupation of this land by a rubber plantation that produces an abundant biomass on these soils. This abundant organic matter would give these soils good fertility for crop production as the mineralisation of the organic matter will provide the nutrients needed by the crops [22]. In addition, the soils in this topographic segment (upper slope) have a lumpy structure at depths of more than 50 cm and a sandy-clay texture along the profile (more than 100 cm deep). These characteristics show that these soils have a very good potential for crop development. Indeed, a lumpy structure and a sandy-clay texture have been shown to be the best structures and textures that offer favourable properties for plant development [23]. This is also explained by the abundance of centimetric roots in the first 20 cm.The soils on the upper slopes are also porous up to 98 cm and not very compact as a whole. This porosity gives these soils good aeration, which means good respiration for the microfauna and above all good water circulation. This attests to the absence of hydromorphic spots along the profile. In addition, this porosity will stimulate the biological activity of the soil (micro-organisms present), improve the water retention capacity and fertilising elements of the soil and act directly on plant growth [24]. The absence of coarse elements in the 0 - 20 cm depth of the soil and the moisture found throughout the profile is a considerable asset for the upper slope soils studied. Indeed, the absence of coarse elements will facilitate the root penetration of the plants. This would explain the abundance of roots in this horizon. The soils are dominated by brown (7.5YR 5/2), reddish (2.5YR 4/6) to yellowish red (5YR 4/6) colours. These colours suggest soils rich in magnesium and potassium [25] finally, the upper slope soils studied are physically favourable for all types of crops. The 0-20 cm horizon is the most favourable zone for crop development. The soils observed on the mid-slope in the locality of Zépréguhé are mostly reworked soils. Indeed, these soils are characterised by a high rate of gravelling (20-30%) and are dry all along the profile. This is a constraint to plant root penetration. This is explained by the subhorizontal orientation of the roots in the 0 - 20 cm depth of the soil and their rarefaction beyond 20 cm. Their clayey depth horizons are sometimes compacted. This could negatively impact soil aeration, root system development and biological activity [26]. This while mid-slope soils are generally not very compact and have a porosity ranging from very porous to porous in the 0 - 20 cm depth. This implies a rapid infiltration of water. This could also be explained by the absence of hydromorphic patches along the profile. The organic matter of these mid-slope soils ranges from moderately abundant to scarce in the 0 - 20 cm soil depth and absent beyond that. This could be explained by the vegetation cover which provides little biomass to the soil. Indeed, this area (mid-slope) is occupied by a poorly developed sorghum field. Indeed, the quantity of organic matter depends on the vegetation in place [27]. However, these soils have a good structure and texture that is favourable to crop development. The texture is silty-sandy at a depth of 0 - 13 cm and sandy-clay beyond 13 cm. The structure is lumpy in the 0 - 20 cm depth. As with the upper slopes, the colouration of the mid-slope soils makes them rich in magnesium and potassium [25]. Given these characteristics, these soils would be suitable for low-rooting crops. If permanent agriculture is to be established, it is essential to restore as much organic matter as possible, to provide the main nutrients in fractionated form and to provide small-scale water and fine soil conservation measures. Indeed, the surface horizons of these gravelly soils tend to be depleted of fine particles and to become skeletal under cultivation, following the leaching of colloids and especially selective erosion combined with the action of various homogenising agents (mesofauna and cultivation techniques) [28]. Observation of the profile of the lowland soils of the Zépréguhé locality shows a soil that contains almost no coarse elements and is dry throughout its depth. This dryness could be explained by the absence of rain during the study period. Indeed, the moisture content of a soil depends on the period of description and the topographic position of the profile. A lowland soil would be wetter in the dry season than a hilltop soil [29]. These soils are porous and humus-bearing along the profile. There is therefore good water circulation, hence the absence of hydromorphic stains throughout the profile. This soil offers good aeration for the respiration of micro-organisms to accelerate their biological activity in the mineralisation of organic matter. The presence of humus throughout the profile gives these soils a good nutrient content for crops [4]. These lowland soils are 80 cm deep and suitable for deep-rooted perennial crops. The intermediate sandy-silty to sandy-clay texture and the lumpy surface structure (0 - 6.5 cm) is an asset for minor crops. The study of the soils of the lower slopes shows that they are suitable for all crops. In the lowland soils of the study area, organic matter is abundant in the surface layer (0 - 5 cm) and gradually decreases and disappears from 43 cm depth. The presence of humus in these soils suggests a high fertility [30] these soils are also porous in the surface horizons (0 - 16 cm) and not very porous beyond. There is therefore good infiltration of water at the surface and stagnation at depth in these soils. This would explain the presence of the hydromorphic stains observed from 16 cm depth. The dominant Gley colour throughout the profile can be explained by prolonged waterlogging by the groundwater table, deprived of oxygen, which causes anaerobiosis and iron reduction. This anaerobiosis is very unfavourable to plants because it leads to plant asphyxia [31]. The structure and texture are respectively lumpy and sandy-silty on the surface. The structure of these soils is an asset for crops. However, this advantage would be limited by the dominant sandy texture which is filtering. The abundance of roots in the 0-5 cm surface horizon shows that the exploitable zone for plants is the surface horizon. However, this exploitable horizon is more prone to degradation as it is a very thin layer. The lowland soils of Zépréguhé present, in view of their general characteristics, constraints linked to hydromorphy at shallow depths, the dominance of sand and the very thin layer that can be exploited by plant roots.

5. Conclusion

The study of the morphopedological characteristics and physical potential of the soils of Zépréguhé in the Centre-West region of Côte d'Ivoire has contributed to a better knowledge and understanding of the phenomena that take place in the soils of the locality. It has highlighted the existence of close links between soil structure and plant cover, as well as the organic matter content and mineral richness of soils. The study showed that the soil types in the area are reworked ferralitic soils on the upper slopes to the lower slopes, while the lowland soils are impoverished ferralitic soils. These soils offer different agricultural potential depending on the topographic segment. The upper slope soils studied are physically favourable for all types of crops. The mid-slope soils are very gravelly and require a high level of organic matter restitution. The lowland soils showed favourable potential for all crops. As for the lowland soils, shallow hydromorphy, the dominance of sand and the very low thickness of the humus layer constitute the major agricultural constraints.

Compliance with ethical standards

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Disclosure of conflict of interest

This work has no conflict of interest whatsoever.

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