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Research article

Morphopedological features of soil landscape in *Cola attiensis* Aubrév & Pellegr. (Sterculiaceae) in Affery and Akoupé (Côte d'Ivoire)

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Abstract

Cola attiensis Aubrév. & Pellegr. is an endangered, relict plant. In Côte d'Ivoire, its presence is rare. That is why, its morphopedological features are not very well-known. While we were carrying out a soil survey in the department of Akoupé (Côte d'Ivoire). The pedon have different colour matrix ranges from reddish (5YR, 2.5YR and 10R) to yellowish shades (7.5YR and 10YR). The texture generally ranges between sandy clay at the surface of the soil to sandy clay loam at the sub-surface. Structures are lumpy soil in humus horizons. In contrast, in the intermediate and deep horizons, the structure is sub-angular blocky. The percentage of coarse particle observed in soil landscape in *C. attiensis* should not exceed 60 percent of the total soil volume. The thin surface horizons and, secondarily, the quality of drainage proved to be constraints to the development of these soils.

Keywords : Morphopedological features, Soil landscape in *Cola attiensis*, toposequence, Afféry -Akoupé, Côte d'Ivoire

Introduction

In sub-Saharan Africa, and particularly in Côte d'Ivoire, shoot *Cola attiensis* Aubrév. & Pellegr. (Sterculiaceae), a plant with a variety of uses in pharmacopoeia [1-2]. Listed on the Red List of the International Union for Conservation of Nature (IUCN) as being "endangered" under the reference A1c, B1 +2 c [3], the plant tends to be scarce in its natural settlement in Côte d'Ivoire, so, is it seemed appropriate to consider protection. Appropriate and proper use of an area of land depends upon the characteristic of such a land. There is therefore need to characterize soils in a manner that will ease communication and transfer of knowledge about such soils to farmers and other stakeholders. It is in this context these investigations were conducted in two areas of the forest region of Mé (Akoupé and Afféry), in the department of Akoupé (south-eastern Côte d'Ivoire). The objective of the study is therefore to describe the morphopedological soil properties of a toposequence (at Afféry) and one soil pit in the classified forest of Besso (at Akoupé), specifically parts of the forest department subjected to a very low human actions influence. It a first step towards domestication of this species solution

Materials and Methods

The study area

The study was conducted at Akoupé and Afféry in the department of Akoupé (approximately 06°23'N and 03°54'W), south-eastern Côte d'Ivoire. The climate of the area is characterized by bimodal rainfall régime [4-5], with precipitation average oscillates between 1350 and 1400 mm per annum, high temperature and relative humidity [6]. The vegetation of the area is tropical rain forest consisting mainly of trees, shrubs and grasses. The forest is now heavily influenced by human presence [7]. The land use is dominated by perennial crops: coffee, cocoa, oil palm, rubber, associated or not with food [7]. Soils of this region are characterized as moderately or strongly kind desaturated, containing mainly biotite, granodiorite and/or hornblende [5]. Soil samples, collected from two zones of the department, were characterized as landscape in *Cola attiensis* on account of the species [8] . Soils were classified following the World reference base for soil resources into Cambisol and Gleysol [9].

Field study

The toposequence studied in Kouaossoua 2 (6 ° 13 'N and 3 ° 58' W), in south-eastern Affery was sampled according to the method of [10]. This first site is 442 m long with elevation ranging from 102 to 164 m above mean sea level in Table 1 and. The second study site was a soil pit located in the classified forest of Besso (06 ° 22' N and 3 ° 42 W), in North- eastern Akoupé. Ultimately, eight (8) soil pits (100 cm x 80cm x 120 cm) were described. The soil pits described was oriented so that the side to watch continues to benefit at the time of observation, a maximum light [11]. The toposequence was delineated into seven (7) topographie units (crest, upper slope, middle slope, 1/3 lower slope, lower slope, valley bottom and shallows). The profile pits were sited at the crest (P5) upper slope (K2), middle slope (P4) lower slope (P3), valley bottom (P2), and Shallows (P1 and P0) positions. The soil pit was sited at the upper slope (BO) positions (Figure 2). Soil samples were collected from identifiable horizons of the profile pit in each of the topographie units. Each of the profile pits position was georeferenced with a Global Positioning System (GPS); the GPS also gave the altitude of each point and the distance from one another (Figure 1). The genetic horizons were identified on the basis of observed differences in some morphological characteristics of the soils which included colour, texture, structure, depth of horizons, inclusions etc. [12]. Soil colours were described using Munsell Soil Colour Charts [13]. Soil samples were collected from each genetic horizon into labelled polythene bags and taken to the laboratory for analysis. Rate appreciation of coarse particles was made according [14] Yao. Their weight rate was evaluated at three levels: less than 20% 20-50% and above 50% [15]. The profile pits were dug and characterized following the guidelines outlined in the Faculty of Earth Sciences and Mineral Resources (STRM), Houphouet Boigny, Cocody University (2012-2013)

Results and discussion

Colour

The location of each of the pedon is given in Table l. The results of some morphological properties of the soils of the two sites are shown in Table 2. The soils are formed on biotite, granodiorite and/or hornblende and have relatively high percentage of coarse material. The soils on mid to upper landscape positions (toposequence) are Plenthic Cambisols and those in lower positions are Gleyic Gleysol [9]. A representative area, near Akoupé (classified forest of Besso), was chosen and every horizon from one Cambisol, high in the local landscape, was sampled and described. The horizons sequences were A, B (Figure 2). For the toposequence studied in Kouaossoua 2 (Figure 3), the various pedon have different colour matrix ranges from reddish (2.5YR; 5YR and 10R) to yellowish shades (10YR and 7.5 YR) down the profile. The surface colour of Pedon P5 (crest) was weak red (10R4/2 and 10R5/2) over dark reddish brown (2,5YR3/4) to various shades of brown colouration. The horizons sequences were A, B.

Table 1: Location data of the pedons taken with a GPS

Pedon	Elévation (m)	Coordinates
P5	164	391858 688381
K2	157	391785 688324
P4	139	391725 688321
P3	132	391664 688258
P2	110	391522 688191
P1	104	391449 688194
P0	102	391419 688187

Fig.1: The Global Positioning System (GPS) used in the study

Also, the surface colour of soils from pedon K2 was weak red (10R4/2 and 10R4/3) over various shades of dark yellowish brown and graded to yellowish brown (10YR5/6) subsoil. The yellowish brown colour in their subsoil may be attributed to residual accumulation of goethite which imparted yellowish colouration [16]. Another important morphological feature common to both sites was the plinthite horizons starting from the depth of 10 cm to 90 cm in upstream and 50 cm in downstream. The plinthite must have developed as a result of migration of sesquioxides and clay into the horizons sequences were generally B. However, the cementation was greater at subsoil horizons which probably contributed to the deterioration of the structure of the subsoil which changed from moderate angular blocky to massive structure in both pedons. Probably the Plinthic horizons came into contact with the air as a result of the gradual erosion of old flooring surfaces. These were hardened irreversibly. These cures that cover the concretions were themselves eroded. There is then a gradual outcrop, where the elevated position of the concretions and nodules in relief [17]. Wealth coarse elements and the presence of induration in places, allow to say, as pointed [11-14], the units of soil landscape in *Cola attiensis* are reworked and rejuvenated.

Abundance of coarse particles

The table 2 showed that the high rate of coarse particles can be an obstacle. *C. Attiensis*. Indeed, the percentage of gravel observed profiles from habitat of *C. attiensis* should not exceed 40 or 60 percent of the total soil volume, between 10 and 90 cm deep. Furthermore, the presence of gravel within 25 cm deep can be undesirable. This morphological constraint to the development of soil *C. attiensis* along landscapes in the study area is similar to that described by [18] for *Theobroma cacao* in south -west of Côte d''Ivoire. The absence of *C. attiensis* in the bottom of the slope and in the shallows was due to drainage flow. [19] reported that topography influences in the distribution of soils. The Pedon P4 (Lower 1/3 from slope) and P3 (middle slope) have colour matrix ranging from dark reddish brown (2.5YR 2.5/4 to 3/4). In pedons P2, P1 and P0 over various shades of dark gray and graded to pinkish gray (7.5 YR 4/1) to greenish black (10Y2,5/1) subsoil, The increasing yellowing of the colour of the soil from the crest to the shallows of landscapes was reported by [20] on Ferralsols in Côte d'Ivoire and that can be explained by the dynamics of water [21-22]. The drainage condition and physiographic position may have major influence on the soil colour [23].

The upland Soil Samples are composed of a wide variety of red, brown, and yellow, as well as nodular gravels and cemented soils. Also, soil Samples are either hard or capable of hardening on exposure to wetting and drying. This further was reported by [24] and [25] that observed lateritic soils. This study showed that the sampled soils are lateritic soils. Lateritic soils are described as product of highly weathered material, under tropical and subtropical condition, rich in secondary oxides of iron, aluminium or both. They are nearly void of bases and primary silicates, but may contain amounts of quartz or kaolinite.

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Table 2: Morphological properties

Pedon	Horizons	Soil Depth (cm)	Colour (moist)* Matrix	Structure**	Texture**	Clay (p.c.)	consistency**	porosity**	Transition **	Limit **	drainage class	Coarse particles (%.)	Silt/clay ratio	Additional Comments
P5 Plenthic Cambisol	A0	0-2	(10R4/2) weak red	F±G	AS±SM	50-65	PC	PP	Pr	R	1,8	45	0,83	Small thickness of the upper soil 0-2 cm Heavy Duty coarse particles from 2 -12cm
	A3	2-12	(10R5/2) weak red	P±A	AS±SFM	65-70	C	P	Pr	IR	1,6	81	0,80	
	B1	12-31	(2,5YR3/4) dark reddish brown	P±A	AS±SM	70-75	C	P	Pr	± R	1,5	84,58	0,66	
	B22	31-66	(2,5YR3/6) dark red	p	AS±SMG	75-80	C	p	Pr	Ond	1,4	87,49	0,39	
	B23	66-84	(10R3/4) dusky red	p	AS±SM	80-85	C	p	Pr	Ond	1,3	88,89	0,34	
	B24	84-98	(10R3/6) dark red	P	AS±SMG	85-90	C	P			1,2	78,57	0,28	
BO Plenthic Cambisol	A0	0-3	(5YR3/2) dark reddish brown	P± G	ALS±SF	45-50	PC±M	PP	Pr	R	1,7	27	0,93	Small thickness of the upper soil 0-3 cm Heavy Duty coarse particles from 3-11cm
	A3	3-11	(5YR3/4) dark reddish brown	G	ALS±SF	60-65	PC±M	P	Pr	± R	1,6	60	0,86	
	B1	11-33	(5YR4/3) reddish brown	P± N	AS	70-75	PC±M	PP	Pr	± R	1,5	58,33	0,56	
	B21	33-72	(10YR3/6) dark yellowish brown	P	AS±SM	80-85	C	P	Pr	Ond	1,4	42,5	0,33	
	B22	72-92	(10YR5/6) yellowish brown	p	AS±SM	80-85	C	p			1,3	47,13	0,30	
K2 Plenthic Cambisol	A3	0-14	(10R4/2) weak red	G	AS±SFM	45-60	PC	PP	Pr	R	1,7	29	0,94	High load of coarse particles from 14-37 cm
	AB	14-37	(10R4/3) weak red	G	AS±SFM	70-75	C	P	Pr	IR	1,6	58,57	0,79	
	B2	37-63	(10YR3/6) dark yellowish brown	P± N	AS±SFM	65-70	C±M	P	Pr	± R	1,5	56	0,57	
	B2	63-84	(10YR5/6) yellowish brown	P	AS±SMG	75-80	C	P			1,4	45	0,40	
P4 Plenthic Cambisol (Oxydic)	A3	0-17	(2,5YR3/4) dark reddish brown	P± G	AS±SFM	45-50	C	P	N	R	1,6	33,33	0,96	High load of coarse particles from 14-37 cm
	B21	17-44	(2,5YR2,5/4) dark reddish brown	P± N	AL±SMG	65-70	C	P	N	R	1,4	75,65	0,88	
	B22	44-72	(2,5YR3/4) dark reddish brown	P± N	ALS	70-75	C±M	P	N	R	1,3	80	0,67	
	B23	72-89	(10R3/6) dark red	P± N	SA±SFM	80-85	C	TP			1,2	78,43	0,44	
P3 Plenthic Cambisol (Oxydic)	A3	0-6	(2,5YR3/4) dark reddish brown	P± G	AS±SFM	45-50	C	P	N	R	1,6	85,82	1,00	Small thickness of the upper soil 0-6 cm Heavy Duty coarse elements from 0-6 cm
	B21	6-32	(2,5YR2,5/4) dark reddish brown	P± N	AL±SMG	65-70	C	P	N	R	1,4	88,96	0,87	
	B22	32-61	(2,5YR3/4) dark reddish brown	P± N	ALS	70-75	C±M	P	N	R	1,3	85,71	0,73	
	B23	61-87	(10R3/6) dark red	P± N	SA±SFM	80-85	C	TP			1,2	84,62	0,46	
P2 Gleyic Cambisol (Oxydic)	AB	0-5	(5YR4/1) dark gray	P	ALS	20-35	C	PP	N	± R	1		0,33	Small thickness of the upper soil 0-6 cm Heavy Duty coarse particles from 0-6 cm
	A121g	05-12	(7,5YR4/6) strong brown	P	AS±SFM	(10-15	C	PP	N	± R	1,8		0,53	
	Bg	12-81	(7,5YR7/2) pinkish gray	P	ALS	60-65	C±M	PP	N	± R	6,5		0,56	
	A 122g	81-101	(10YR8/1) white	P	SA±SFM	15	C	PP	N	± R	3,5		0,52	
	A123g	101-118	(7,5YR6/2) pinkish gray	P	ALS±SF	10	C	PP			3		0,70	

Be continued

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P1	A1	0-5/8	(5YR2,5/1) black	P	SLA±SF	30-35	C	PP	Pr	± R	1,8		0,32	Small thickness
Gleyic	A121g	0-5/8-29	(7,5YR6/6) Reddish yellow	P	SA±SFM	30-35	C	PP	N	± R	5,5		0,50	of the upper soil
Reductic	ABg	29-52	(7,5YR6/3) light brown	P	SA±SMG	35-40	C	P	N	± R	6,5	53,85	0,57	0-5 cm horizon.
Gleysol	A 122g	52-100	(7,5YR6/2) pinkish gray	P	SA±SFM	80-85	C	P	N	R	10		0,52	Unless drained
Plenthic	A123g	100-111	(10YR4/4) dark yellow brown	M± P	ALS±SF	80-90	C				11,5		0,70	
	A11	0-12/13/19	(5YR2,5/1) black	P±S	SLA±SF	(10-15	C	TFP	Pr	Dif	1,8		0,27	
P0 Gleyic	A121g	13/19-31	(2,5YR8/1) white	P±S	SLA±SF	(15-10	C±M	PP	Pr	Dif	4,5		0,54	stone line
Plenthic	A122g	31-47	(7,5YR4/1) dark gray	P±S	SA	5	C±M	FP	Pr	Dif	4,3		0,57	horizon to 47-89
Gleysol	A123g	47-89	(10YR5/3) brown	P±S	SA±SM	5	C	FP	N	R	7,5	55	0,52	to 87-100 cm
Arenic	Gley	89-100	(10Y2,5/1) greenish black	M	S±SF,M	95	C	TFP			11,5		0,65	

*Munsell Colour values (Munsell Colour Company, 2009).
**Structure: G = Lumpy P = blocky, P ± S = subangular blocky; PS ± G = subangular blocky to lumpy trend, P ± A = angular blocky
**Texture: A = Clay, AS = Clay-sand, SA = Sandy-clay; SLA = Sandy-silty clay, clay and ASL = sandy loam; LSA = Silty-sandy clay;
**Consistency: C = Consistent, PC = No coherent, TC = Very consistent, M = C ± Consistent with furniture
**Porosity P = Porous, PP = low porosity; TP = Very porous, very low porosity TPP
**Transition between horizons: Pr = Progressive, N = Net, Dif. = Diffuse
** Limit: R = Regular; ± R = more or less regular Ond = crimpy

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Horizon Depth Characteristics

0-3cm: dark reddish brown (5 YR 3/2); fresh humus, sandy clay loam texture, fine to medium sand, coherent, porous (45-50% clay), more or less limited regular, gradual transition, drainage class 1.7.

3-11cm: dark reddish gray (2.5 YR 3/1) charges, humus, sandy clay loam texture, medium to coarse sand, coherent, porous (60-65% clay), some roots (mm) , drainage class 1.6, limit more or less regular, gradual transition.

11-33cm: reddish brown (5 YR 4/3), fresh, slightly humus, sandy clay texture, coherent furniture; porous (70-75% clay). Limit more or less regular progressive transition; Class graining 1.5.

33-72cm: dark yellowish brown (10 YR 3/6), fresh, slightly humus, sandy clay texture, coherent furniture; porous (80-85% clay.). Limit more or less regular progressive transition; Class graining 1.4.

72-92cm: yellowish brown (10 YR 5/6), fresh, slightly humus, sandy clay texture, coherent furniture; porous (80-95% clay); Class graining 1.3.

Figure 2: Morphological characteristics of the soil pit in the classified forest of Besso

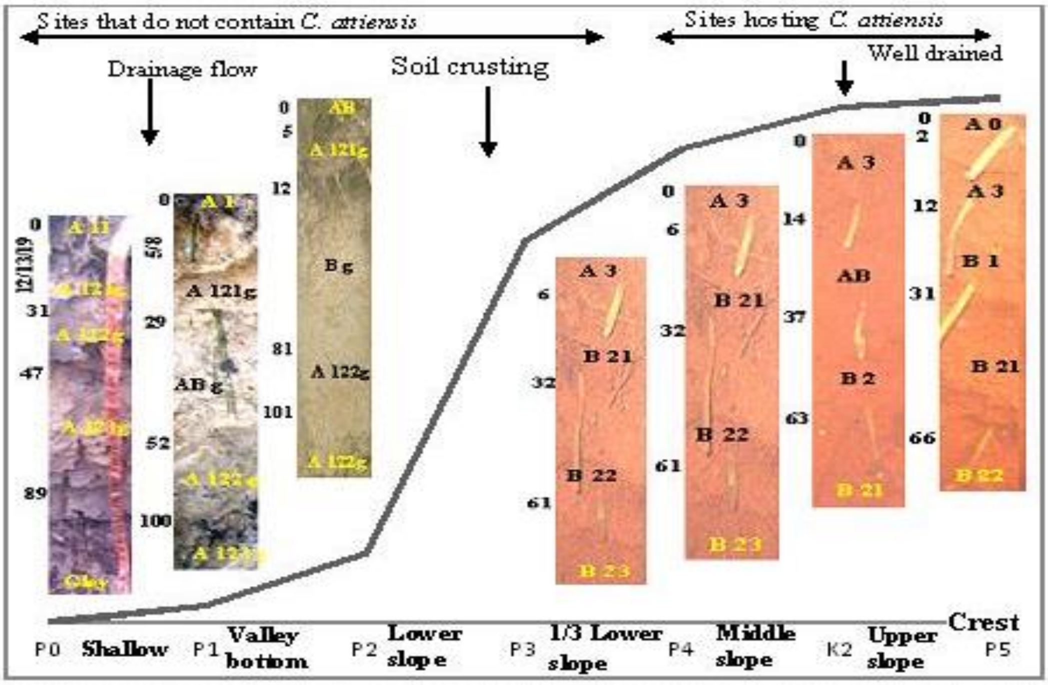

Figure 3: Schematic representation of a toposequence in the soil landscape *Cola attiensis* in Côte d'Ivoire

Texture

Water availability is an important requirement for growing plants *C. attiensis*. Therefore, a silty clay-sandy or clay-sandy texture is preferred. Besides the dubious role of gravel moisture results in wide variation in estimates of the maximum amount of water stored in the gravel, from 1 % as evidenced by [26] to 20 %. as reported by [27], the texture appears to be a major constraint to the development of soils studied, joining with the conclusions of [11].

Structure

The structure of the surface soil of pedon described in Akoupé and Affery was lumpy. Similarly, the structure varied from lumpy surface soil to polyhedral subangular subsoil. This further confirmed the reports of [12] that observed polyhedral subangular structure promote good water retention and nutrients, good drainage and good aeration, good resistance to erosion and are conducive to proper development of the root system of plants, unlike subangular blocky structure [28]. Tasks observed at horizons subangular blocky structure are due to the alteration minerals [19] show the event of a temporary waterlogging.

Conclusion

In conclusion, the circumstances of the case morphopedological *Cola attiensis* Aubrév. & Pllegr.in the site of Akoupé and Affery, can be expressed as follows soils described in Akoupé and Affery are browns Cambisol soil types, provided in a high rate of coarse elements, well structured, especially at the humus horizons of up to 0-20 cm. Beyond this depth, the structures are less good, with conditions of temporary waterlogging at the bottom of the slope of coarse matter, the thin surface horizons and, secondarily, the quality of drainage proved to be constraints key to the development of these soils.

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