CHARACTERIZATION AND FERTILITY CAPABILITY CLASSIFICATION OF THE SOILS OF SHASHA RIVER FLOODPLAIN, OSUN STATE, NIGERIA

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ABSTRACT

Characterization and fertility capability classification of soils of a floodplain in Osun State, Nigeria were carried out. Soil samples from horizons of identified mapping units were analyzed for their properties. Soils were grouped based on their fertility capabilities. Soil texture ranged from sandy loam to sandy clay loam in the upper and mid basins while the basin floor was sandy loam. The soils were slightly to strongly acidic, organic matter content ranged from low to high, available phosphorus was low, while the exchangeable bases were high. The soils were characterized by the fertility indicators: Lhkig for upper basin, Lir^{++}g for mid basin and Lkig for basin floor. The agronomic constraints of the soils include high acidity, low P content, low nutrient reserve, gravelly condition and gleying. Sustainable management of the soils would require efficient soil management systems through effective drainage, liming and fertilization with the use of bed and mound

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Key words**: **Fertility capability classification, Floodplain aquic moisture regime, Shasha river

INTRODUCTION

Fertility capability classification (FCC) is a technical system for grouping soils according to the kinds of problems they present for agronomic management (Sanchez *et al*., 1982; Sanchez and Buol, 1985). It is based on quantitative topsoil and subsoil parameters directly relevant to plant growth and derived from the class limits of soil taxonomy or from legend of the FAO/UNESCO soil map of the world (FAO, 1974). The system was designed specifically to group soils having similar limitations for effective fertility management and, as a guide for the extrapolation of the fertilizer responses based on soil parameters designated as Types, Substrata type and Modifiers (Buol and Couto, 1980). It can serve as basis for grouping soils for specific soil management practice and land use planning. It is, therefore, an essential prerequisite for any technical classification that addresses fertilizer-plant-soil interaction. Crop-species or cultivars with distinctly different requirements, such as flooded rice, oil palm and yam, may require specific technical grouping that utilize soil parameters most critical to the need of that cropping system (Akele *et al*., 2006). In most developing countries of the world, the FCC system has not been preferably used as an indicative classification along with more inclusive natural classification system. This is unlike the advanced countries where the system has been used along with data from soil survey reports and soil test to administer effective fertilizer applications that will ensure agricultural land sustainability. The information obtained relating to taxonomic system can be used for effective land use planning with clear understanding of their agronomic constraints (FAO, 1983; Abdukadir, 1988; Braimoh, 2000). It also enhances the management guidelines in order to promote a more sustainable use of soil and environmental resources.

Soils occupying the floodplain of many rivers have received overwhelming acceptance for agriculture and other uses. However, because few studies have been carried out on floodplain soils in southwestern Nigeria, they are therefore underutilized. In view of their aquic moisture regime which predisposes them to be chemically dynamic, proper understanding of their morphological, physical and chemical properties is required for proper management of the soils. Specifically, the agronomic potential and constraints of Shasha river floodplain soils in Southwesthern Nigeria for food crops production have not received the desired research attention. Therefore, the specific objectives of this study were to characterize the soils and establish their fertility capability classes.

Materials and methods

The study was conducted in a section of Shasha river floodplain, about 1 km from Edunabon town in Osun State Nigeria. It lies approximately between latitudes 7^{o} 33.247′ N and 7^{o} 33.307′ N and longitudes 4^{o} 26.401′ E and 4^{o} 26.735′ E. The elevation of the study area ranged from 218 m to 242.5 m above mean sea level. The climate of the area is humid tropical, with distinct dry and wet seasons. The wet season spans mid-March to late October, and rainfall pattern is bimodal with peak periods in June/July and September/October. The dry season runs from early November to early March. The influence of the north-east trade wind, which loses all its moisture as it passes over the Sahara desert towards the equator, is felt in the study area as ‘harmattan’ (cold dry wind) between late December and early January. Atmospheric temperature is moderately high throughout the year, with a low range between the mean monthly minimum and maximum temperatures. The peak of the maximum is usually in March (40.3^{o} C) just before the onset of rains while the lowest minimum temperature is between December and January (12.6^{o} C). The area also records the following average monthly data: humidity 89.15 % and sunshine 6.6 hours.

A topographic map (Iwo Toposheet Number 242 SE) at a scale of 1:50,000 was used to delineate the entire soil boundaries of the study area. Reconnaissance field study was carried out to identify representative geomorphic soil units. Soil profile pits were dug and examined. These pits were located at the upper basin, mid basin and the basin floor. The genetic horizons of each soil profile pit were identified, described and sampled according to FAO/UNESCO (2006) guildlines. The soil samples were air-dried, crushed gently and passed through 2 mm sieve. The fraction less than 2 mm was retained for laboratory analysis.

Particle size analysis was determined by the modified hydrometer method (Bouyoucos 1962; Gee and Or, 2002), using 0.2 M NaOH solution as the dispersing agent. Soil pH was determined in 1:1 soil/water and KCl solution using glass electrode pH meter. Organic carbon was determined using Walkley-Black method as reported by Nelson and Sommers (1982). Total nitrogen was determined by regular Kjeldahl digestion method (Bremner, 1996) while exchangeable calcium (Ca), magnesium (Mg) sodium (Na) and potassium (K), were extracted with 1 N NH_4OAc. The concentrations of K and Na were determined using flame photometer while those of Ca and Mg were determined using atomic absorption spectrophotometer. Available phosphorus was determined by the Bray-1 method (Bray and Kurtz, 1945), exchangeable acidity was by 1 N KCl extraction and titrated with 0.05 N NaOH solution (McLean, 1965) while the effective cation exchange capacity (ECEC) was estimated by the summation of exchangeable cations and exchangeable Al^{3+}. The soils were grouped on the basis of their fertility capability using the guidelines provided by Sanchez *et al.* (2003)

Results and discussion

Morphological properties of the soils

Summary of the morphological description of the soils is presented in Table 1. The soils occupied low topographic position and were developed from alluvium and local colluvium (Smyth and Montgomery, 1962). The colour of the surface horizons ranged from dark reddish brown (5YR 3/4) in profile 01 to dark gray brown (10YR 4/2) in profile 04. The dark colour of the surface horizon could be attributed to higher content of organic matter (OM). The colour of the subsoil ranged from reddish brown (5YR 4/3) in profile 01 to dark yellowish brown in profile 04. This reddish colouration may be due to the presence of haematite as explained by Davey *et al.* (1975) and Bigham *et al.* (1978). The decrease in redness of poorly-drained soils can be attributed to increasing hydration of iron (Nye, 1955; Torrent *et al.*, 1983). In profiles 04 and 06, presence of mottles and evidence of gleization were observed in the subsoils. These involve oxidation and reduction of Fe and Mn compounds, and were favoured by the low topographic position and seasonal fluctuating water table, coupled with seasonal flood water seepage prevalent at the site. The soils had sandy loam top soil underlain by sandy clay loam to clay loam subsoil in the profiles. At the basin floor (profile 06), the soils received both seasonal alluvium and colluvium. The soils were poorly drained with reddish gray (5YR 5/2) to gray (5YR 5/1) colour. The variation in soil colour was primarily due to physiographic position of each profile and drainage condition of the soils. The dark brown to dark reddish brown colour in the surface of the upper basin soils (profiles 01 and 02) was an indication of good internal drainage (Periaswamy and Ashaye, 1982). The influence of physiographic position on soil colour had earlier been reported by Gerrard (1981) who noted that variation in soils' colour is usually attributed to the sequence of drainage.

Physical properties of the soils

Table 2 shows the physical properties of the soils. The gravel content varied from 0.06 to 97.10%, with profiles 02 and 05 having relatively higher values while profiles 01 and 06 had lower values. This could be as a result of deposition (alluvial sediment) in the floodplain. Generally, the gravel content increased from A to B horizon except in profiles 02 and 03 which did not follow any regular pattern. Particle size distribution data showed that the texture of the surface soils of the six profiles in the study area was sandy loam. With the exception of profile 06 (basin floor), clay content increased with depth. Clay eluviation from the topsoil to the subsoil and differential sorting of materials are factors that could be accountable (Smyth and Montgomery, 1962). The sand particles appeared to be the most dominant size fraction with a range of 35 to 80%. The clay particles ranged from 8 to 39% while silt was the least with a range of 4 to 30 % in the soils. The predominance of sand in the surface horizon was attributed to the preferential removal of clay and silt by water erosion (Ojanuga, 1971). Amusan (1991) attributed the higher content of sand in the surface horizon to the translocation of colloidal clay particles deep into the profile with percolating water and selective erosion and transport of fine particles to the lower slope position during heavy downpour. The highest sand content occurred in the surface horizon of profiles 01, 02 and 03 but decreased with depth while clay content increased with depth. This trend in particle size distribution followed the findings by various workers (Smyth and Montgomery, 1962; Amusan, 1991; Ogunkunle, 1993; Akinbola *et al.*, 2006; Ojetade *et al.*, 2014) in soils of southwestern Nigeria. The lower values of sand in B-horizons are possibly due to dilution effect of illuvial clay in the subsoil and differential sorting of clay from surface horizon to the subsoil (Ojanuga and Nye, 1969). Bulk density ranged from 1.19 - 1.41 g/cm^3 in the A and B horizons, respectively. Bulk density is a reflection of texture and structure. Usually, soils with low bulk density are known to be associated with high total porosity, while root penetration becomes a problem when bulk density exceeds 1.6 g/cm^3 (Russell, 1976). Therefore, the soils are not likely to pose any difficulty to seedling emergence and root development. In profiles 01, 03 and 04, bulk density decreased with depth and latter increased with depth while in profiles 02, 05 and 06, it increased with depth.

Chemical properties of the soils

Table 3 shows the chemical properties of the soils. The soils were acidic with pH range of 5.6 to 6.9 and 4.6 to 5.8 in distilled water and 1 M KCl solution, respectively. The surface horizons were slightly acidic in reaction while the subsoils were strongly acidic. In the surface horizons, the pH ranged from 5.7 to 6.9 and 5.0 to 5.8 in distilled water and 1 M KCl solution, respectively. The low pH of the soils could be as a result of high rainfall in the area which made the soils to be fragile and susceptible to leaching (Udo *et al.*, 2009). Enwezor *et al.* (1981) stated that leaching of Ca and Mg was largely responsible for the development of soil acidity. Phytocycling and upward movement of bases due to intense evaporation during dry season in the humid tropics were further suggested to account for the relatively higher pH of the surface horizons (Amusan, 1991). The pH difference [pH(KCl) – pH(H_2O)] was negative in all of the horizons of the soil profiles indicating that silicate mineralogy in the soils is dominant over oxidic mineralogy (Van Raij and Peech, 1972) and/or that the soil colloids are still negatively charged (Mekaru and Uechera, 1972). The OM content of the soils ranged from low to high in all the profiles, varying from 0.3 to 4.0%. Adepetu (1986) classified percentage soil organic matter (SOM) in southwestern Nigeria into low (0 - 1.5%), medium (1.5 – 2.5%) and high (>2.5%). The SOM contents were low in the surface horizons of profiles 01, 03, 06 and higher in the surface horizons of profiles 02, 04 and 05. The high OM content at the topsoil of most of the soil profiles could be attributed to more decomposable organic materials in the surface soils (Lal, 1991). This high content of OM at the surface soil was not unexpected since it is at the soil surface that litters accumulate which subsequently decayed and mineralized to yield OM (Olayinka, 2009). It was also observed that SOM content in profile 05 was higher than other profiles examined; this is because profile 05 was under cacao plantation. Visual field observation indicated that greater canopy cover was found within cacao plantation compared to other locations, which possibly explained the higher OM content in profile 05 than in other profiles. In all the soil profiles that were examined, OM content decreased with depth. This agrees with the findings of other workers (Smyth and Montgomery, 1962; Ogunkunle, 1993; Akinbola *et al*., 2006; Ojetade *et al*., 2014). The OM content was low in profiles 01 and 06. The low OM content in profile 01 (upper basin) could be attributed to water erosion effect and continuous cultivation which was common in the area. While the low OM content in profile 06 (basin floor) could be due to paddy rice cultivation being practiced at the basin floor due to its hydromorphic condition which was usually harvested leaving little or no organic residue to accumulate.

The available P contents in the profiles examined varied from low to medium. Adepetu (1986) classified the soil test value of available P into low (0-8 mg/kg), medium (8-15 mg/kg) and high (> 15 mg/kg). It could be observed that the available phosphorus content of the soils varied from 0.39 to 11.0 mg/kg in all the soil profiles with the higher values at the surface horizons in profiles 01, 03, 04 and 05 while showing no definite pattern in profile 06, an indication that OM contributes significantly to the available phosphorus in the soils. The available P values are considered low in profiles 01, 02, 03, 04 and 06, respectively, as they were below the critical limit recommended for most commonly cultivated crops in the area (Uponi and Adeoye, 2000; Aduayi *et al*., 2002; Obigbesan, 2009). However, in the subsoil, available P content was highest in the basin floor. This trend could be due to the deposition of P through run off in the valley bottom soils of the toposequence. Like most tropical soils, the exchange sites were dominated by exchangeable Ca. The exchangeable Ca of the soils varied from 10 to 66 cmol/kg. In profiles 01, 03 and 06, it increased with depth while it decreased with depth in profiles 02, 04, 05. Generally, the Ca content fluctuated irregularly with soil depth. This could be attributed to the content of OM at the upper horizons since it serves as the main source of cation exchange sites in most soils, especially in highly weathered soils (Olayinka, 2009). Magnesium content of the soils ranged from 5.1 to13.0 cmol/kg. In profiles 01 and 02, Mg content increased with depth while in profiles 03, 04, 05 and 06, it followed no specific pattern. Exchangeable K varied from 0.1 to 0.4 cmol/kg in the soils. In profiles 01, 03 and 06, the K contents were the same in the surface and subsurface horizons. The K contents were highest in the surface horizon of profiles 02, 04 and 05 and the value decreased with depth. The higher content of K in the surface horizons of profiles, 02, 04 and 05 may be attributed to higher OM content (Ano, 1991). The exchangeable Na remained fairly constant in all the profiles. The cations occurred in the order: Ca> Mg>K>Na at the exchange sites. The generally low values of exchangeable bases, especially K and Mg, of the soils may be attributed to high rainfall intensity, intensity of weathering, leaching and translocation of bases (Solarin, 2000). The base saturation values computed on the basis of the ECEC were high and varied from 97.53 to 99.62% in all the pedons. The values increased with depth.

Classification of the soils

The soils were correlated based on report of soil survey work by Smyth and Montgomery (1962). The parent material, topographic position, soil colour and presence or absence of mottles, soil texture and general profile morphology were the main criteria used in correlating the soils. Profiles 01, 02 and 03 occupy gently sloping upper basin and in the upper reach, close to Shasha river. They are dark reddish brown to reddish brown in colour, and are sandy loam to sandy clay loam in texture. Due to the presence of mottles in the horizon below 104 cm depth, they were therefore classified as Jago series. Profiles 04 and 05 occupied the mid basin in the terrain. They are dark gray brown to dark brown in colour and sandy loam to sandy clay loam in texture. They were therefore classified as Matako series. Profile 06 occupies a valley bottom site adjacent to Shasha river and sandy loam in texture. It is dark reddish brown to reddish gray in colour with evidence of mottling below 28 cm and was water saturated at 52 cm depth. It was therefore classified as Oshun series.

The soils did not have histic epipedon or cambic horizon, no oxic, no spodic, no sulphuric horizon within 150 cm of the mineral soil surface and the temperature regime is isohyperthermic. Due to the absence of these diagnostic features/horizons in most of the soils examined, and because the soils were located in the floodplain which makes soil development slower, coupled with continuous deposition of alluvium, the soils were placed in the order Entisols. Profiles 01, 02, 03, 04 and 05 do not have densic, lithic or paralithic contact within 25 cm of the mineral soil surface, are located on a slope of less than 25 percent, have an irregular decrease in organic carbon content within a depth of 125 cm below the mineral soil surface with isohyperthemic soil temperature regime. They were therefore classified in the sub order Fluvents and great group Udifluvents and sub group Typic- udifluvents. The presence of aquic condition or permanent saturation with water and a reduced matrix in all horizons below 25 cm from mineral soil surface, place the soil of profile 06 into the sub order aquents and great group Fluvaquents and sub group Typic fluvaquents (USDA). The soils of the study area would correlate as Fluvisols (FAO/UNESCO, 2006).

Fertility Capability Classes of the soils

The result of Fertility Capability classification of the soils of Shasha river flood plain is shown in Table 4. The soils were classified as Lhkig, Lki, Li, Lir^{++}g, Lir^{++} and Lkig, respectively. This implies that the soils were loamy in texture (L), with constraints of high acidity (h), low nutrient reserve (k), high P fixation (i), gleying (g), gravel (r^{++}) and poor drainage. The low pH and OM content could be responsible for low ability to supply nutrients, hence, availability of nutrients should be monitored and fertilizers may be required. The acidity could have resulted from high rainfall and its associated leaching effect as the major pedogenetic process was gleization.

The soils are poorly drained for most part of the year. This is a key feature that tends to limit or hinder all year round utilization of wetland soils for agricultural production (Ojanuga and Lekwa, 1984). Sanches *et al.* (1982) reported that waterlogging affects the workability of floodplain soils and poses environmental hazard by emitting greenhouse gases like methane and nitrous oxide into the atmosphere. For these soils to be used efficiently, elevated beds and mounds should be used for planting of crops, which could adapt to waterlogging condition. Low nutrient reserve is another constraint of the soils studied. The low availability of nutrients and basic cations may be caused by low pH. Whalen *et al.* (2000) reported that soil pH affects nutrient solubility and influences the sorption or precipitation of nutrients with Al and Fe. Also Hue (1992) reported that increasing the pH of acidic soils improved plant availability of macronutrients while reducing the solubility of elements such as Al and Mn.

Conclusion

The fertility constraints of the soils were assessed using the Fertility Capability Classification (FCC) system. The study revealed that the general agronomic constraints of the soils were low nutrient reserve (k), gleying (g), acidic reaction (h), high p fixation (i) and gravelly (r^{++}) condition. However, with efficient soil management through effective drainage, liming, fertilizer use based on soil test, sustainable productivity of the soils can be guaranteed.

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Table 1: Morphological description of the soils

Horizon	Depth (cm)	Colour (moist)	Texture[a]	Structure[b]	Consistence[c]	Concretion[d]	Boundary[e]	Note
Upper basin (Profile 01)								
Ap	0-25	5YR ¾	ngrsl	2sbk	mnstnpl	vfgr	cs	Many fine, few medium and coarse roots
AB	25-64	5YR 4/3	ngrsl	2sbk	Mstpl	vfgr	ds	Few fine and medium roots
B1	64-104	5YR 5/4	ngrsc	2mcr	Mstpl	vfgr	ws	Few mediun roots
B2	104-183	5YR 4/4	ngrsc	2mpl	Mstpl	vfgr	-	Few medium roots
Upper basin (Profile 02)								
Ap	0-20	7.5YR 3/2	grsl	2sbk	mwstpl	grd	cs	Many fine medium and few coarse roots
AB	20-47	7.5YR 5/4	sgscl	2sbk	mwstpl	grd	cs	Many medium roots
Bt_1	47-70	7.5YR 4/4	vgrcl	2sbk	mwstvpl	grrd	cs	no root
Bt_2	70-170	7.5YR 5/6	ngrcl	2sbk	mwstvpl	-	-	Merge into saprolite
Mid basin (Profile 03)								
Ap	0-22	7.5 YR 4/2	ngrsl	2sbk	mwnstnpl	vfgr	cs	Frequent medium and fine roots
AB	22-48	7.5 YR 4/4	ngrsl	2sbk	mwstpl	vfgr	cs	Frequent medium and fine roots
Bt_1	48-78	5YR 4/8	ngrcl	2sbk	mwstvpl	vfgr	cs	Few medium and fine roots
Bt_2	78-156	5YR 4/8	ngrscl	2sbk	mwstvpl	vfgr	-	Few medium roots

[a] Texture: gr =gravelly, sgr = slightly gravelly, vgr = very gravelly, ngr = non gravelly c = clay, s = sandy or sand, l = loam or loamy

[b] Structure: 1 = weak, 2 = moderate, 3 = strong, m = medium, cr = crumb, sbk = subangular blocky, pl = platy

[c] Consistence: m = moist, w = wet, fr = friable, st = sticky, nst = non sticky, pl = plastic npl = non plastic vpl = very plastic

[d] Concretion: vf = very few, gr = gravel, rd = rounded, st = stone, fr = frequent, vfr = very frequent, cr = saprolite

[e] Boundary: c = clear, d = diffuse, g = gradual, s = smooth, w = wavy.

Table 1 continued: Morphological description of the soils

Horizon	Depth (cm)	Colour (moist)	Texture[a]	Structure[b]	Consistence[c]	Concretion[d]	Boundary[e]	Notes
Mid basin (Profile 04)								
Ap	0-22	10YR 4/2	sgrsl	1msbk	mwst pl	vfgr	cs	Abundant fine and few medium roots
AB	22-34	10YR 4/3	grsl	1msbk	mwst pl	Gr	ds	Few fine and medium roots
B	34-64	10YR 4/4	grscl	2mpl	mwstpl	Gr	ds	No root
Bv	64-93	10YR 6/2	vgrsl	2mpl	mwstpl	grrdcr	-	Saprolite is present
Mid basin (Profile 05)								
Ap	0-20	7.5YR 4/2	ngrsl	2mcr	mwnstnpl	vfgr	ds	Frequent fine and medium roots
AB	20-40	7.5YR 4/4	grsl	2sbk	mwstpl	vfgr	ds	Common fine and medium roots
Bt1	40-70	7.5YR 5/6	vgrsc	2sbk	mwstpl	grst	ds	Few medium roots
Bt2	70-120	7.5YR 5/8	grsc	2sbk	mwstvpl	vfgr	-	Few medium roots
Basin floor (Profile 06)								
Ap	0-28	5YR 3/2	ngrsl	2mpl	mwstpl	vfgr	cs	Common fine roots
AB	28-52	5YR 5/2	ngrsl	2mpl	mfwstpl	vfgr	cs	Few fine and medium roots
Bg	52-73	5YR 5/1	ngrsl	2mpl	mfwstpl	vfgr	-	No root

[a] Texture: gr =gravelly, sgr = slightly gravelly, vgr = very gravelly, ngr = non gravelly c = clay, s = sandy or sand, l = loam or loamy

[b] Structure: 1 = weak, 2 = moderate, 3 = strong, m = medium, cr = crumb, sbk = subangular blocky, pl = platy

[c] Consistence: m = moist, w = wet, fr = friable, st = sticky, nst = non sticky, pl = plastic npl = non plastic vpl = very plastic

[d] Concretion: vf = very few, gr = gravel, rd = rounded, st = stone, fr = frequent, vfr = very frequent, cr = saprolite

[e] Boundary: c = clear, d = diffuse, g = gradual, s = smooth, w = wavy.

Table 2: Physical properties of the soils

Horizon	**Depth (cm)**	**Sand**	**Silt**	**Clay**	**Gravel**	**Bulk density (gcm^{-3})**	**Textural class**
		←		**%**	→		
			Upper basin (Profile 01)				
Ap	0-25	76	16	8	0.33	1.54	SL
AB	25-64	63	19	18	0.39	1.44	SL
B1	64-104	57	18	25	1.27	1.52	SCL
B2	104-183	55	18	27	0.62	1.39	SCL
			Upper basin (Profile 02)				
Ap	0-20	59	24	17	17.03	1.38	SL
AB	20-47	55	20	25	23.00	1.49	SCL
Bt1	47-70	41	30	29	97.10	1.15	CL
Bt2	70-170	35	26	39	0.10	1.18	CL
			Upper basin (Profile 03)				
Ap	0-22	80	4	16	0.08	1.25	SL
AB	22-48	75	7	18	0.06	1.43	SL
Bt1	48-78	61	8	31	0.10	1.32	SCL
Bt2	78-156	57	14	29	0.15	1.32	SCL
			Mid basin (Profile 04)				
Ap	0-22	59	27	14	3.99	1.31	SL
AB	22-34	65	19	16	22.10	1.28	SL
B	34-64	49	22	29	41.12	1.41	SCL
Bg	64-93	71	13	16	79.0	_	SL
			Mid basin (Profile 05)				
Ap	0-20	61	29	10	0.13	1.19	SL
AB	20-40	69	13	18	34.28	1.44	SL
Bt1	40-70	45	16	39	90.90	1.13	SC
Bt2	70-120	49	19	32	15.68	1.20	SCL
			Basin floor (Profile 06)				
Ap	0-28	65	21	14	0.35	1.34	SL
AB	28-52	75	13	12	0.84	1.43	SL
Bg	52-73	76	12	12	0.77	1.20	SL

Table 3: Chemical properties of the soils

Horizon	Depth (cm)	pH			O.M (%)	TN (%)	AP (mg/kg)	Exchangeable Cations				EA		TEB	TEA	ECEC	BS (%)	SAR
		H_2O	KCl	ΔpH				Ca^{2+}	Mg^{2+}	K^+	Na^+	Al^{3+}	H^+					
								← cmol $_{(+)}$ Kg^{-1} soil →										
Upper basin (Profile 01)																		
Ap	0-25	5.7	5.0	-0.7	0.9	0.46	5.0	11	5.1	0.1	0.10	0.4	0.4	16.30	0.8	16.70	97.60	0.035
AB	25-64	5.7	4.6	-1.1	0.3	0.63	3.0	17	6.8	0.1	0.03	0.3	0.3	23.93	0.6	24.23	98.76	0.0087
B1	64-104	5.8	4.6	-1.2	0.8	0.53	1.0	24	8.9	0.1	0.03	0.4	0.2	33.03	0.6	33.43	98.80	0.0074
B2	104-183	5.6	4.8	-0.8	0.4	0.49	2.0	26	9.3	0.1	0.03	0.3	0.3	35.43	0.6	35.73	99.16	0.0071
Upper basin (Profile 02)																		
Ap	0-20	6.7	5.8	-0.9	1.69	2.9	6.0	15	8.4	0.3	0.10	0.3	0.5	23.80	0.8	24.10	98.76	0.029
AB	20-47	6.2	5.3	-0.9	0.76	1.3	4.0	13	8.4	0.2	0.10	0.3	0.3	21.70	0.6	22.00	98.64	0.031
Bt1	47-70	6.0	5.0	-1.0	0.41	0.7	8.0	14	10.1	0.3	0.10	0.3	0.7	24.50	1.0	24.80	98.79	0.029
Bt2	70-170	5.9	4.7	-1.2	0.64	1.1	2.0	18	11.7	0.2	0.10	0.4	0.3	30.00	0.7	30.40	98.68	0.026
Mid basin (Profile 03)																		
Ap	0-22	6.2	5.7	-0.5	1.5	0.81	6.0	16	6.7	0.1	0.04	0.3	0.4	22.84	0.7	23.14	98.70	0.012
AB	22-48	6.1	5.1	-1.0	0.9	0.74	3.0	14	6.1	0.1	0.04	0.3	0.4	20.24	0.7	20.54	98.54	0.013
Bt1	48-78	6.0	4.9	-1.1	0.9	1.12	2.0	12	6.7	0.1	0.10	0.2	0.5	18.90	0.7	19.10	98.95	0.033
Bt2	78–156	6.0	5.0	-1.0	0.7	0.49	2.0	11	9.4	0.1	0.10	0.3	0.4	20.60	0.7	20.90	98.56	0.031
Mid basin (Profile 04)																		
Ap	0-22	6.9	5.7	-1.2	2.3	0.63	4.0	39	9.4	0.3	0.03	0.3	0.4	48.73	0.7	49.03	99.39	0.0061
AB	22-34	6.8	5.6	-1.2	1.6	0.56	4.0	29	8.7	0.1	0.03	0.2	0.6	37.83	0.8	38.03	99.47	0.0069
B	34-64	6.7	5.2	-1.5	1.0	0.46	2.0	66	13.0	0.1	0.04	0.3	0.4	79.14	0.7	79.44	99.62	0.0064
Bg	64-93	6.9	5.2	-1.7	1.0	0.98	4.0	63	12.5	0.1	0.04	0.3	0.5	75.64	0.8	75.94	99.60	0.0065
Lower basin (Profile 05)																		
Ap	0-20	6.6	5.8	-0.8	4.0	0.81	11.0	10	5.3	0.4	0.1	0.4	0.4	15.80	0.8	16.20	97.53	0.036
AB	20-40	6.2	5.1	-1.1	0.9	0.63	7.0	13	9.0	0.2	0.1	0.4	0.1	22.30	0.5	22.70	98.23	0.030
Bt1	40-70	6.1	5.0	-1.1	0.7	0.67	4.0	12	10.5	0.3	0.1	0.3	0.1	22.90	0.4	23.20	98.71	0.029
Bt2	70-120	6.3	4.9	-1.4	0.9	1.37	7.0	18	9.4	0.3	0.1	0.2	0.1	27.80	0.3	28.00	99.29	0.027
Basin floor (Profile 06)																		
Ap	0-28	6.2	5.2	-1.0	0.81	1.4	3.0	32	9.0	0.1	0.03	0.3	0.2	41.13	0.5	41.43	99.28	0.0066
AB	28-52	6.2	5.2	-1.0	0.76	1.3	7.0	27	8.6	0.1	0.04	0.3	0.3	35.74	0.6	36.04	99.17	0.0095
Bg	52-73	6.5	5.2	-1.3	0.41	0.7	1.0	22	7.6	0.1	0.03	0.2	0.4	29.73	0.6	29.93	99.33	0.0078

Keys: O.M. = organic matter, TN = total nitrogen, AP = available phosphorus, EA = Exchange Acidity, TEB = total exchangeable bases, TEA = Total exchangeable acidity, ECEC = Effective cation exchange capacity, BS = Base saturation, SAR = sodium adsorption ratio.

Table 4: Fertility capability classification (FCC) of the soils

Pedon	**Top soil**	**Sub soil**	**Condition modifier**							**FCC Units**
			H	K	e	I	G	A	r^{++}	
01	L	L	+	+	-	+	+	-	-	Lhkig
02	L	L	-	+	-	+	-	-	-	Lki
03	L	L	-	-	-	+	-	-	-	Li
04	L	L	-	-	-	+	+	-	+	Lir^{++}g
05	L	L	-	-	-	+	-	-	+	Lir^{++}
06	L	L	-	+	-	+	+	-	-	Lkig

L = Loamy, h = acidic, k = low nutrient reserve, e = leaching potential, i = high P fixation, g = gleying (drainage), r^{++} = gravel, a= Aluminum toxicity.