Original Research Article

Comparison of Selected Physico-Chemical Properties of Upland and Swampland Soils in the Tropical Rainforest of Delta State, Nigeria

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Abstract

A comparison was made between upland and swampland soils in Abbi, Ndokwa West local Government Area of Delta State, Nigeria. Some selected morphological, physical and chemical properties were assessed to determine the relationship and differences between both soils. The study established that the soils were generally low in selected physiochemical properties. The upland and swampland soils deferred significantly ($P < 0.05$) in sand, clay, bulk density, exchangeable cation and silt contents. The upland soils had the highest values in sand particles, and ranged from 87.7 to 95.1%. Clay and silt contents in swampland soils were much higher than in the upland soils, with clay values ranging from 5.8 to 28.4% and silt ranging from 1.2 to 5.6%. The top soils contained higher levels of organic matter and total nitrogen than the subsoils. Available P (phosphorus) obtained were generally low in both the upland and swampland soils. Both values ranged from 2.15 to 7.42ppm. Morphologically, the major differences between both soils were in soil colour, mottles and submergence of soils by water. From the study there were fluctuations in the coefficients of variation of the physical and chemical properties, and were generally throughout the profiles within the upland soils and this could be attributed to human activities, cultural practices, excessive crop cultivation and climatic conditions. It was recommended that good soil management, such as application of organic and inorganic amendment, for sustainable crop yield and soil conservation in the area should be applied.

Keywords: Comparison, Upland, Swampland, Morphologically and Physiochemical Properties

Introduction

Land is a renewable natural resources which often can be improved and used again and again. However, there is always the danger that serious misuse of land may not only diminish its present value, but will almost irreparably damage its future usefulness as eroding slopes and the spread of deserts testify (Julian, l999). Land resources need to be managed appropriately to ensure their effective conservation. Abbi is an agrarian community in Delta State, Nigeria with access to upland and swampland resources. The land use pattern in the area is the result of the interaction of a number of factors such as the physical features of the land, and human occupation and interests, all of which have distinctive effects on the pattern of agriculture which characterizes the Abbi area.

Swamplands are seasonally water-logged non-settlement areas for hunting, gathering, fish farming and growing of specific crops while the upland areas are settlement area where intensive and extensive cultivation of annual and perennial crops are carried out. Swamplands are therefore areas that are water-saturated near the surface for prolonged periods when soil temperatures and other conditions are such that plants and microbes can grow and remove the soil oxygen thereby assuring anaerobic conditions (Brady and Weil, 2015). In addition, according to Wills (1962), the upland soils of the zone have been considerably modified in their topsoil layers by tanning. Not originally of any high inherent fertility they have decreased in productivity because of continuous cropping. Expectedly, the characteristics of the soils formed in this area are supposed to be the same as they are formed from the same parent materials, but they differ. The reasons for such differences in the area are yet to be understood. Thus, there is the need to study the upland and swampland in the Abbi area in order to provide the necessary data that will help plan for their conservation. This study was therefore carried out to determine the differences in selected morphological, physical and chemical properties between the upland and swampland soils in Abbi area and make recommendation for sustainable use of the land.

Materials and Methods

Description of Study Area

The study was carried out in Abbi, in Ndokwa West Local Government Area of Delta State, Nigreria. Abbi is located on Latitude $5^0$40’N and longitude $6^0$10’E. Geographically, it falls in the humid tropical climatic zone where rainy season and dry season occur yearly. Rainfall distribution is bimodal, with July and September being the peak periods, and with a dry spell known as “August break” in August. The total annual rainfall ranges from 1100mm to 1500mm. The rains usually begin from March and end in October. The annual temperature generally ranges from 25^0C to 35^0C, but this may fall below 22^0C during the harmattan period in the month of December through to the end of February.

The area is characterized by secondary vegetation because of the slash- and-burn system of land preparation used by farmer in the area, except in the swampland area where larger area of the land are covered with large trees and extensive fish ponds. Generally the topography of the area is gentle-sloping to almost flat in shape. The land used for cultivation in the upland area is of higher proportion than that of the swampland area. The features of the upland and swampland soils in Abbi remain in their natural forms, and are characterized by trees of timber-able size found in relation to ponds of various sizes covering large areas of the swamplands. Examples of trees and other plant species prevalent in this area include oil palm, *Iroko*, and *Obeiche* trees among others, while the other plant species include *Tridas pocubense, Chromolena odorata*. Usually, the main characteristics of the upland areas remain as those in the swampland, the difference being the secondary vegetation that dominates a large proportion of the upland, and water accumulation for a very long period of time in the swampland for most of the year. Most of the arable crops planted or cultivated in the area include water yam, white yam, yellow-yam, maize, cassava and other vegetable crops. Shifting cultivation remains the predominant farming system in the area.

Field Study

Soil samples were collected from two adjacent upland and swampland plots, 100 to 200 meter apart in relation to the nature of the area, using a soil auger at depths of 0-20cm during the preliminary stage of the study. Consistencies were used to estimate the texture and group the soils into textural classes. At the end of the preliminary survey two profile pits were sited to represent the homogenous soil units at depths of 0-20, 20-40, 40-60, 60-80, 80-100, and 100-120cm. The profile pits were fully described and sampled based on the diagnostic horizons.

Soil samples were labeled in the field, air dried at ambient temperature, sieved with a 2mm mesh before transporting them to the laboratory for analysis.

Laboratory Analysis

The selected physical properties included particle size, bulk density, colour, organic matter content, soil pH, total Nitrogen, available phosphorus, exchangeable bases, base saturation (BS), exchangeable acidity, total exchangeable bases (TEB), and extractable micronutrients. The particle size distribution was determined using the method by Bouyoucos (1951), using sodium hexa meta phosphate (calgon $NaPO_3$) solution as the dispersant. Soil pH was determined with a glass electrode pH meter in a 1:1 soil/H_2O suspension. The exchangeable bases were extracted with 1N neutral ammonium acetate ($NH_4CH_2CO_2$) and determined in the flame photometer and Diethylenetriaminepentaacetic acid (DTPA) titration. The exchangeable acidity (Al and H^+) was determined by the method outlined by Mclean (1965), the organic carbon was determined by the method of Walkley and Black (1934) as described by Allison (1965), and was converted to organic matter by multiplying the percentage carbon by Van Bermelen factor (1.724). Effective cation exchange capacity (ECEC) was obtained by adding Total Exchangeable Bases (TEB) and Total Exchangeable Acidity (TEA). The available phosphorous (P) was determined by Bray I method (Bray and Kurtz 1945). Total nitrogen (N) was determined by the Kjeldahl wet oxidation method or colorimetric method using sodium phanate, sodium hypochloride, sodium potassium tartrate and standard nitrogen stock solution. Extractable micro nutrient was determined using the hydrochloric acid method.

Results and Discussion

Physical properties

The distinctive information on the representative locations and profile characteristics of the upland and swampland soils are presented in Tables 1 and 2. In Table 1, a high coefficient of variation was observed across the profiles in the upland soils compare to the swampland soils, and this is in agreement with Castaneda *el al*. (2015), and Rossi and Rabenhorst (2015) who stated that the genesis of soils in these transitional environments, soil properties and pedogenenic processes can vary depending on time and other environmental factors.

Table 1: Physical properties of Upland and Swampland Soils

Horizon	Depth (cm)	% Sand (2-0.02mm)	% Silt (0.021-002mm)	% Clay (<0.002mm)	T.C	BD g/cm^3
Swampland						
Ap	0 -20	88.7	5.6	5.8	LS	1.17
AB	20 – 40	80.6	3.1	16.3	SL	1.26
Bt_1	40 – 60	78.8	2.8	19.2	SL	1.29
Bt_2	60-80	78.2	2.1	19.7	SL	1.32
Bt_3	80-100	72.0	1.2	26.8	SCL	1.33
BC	100- 120	70.5	1.2	28.4	SCL	1.49
X		78.1	2.7	19.3		1.31
SD		4.1	0.3	5.4		0.05
CV(%)		5.2	11.1	28.0		3.82
Upland						
Ap	0 - 20	95.1	3.1	1.8	S	1.21
AB	20 – 40	94.7	2.7	2.6	S	1.28
Bt_1	40 – 60	91.5	2.4	6.1	S	1.20
Bt_2	60- 80	89.3	2.1	8.6	LS	1.29
Bt_3	80-100	88.7	1.9	9.4	LS	1.30
BC	100-120	87.7	1.7	11.2	LS	1.42
X		91.2	2.3	6.6		1.28
SD		2.8	0.48	3.5		0.10
CV(%)		3.0	20.7	50		5.2

BD = Bulk Density, TC= Textural class; X = mean; SD= standard deviation; CV=Coefficient of variation

The soils of both locations were very deep, well aerated, and with no surface or subsurface stoniness. The uplands were used for intensive cultivation of crops (annual and perennial) with little or no yield; cassava, maize and yam were the major crops, supplemented with other vegetable crops during the farming season. The only crops cultivated in the swampland due to submergence in water for some periods of the year were water yam of various cultivars, vegetable crops, and oil palm, kola nut and rubber trees. Other features found in this area of study were hunting and gathering of food. The result also shows that clay content was higher in the swampland than in the upland soils, with $P = 0.05$. The swampland also had a significantly ($P<0.01$) higher silt content compared to the upland areas. Sand particles dominated the upland areas ($P = 0.05$) compared to the swampland. This reveals why infiltration rate was very high, and organic matter contents low in the upland compared to the swampland area. The swampland also presented a higher bulk density from the result in Table 1. Distinctive differences in both soils' textural classes were S (sand), SL (sandy loam), and SCL (sand clay loam).

Table 2: Chemical Properties of the Upland and Swampland soils

Horizon	Depth cm	pH H_2O	OC %	OM —	N —	P gkg^{-1}	Ca $Cmolkg^{-1}$	Mg —	K —	Na —	TEB —	ECEC —	BS —	AL —	H —	TEA —	Zn gkg^{-1}
Swampland																	
Ap	0-20	4.40	1.22	2.10	0.089	7.42	1.12	0.56	0.14	0.29	2.11	3.31	63.7	0.70	0.50	1.20	1.60
AB	20-40	4.20	0.93	1.62	0.074	6.20	0.96	0.50	0.09	0.22	1.77	3.07	58.8	0.80	0.50	1.30	1.60
Bt_1	40-60	4.90	0.74	1.21	0.056	5.89	0.88	0.48	0.07	0.16	1.59	2.89	55.0	0.90	0.40	1.30	0.60
Bt_2	60-80	3.80	0.49	0.83	0.041	5.64	0.72	0.40	0.05	0.13	1.30	2.70	48.1	1.00	0.10	1.40	0.30
Bt_3	80-100	3.50	0.26	0.47	0.025	5.56	0.66	0.32	0.04	0.11	0.13	2.73	41.4	1.30	0.30	1.60	1.10
BC	100-120	3.20	0.10	0.50	0.012	2.28	0.56	0.24	0.03	0.09	0.92	1.62	35.1	1.50	0.20	1.70	1.40
X		4.00	50.4	0.62	1.12	0.05	0.82	0.42	0.07	0.17	1.30	2.72	0.72	1.03	0.33	1.42	1.2
SD		0.53	0.39	0.54	0.18	1.57	0.21	0.11	0.69	0.69	0.64	0.53	9.91	0.28	0.02	0.25	0.51
CV(%)		13.0	62.2	48.2	37.0	28.5	25.0	31.0	40.0	26.2	97.0	17.5	19.5	49.0	27.0	6.06	42.0
Upland																	
Ap	0-20	4.50	1.15	1.98	0.084	6.44	0.96	0.64	0.09	0.23	1.92	2.92	65.8	0.60	0.40	1.00	1.20
`AB	20-40	4.20	0.94	1.62	0.076	5.73	0.80	0.56	0.07	0.19	1.62	2.92	55.5	0.80	0.50	1.30	1.10
Bt_1	40-60	4.10	0.70	1.21	0.052	5.28	0.72	0.48	0.06	0.14	1.40	2.90	18.3	0.10	0.40	1.50	0.90
Bt_2	60-80	3.40	0.48	0.83	0.039	4.85	0.64	0.40	0.05	0.11	1.20	2.80	42.9	1.20	0.40	1.60	1.20
Bt_3	80-100	3.20	0.33	0.47	0.031	3.12	0.48	0.32	0.03	0.09	0.92	2.62	35.1	1.40	0.30	1.70	2.00
BC	100-120	3.40	0.29	0.50	0.019	2.15	0.40	0.24	0.02	0.07	0.73	2.53	28.9	1.50	0.30	1.80	1.20
X		3.80	0.82	1.10	0.050	4.60	0.67	0.44	0.05	0.14	1.29	2.78	41.1	0.93	0.38	1.48	1.27
SD		0.34	0.36	0.56	0.02	1.60	0.39	0.14	0.05	0.08	0.59	0.16	2.09	0.49	0.16	0.27	0.34
CV(%)		8.99	43.8	50.0	42.6	35.0	58.0	31.0	93	57	45.4	5.61	5.10	52..0	43.0	18.0	18.0

SD=standard deviation; CV=Coefficient of variation; Ca^{2}=Calcium; Mg^{2}=Magnesium; Na^{-}=Sodium; K^{-}Potassium; TEB Total Exchangeable bases; Al Aluminum; H^{+} Hydrogen TEA=Total exchangeable acidity; ECEC Cation exchange capacity; BS Base Saturation %C=percentage carbon O.M;= organic matter; N= nitrogen, A.P= available phosphorus; and Zn = zinc

Chemical Properties

The chemical properties of the upland and swampland soils are presented in Table 2. The result shows little or no difference between both soils. The highest pH values were 4.4 and 4.5 for swampland and upland soils respectively, and these are said to be very strongly and strongly acid soils (Weil and Brady, 2015).

In Table 2, a high coefficient of variation was observed across the profiles in the upland soils compared to the swampland soils. This is in agreement with Parry *et al.* (2014) who also recorded variations in soil form and function across special levels in chemical properties. Secondly Bartlett and Harriss (1993) observed a pedogenetic variability in profile morphology, and in soil elements that occur in land forms, soil map units and ecology.

Conversely, the exchangeable bases in the upland and swampland soils were generally low with no significant difference. Base saturation (BS) and total exchangeable acidity (TEA) were the same as in exchangeable bases. The cation exchange capacity (ECEC) was significantly higher in the swampland soil than in the upland with P = 0.01. The organic matter content was relatively higher in the swampland than in the upland soils. This was probably as a result of alluvial deposits, remains of plants and animal deposits (Brady and Weil, 1999) and other weathered materials present in the swampland area. However, statistical analysis showed little or no significant difference between soils. The Ap horizon of swampland contained higher values of organic matter and total nitrogen content, with both having 0.089% N (nitrogen) and 2.10% O.M (organic matter). The available P (phosphorus) obtained were generally low in both the upland and swampland soils with the highest value of 7.42ppm at the Ap horizon, and 6.44ppm in the upland with no significant difference from the entire profile.

Zn (zinc) was the only micro nutrient element studied and was higher, though not significantly, in the upland soil than in the swampland. According to Julian (1999) the first stage in evaluating land and preparing a land-use plan is to gather data to classify land according to what it may be able to grow. From land use and capability classification, the results obtained from the morphological, physical and chemical properties show that the upland soil can support a variety of crops such as cereals, yam, cassava and vegetables, while crops like water yam, rice, late maize and vegetable crops can comfortably grow in the swampland area.

Land use recommendations involving the prescription of animal/crop production methods, fertilizer use and land management using data collected from soil tests and environmental evaluation in the area of study are essential. The people of the area have a land use pattern put in place by ancient fathers which should not be discontinued, but should be added to present-day practices by amendment to increase productivity. The low productivity however, is due to high pressure on land and increasing population.

There is therefore a need to improve farmers' understanding on the nature and properties of soils in the area vis-à-vis better soil management, soil tillage, and use of organic and inorganic fertilizer to promote plant debris restitution for sandy soils in particular in a cropping succession. On soils of low inherent fertility, improvement can be achieved only by raising the nutrient levels through the use of nutrient recycling, and application of inorganic and organic fertilizer (Lay, 1995).

In Abbi, there is little or no use of liming materials, and fertilizers; but measures should be taken by the farmers to adopt the use of improved agricultural farm practices. Soil acidity is a major problem, and should be taken care of through adequate liming of the soil before any planting season for the soil to be productive.

In Summary, the major differences between the upland and swampland soils were credited to the climatic conditions in the study area (excessive rainfall, sunshine, topography, vegetation, and prevailing winds), and human activities. The climatic conditions and human activities may also have determined the rate of decomposition, run-off and leaching of important nutrient element, and facilitated a chronic rate of degradation in both soils. However, the swamp erodibility relates to the properties of the soils and to the degree of slope of the area Brady and Weil (1999).

Conclusion and Recommendation

The study of the morphological, physical and chemical properties of upland and swampland soils of Abbi area show that the soils were low in nutrient status and dominated by sand particles. The low nutrient status of the upland and swampland soils and their comparative differences resulted from the cultural, practical, climatic conditions and other soil degradation processes in the area. It is therefore important that these soils be better managed through application of organic and inorganic amendments for sustainable crop yield and soil conservation.

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