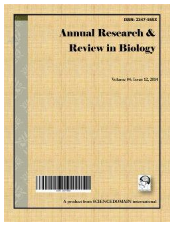

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Interaction between Some Soil Physicochemical Properties and Weather Variables on Sub-humid Tropical Rainforest Soils of Cross River State, Southeastern Nigeria

John, Kingsley[1*], Ayito, Esther O.[1] and Odey, Scholastica[1]

[1]Department of Soil Science, University of Calabar, Cross River State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study deals with the interaction between some soil physicochemical properties and weather variables on sub-humid tropical rainforest soils of Cross River State, Southeastern Nigeria. The study aims to determine the interactions between soil properties and weather variables of three land uses occurring on the tropical sandy soils. Soil samples were obtained from 10,000 m^2 of UNICAL Teaching and Research farm (Arable farm), Oil palm plantation and Forestry Teaching and Research farm (Forest and wetland land use) respectively. A total of twenty-seven (27) soil samples were collected with nine (9) samples from each land use at 20 cm depth and at an interval of 50 m with the aid a soil auger and core sampler. The weather variable data from 2012 to 2015 was obtained from NIMET. The result revealed that the sandy soils of Calabar are characterised with coarse, predominantly sandy loam and loamy sand texture with particle size ranging 610-850 g/kg for sand 80 to 240 g/kg for clay and 30-150 g/kg for silt; generally acidic with low to medium organic matter content, low ECEC, low nitrogen, medium available P (15.04 mg/kg, 8.65 mg/kg and 2.78 mg/kg for arable farm, oil palm plantation and forestry land uses respectively). The study showed

**Corresponding author: E-mail: johnkingsley0107@gmail.com;*

the correlation coefficient analysis between the high and low impact of weather variables on some soil properties and also recommended a proper management practice such as mulching to avoid direct impact of sunlight on the soil thereby ensuring maximum utilisation of tropical sandy soils of Calabar.

Keywords: Sub-humid tropical rainforest soils; organic matter; soil temperature; soil moisture; weather variables.

1. INTRODUCTION

Sub-humid tropical soils are predominantly sandy and are characterized by less than 18% clay and more than 68% sand in the first 100 cm of the solum found within the tropical zone of the world which is on the coordinate between latitude $32\,{}^{1}\!/_{2}°$ N and $23\,{}^{1}\!/_{2}°$ S topic of cancer and Capricorn respectively [1]. They are composed of essential and interrelated properties which make them useful in crop production and sustainability worldwide; their characteristics are a function of parent material and climatic factors which cause a gradual change based on different land uses [2]. Furthermore, the soils of Cross River State under this coordinates are formed from residual rocks deposited mostly in a marine environment, which are uplifted and tilted seaward with the part being submerged by Atlantic Continental Shelf at the coastal region of south-south, Nigeria [3]. Bulk trade, 1989 stated that they are deposits of insoluble materials primarily rock and soil particles, transported from land areas to the coast of rivers and oceans. When rivers overflow their banks in the rainy season, sediments are deposited around the river courses and are found along Akpabuyo, Anantigha and Calabar Metropolitan while at the central and northern part of Cross River State are colluvial deposits.

Soil physical properties such as soil moisture and temperature impact soil-plant relationships and shows to influence soil chemical, mechanical and biological processes. These soil physical properties (soil moisture and temperature) are in turn influenced by percent slope is independent of units, not only percent but degree also are factors, aspect, vegetative cover (biotic communities and spatial cover), relative humidity is air or porous space inside soil, runoff surface or subsurface, soil depth, soil texture, soil mineralogy, soil bulk density, elevation, latitude, percent possible sunshine annual, daylength daily, wind speed, temperature air, and precipitation as reported by Christopher [4]. Similarly, sub-humid tropical rainforest soils of Cross River State which falls within, are characterised with high soil temperature of 28.7°C [5] as a result of the impact of the mean annual air temperature of 28-33°C, impacting the circulation of potential evapotranspiration and thus has a large measure of control on the amount of effective rainfall [6]. The high rainfall of about 3000 mm per annum impacts a wet soil environment and also a relative humidity of 80-90% [7] results in the a significant slow rate of organic matter decomposition.

Some researchers have shown that the soils have poor structural stability, retain little water at high water potential and soil temperature while according to high pH, relative humidity and precipitation lowers the decomposition of organic matter and the activities of microorganism [8-10]. However, the low production capacity of the soils is played down to the erratic rainfall pattern and poor soil texture which has directly influenced nutrient availability and organic matter content. Also, Brady and Weil [11] reported that tropical rainforest soils are generally highly weathered soils due to high impact of atmospheric variables and are characterised by low soil fertility, sandy texture, acidic pH values, low contents of basic cations, organic carbon and low activity clays and are classified as Ultisols under USDA Soil Taxonomy [12].

Concerning the high agricultural potentials of the soils such as crops tree crops plantations (rubber, coconut, oil palm etc.) and arable crops such as vegetables, yam, cassava etc. and millions of humans who depend on the products. The major problem of the soils which are relevant to SDGs (Sustainable Development Goals) of zero hunger world by 2030 are those related to soil nutrient availability and fertility status maintenance which includes low organic carbon content, excessive soil moisture, high soil temperature with a high rate of precipitation of about 3000 mm per annum. The study was aimed to determine the physicochemical properties of the sandy soils of sub-humid tropical rainforest under three different land uses; to determine the relationship between soil organic matter, soil moisture content, pH and sunshine hours, relative humidity, evapotranspiration, precipitation and air and soil temperature using correlation coefficients and make recommendations for easy determinations.

2. MATERIALS AND METHODS

2.1 Study Location

Cross River State lies between latitude $4^{o}27^{'}$ and $6^{o}45^{'}$ North and longitude $7^{o}15^{'}$ and 9° 28^{1} East of the Greenwich Meridian. The study was carried out on three different land uses located at University of Calabar which were arable farm (longitude $8^{o}21^{'}$ E and latitude $4^{o}57^{'}$ N at 36 m asl), Oil palm plantation (longitude $8^{o}20^{'}$ E and latitude $4^{o}56^{'}$N at 18 m asl) and secondary forest with wetland points on a coordinates of longitude $8^{o}20^{'}$ E and latitude $4^{o}56^{'}$ N at 11m asl, all within the University of Calabar Teaching and Research Farms. The map of the study area is shown in Fig. 1. The study area was characterised by a humid tropical climate with distinctive wet and dry seasons. The rainy season spans between March and November while dry seasons range between December and March (Table 1). Within the dry period, harmattan weather condition occurs between December and February which is characterised by a dry, dusty wind with very low night temperatures. Annual rainfall is between 2700 mm and 4,000 mm, and average temperature ranges from 22 to 31°C.

2.2 Field Study

The study was carried out on three land use which are 100 m x 100 m UNICAL Teaching and Research Farm, (Arable land use), 100 m x 100 m UNICAL Oil palm plantation (plantation) and UNICAL Forestry Teaching and Research Farm (forest and wetland land use). The Soil pH and the temperature was obtained directly from the field using the "4 in 1" soil survey equipment probe which is multifunctional field equipment; the probe was inserted to a depth of 20 cm in all the study locations.

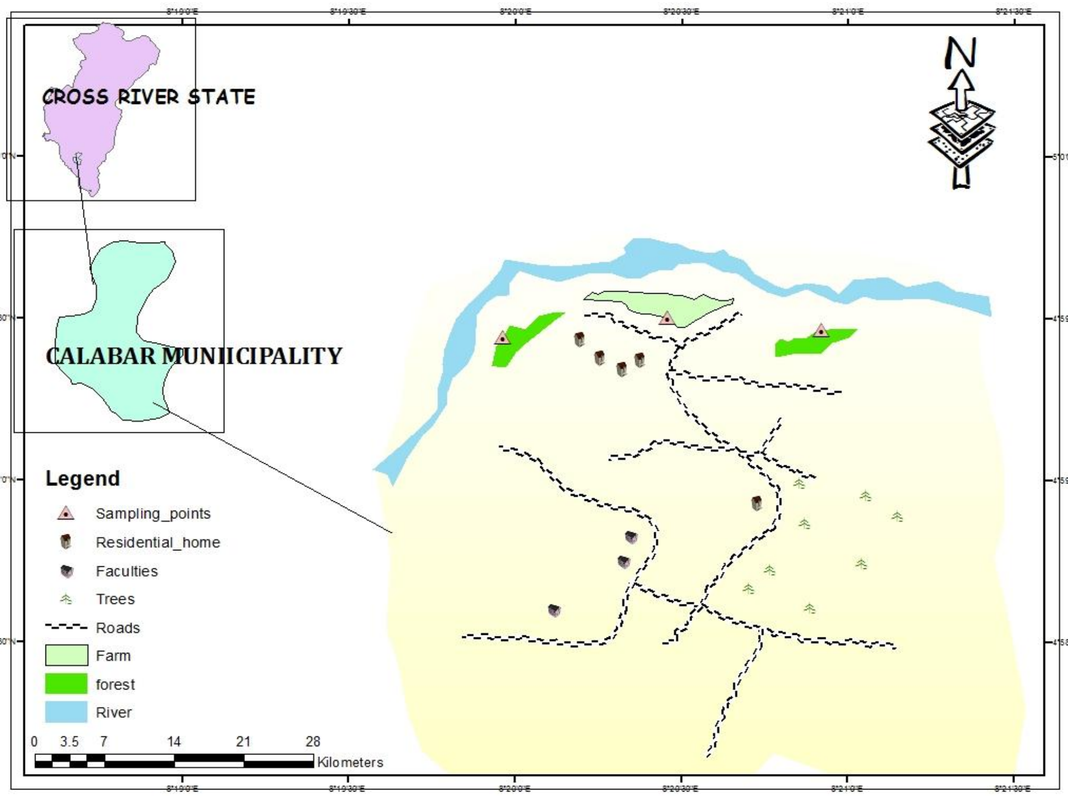

Fig. 1. Map of the University of Calabar showing study location.
Source: PEDOENVIRON [13]

2.3 Soil Sampling

A fixed rigid grid method of sampling was adopted in the study. The 3 ha study sites each measuring 100 m x 100 m were cut into transverses at 50 m intervals with the aid of soil surveying equipment. Using a core sampler twenty-seven (27) core soil samples were collected from the three study sites with nine (9) samples from each land use and these were properly stored in a core sampler kit to avoid moisture loss. Using the soil auger, twenty-seven (27) composite soil samples were collected from the surface, 0-20 cm with nine (9) from each of the 3 locations at 50 m intervals. The samples were stored in a well-labelled polyethene bags and transported to the laboratory for analysis. The collected soil samples were air dried and passed through a 2 mm sieve. Particle size distribution of the less than 2 mm fine-grain fractions was determined by the hydrometer method as described by Gee and Bauder [14]. Soil pH was determined in a 1:2.5 soil/water suspensions. The soil organic carbon was determined by the Walkley and Black method described by Nelson and Sommers (1982). Exchangeable bases were determined by the method of Thomas [15]. Base saturation was estimated as the sum of exchangeable bases divided by the effective cation exchange capacity.

2.4 Statistics

Data collected were subjected to discrete statistics. Correlation coefficient analysis was also carried out to find the magnitude and nature of the association between the parameters using SPSS version 21 statistical software.

3. RESULTS AND DISCUSSION

3.1 Soil Physical Properties

The results of the soils physical properties of the three land use which are an arable farm, oil palm plantation and forestry are presented in Tables 2, 3 and 4 respectively. The sand component of the soils of the land uses (Arable farm, Plantation and Forestry) ranged from 730 to 790 gkg^{-1}, 790 to 850 gkg^{-1} and 640 to 810 gkg^{-1} respectively. The mean values of the sand content obtained are 760 gkg^{-1}, 804.4 gkg^{-1} and 710 gkg^{-1} respectively while the highest sand content was obtained at oil palm plantation and the lowest at forestry. The clay section of the soils under the different land uses ranged from 80 to 240 g/kg with high clay value obtained at soil under forestry land use and low clay fraction at soil under oil palm plantation as result of high impact of rainfall leading to soil erosivity [16] while the silt fraction of soil under study varies from 30-150 g/kg with the highest value obtained at forestry and the lowest at oil palm plantation. The soils are coarse textured with high sand content of 700 g/kg; giving the dominant texture of the soils were sandy loam and loamy sand. This is consistent with the result obtained at Obudu cattle ranch and Onwu river floodplain tropical sandy soil [17] and [18].

The Bulk density values of the soils varied from 1.01 to1.6 g cm^{-3}. Arable and forestry sites were observed to have recorded a similar mean value of 1.42 g cm^{-3} while oil palm plantation was 1.36 g cm^{-3}. The mean of the volumetric moisture content of three land uses are 0.072 cm^3cm^{-3}, 0.097 cm^3cm^{-3} and 0.1 cm^3cm^{-3} with lowest value obtained at both arable farm and oil palm plantation with 0.072 and 0.097 cm^3cm^{-3} which is similar to the findings of Sakai *et al.* [19] that harvesting operation will result to compaction thereby resulting to reduction in volumetric moisture content of the soil.

3.2 Soil Chemical Properties

The results of the soil chemical properties of the three land use which are an arable farm, oil palm plantation and forestry are presented in Tables 5, 6 and 7. The mean of the organic matter content for the three study location ranged from 2.18% to 2.24%. These findings are consistent with the works of Udo [20] and Enwezor *et al*. [21], who reported mean of 1.45% and 1.03% for soils formed on coastal plain sands in Uyo, Akwa Ibom State, Nigeria. The highest organic matter was obtained at both arable and oil palm plantation with a mean value of 2.24%, which may be due to the system of crop management and is consistent with the report by El-shakweer *et al*. [22]. The result obtained is similar to the report by Dengiz *et al.* [23] who reported the effect of soil depth and land use type on organic matter content. The total nitrogen content of the soils ranged from 0.01 to 0.14% as most values were below 0.45% [24] established for productive soils in the ecological zone. This low content of total nitrogen could be ascribed to rapid microbial activities, leaching of nitrates and crop removal in the soil environment.

Table 1. Weather variables from 2012 to 2015 of the study area

	Relative Humidity (%)				Min. Temperature (^{o}C)				Max. Temperature (^{o}C)				Rainfall (mm)				Evapotranspiration				Sunshine Hours			
Month/ Year	**2012**	**2013**	**2014**	**2015**	**2012**	**2013**	**2014**	**2015**	**2012**	**2013**	**2014**	**2015**	**2012**	**2013**	**2014**	**2015**	**2012**	**2013**	**2014**	**2015**	**2012**	**2013**	**2014**	**2015**
JANUARY	86	80	82	67	22.5	23.8	22.1	21.6	32	33	31.3	33.1	32.6	1.41	81.1	0	3.6	3.4	4.2	6.1	5.3	5.5	5.8	5.0
FEBRUARY	82	83	84	84	23.6	22.9	23.2	23.7	31.5	33	33.1	33.3	376.7	83.7	61.1	96.6	2.3	3.0	3.9	3.7	4.0	5.1	4.9	4.3
MARCH	82	87	87	85	25.1	23.9	22.6	23.4	33.7	31.9	31.9	32	38.0	23.14	366.2	143.1	3.1	2.2	2.8	2.7	3.8	3.5	3.5	4.7
APRIL	87	84	84	81	23.4	23.7	22.9	23.5	32.1	32	32.1	32.5	99.9	286.9	245	100.2	2.8	2.7	3.0	3.2	4.3	5.0	3.8	4.2
MAY	87	84	84	84	23.4	23.7	22.9	23.3	31.7	31.6	31.6	31.8	439.4	466.9	332.2	401	2.6	2.5	2.8	2.7	4.2	4.8	3.9	4.0
JUNE	92	89	87	92	23.4	23.8	22.7	22.6	30.3	29.8	30.2	28.9	398.8	459.8	220	678.7	2.1	1.9	2.3	1.5	3.3	2.4	2.2	1.9
JULY	90	91	92	91	23.1	23	22.2	22.8	28	27.9	27.8	28.2	637.1	477	249.9	386.6	1.2	1.5	1.3	1.3	1.6	1.1	1.1	1.5
AUGUST	90	91	90	93	22.9	29.9	21.9	22.7	28.4	27.4	28.3	28	861.3	411.1	410.3	422	1.4	1.7	1.2	1.0	1.9	1.1	2.0	1.3
SEPTEMBER	90	91	90	92	22.9	23.3	22.1	22.6	29.1	28.8	29	30.2	619.4	340.4	501.5	476.8	1.4	1.7	1.5	1.3	2.4	1.8	2.4	2.2
OCTOBER	87	88	89	89	22.5	22.5	21.1	22.9	30.3	29.9	30.1	30.1	410.4	306.2	136.8	208.4	1.9	2.3	1.8	1.8	3.7	3.3	2.9	3.7
NOVEMBER	84	87	88	86	23.7	23.3	22.2	23.	31	30.6	31.3	31.8	126.5	220.9	136.8	392	2.0	2.0	2.1	2.3	3.9	3.5	4.5	4.0
DECEMBER	83	82	80	68	23.4	22.1	22.3	21.4	32.1	30.8	32	32.9	30.6	81.1	18.3	0	2.9	3.0	3.6	2.6	5.4	5.3	4.8	4.3
Mean	**86.33**	**86.42**	**86.45**	**84.33**	**23.45**	**23.11**	**22.4**	**22.79**	**30.85**	**30.6**	**30.68**	**31.07**	**4070.7**	**3158.5**	**2759.3**	**3305.4**	**2.28**	**2.325**	**2.54**	**2.52**	**3.65**	**3.53**	**3.48**	**3.425**

Source: NIMET [7]

Table 2. Soil Physical properties of Arable crop farm at depth of 0-20 cm (N =9)

CODE	Lat. (N˚)	Long (E˚)	Alt (M)	Sandy	Silt g/kg	Clay	Texture	B.D (gcm^{-3})	VMC (cm^3cm^{-3})
AF – 1	04˚57.020'	008˚ 21.270'	37	740	140	120	SL	1.37	0.0519
AF – 2	04˚57.032'	008˚ 21.255'	36	790	90	120	SL	1.46	0.0538
AF – 3	04˚57.042'	008˚ 21.229'	34	760	120	120	SL	1.34	0.0914
AF – 4	04˚57.023'	008˚ 21.219'	34	730	150	120	SL	1.54	0.0314
AF – 5	04˚57.010'	008˚ 21.241'	36	760	110	130	SL	1.2	0.1169
AF – 6	04˚56.010'	008˚ 21.241'	37	780	110	110	SL	1.4	0.0402
AF – 7	04˚56.979'	008˚ 21.244'	38	740	80	180	SL	1.6	0.1109
AF – 8	04˚56.992'	008˚ 21.228'	37	750	110	140	SL	1.4	0.0932
AF – 9	04˚57.003'	008˚ 21.208'	35	790	30	180	SL	1.5	0.0578
			MEAN	**760**	**104.4**	**135.6**		**1.42**	**0.0720**
			SEM	**7.45**	**11.80**	**8.84**		**0.04**	**0.0110**
			CV%	**2.94**	**33.89**	**19.56**		**8.34**	**43.8200**
			RANGE	**730-790**	**30-150**	**120-180**		**1.2-1.6**	**0.031-0.12**

Table 3. Soil Physical properties of Oil palm plantation site sampled at depth 0-20 cm (N =9)

CODE	Lat. (N˚)	Long (E˚)	Alt (M)	Sandy	Silt	Clay	Texture	B.D (gcm^{-3})	VMC (cm^3cm^{-3})
OPP -1	04˚ 56.447'	008˚20.946'	13	850	70	80	LS	1.47	0.0709
OPP -2	04˚ 56.515'	008˚20.931'	22	810	100	90	LS	1.41	0.1007
OPP -3	04˚ 56.488'	008˚20.893'	15	790	90	120	SL	1.43	0.0928
OPP -4	04˚ 56.440'	008˚20.901'	10	800	90	110	SL	1.49	0.0904
OPP -5	04˚ 56.476'	008˚20.934'	21	800	90	110	SL	1.01	0.1001
OPP -6	04˚ 56.453'	008˚20.919'	19	810	80	110	SL	1.47	0.0954
OPP -7	04˚ 56.436'	008˚20.900'	15	790	70	140	SL	1.30	0.0771
OPP -8	04˚ 56.459'	008˚20.895'	19	790	100	110	SL	1.29	0.1011
OPP -9	04˚ 56.485'	008˚20.891'	21	800	80	120	SL	1.36	0.1460
			MEAN	**804.4**	**85.6**	**110**		**1.36**	**0.0970**
			SEM	**6.26**	**3.77**	**5.77**		**0.05**	**0.0071**
			CV%	**2.34**	**13.21**	**15.75**		**11.02**	**21.7800**
			RANGE	**790-850**	**70-100**	**80-120**		**1.01-1.49**	**0.0709-0.147**

Table 4. Soil Physical properties of Forestry Site at depth 0-20 cm (N =9)

CODE	Lat. (N˚)	Long (E˚)	Alt (M)	Sandy	Silt	Clay	Texture	B.D (gcm^{-3})	VMC (cm^3m^{-3})
FTRF - 1	04˚ 56.284'	008˚20.971'	15	740	140	120	SL	1.46	0.07
FTRF - 2	04˚ 56.281'	008˚20.994'	17	710	140	150	SL	1.38	0.11
FTRF - 3	04˚ 56.278'	008˚21.022'	19	750	120	130	SL	1.29	0.08
FTRF - 4	04˚ 56.259'	008˚21.015'	8	720	130	150	SL	1.42	0.08
FTRF - 5	04˚ 56.260'	008˚20.996'	4	660	120	220	SCL	1.62	0.17
FTRF - 6	04˚ 56.263'	008˚20.967'	12	640	120	240	SCL	1.25	0.10
FTRF - 7	04˚ 56.238'	008˚20.966'	10	650	140	210	SCL	1.47	0.08
FTRF - 8	04˚ 56.238'	008˚20.992'	3	810	110	80	LS	1.32	0.17
FTRF - 9	04˚ 56.236'	008˚21.014'	4	710	90	200	SL	1.53	0.06
			Mean	**710**	**123.3**	**166.7**		**1.42**	**0.10**
			Sem	**18.10**	**3.77**	**17.80**		**0.04**	**0.01**
			CV%	**7.65**	**33.89**	**17.03**		**8.41**	**40.98**
			Range	**640-810**	**90-140**	**120-240**		**1.29-1.53**	**0.06-0.17**

Keys: ***B.D*** *= Bulk density,* ***VMC*** *= volumetric moisture content* ***Sem*** *= standard mean error,*
CV *= coefficient of variation*

Table 5. Soil chemical properties of Arable crop farm sampled at depth of 0-20cm

CODE	Lat. (N˚)	Long (E˚)	Alt (M)	Org. C (%)	Org. m (%)	TN (%)	Avali. P (mg/kg)	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	TEB cmol/kg	Al^{3+}	H^{+}	EA	ECEC	BS (%)
AF - 1	04˚ 57.020'	008˚21.270'	37	2.6	4.48	0.21	26.63	4.6	5.2	0.11	0.09	10.00	0.28	0.56	0.84	10.84	92.25
AF - 2	04˚ 57.032'	008˚21.255'	36	0.3	0.51	0.01	11.5	4.4	0.2	0.10	0.07	4.77	0.56	0.48	1.04	5.81	82.09
AF - 3	04˚ 57.042'	008˚21.229'	34	1.7	2.93	0.14	15.5	4.0	2.0	0.11	0.08	6.19	0.84	0.84	1.68	7.87	78.65
AF - 4	04˚ 57.023'	008˚21.219'	34	1.3	2.24	0.09	18.5	5.0	1.4	0.10	0.06	6.56	1.28	1.04	2.32	8.88	73.87
AF - 5	04˚ 57.010'	008˚21.241'	36	1.2	2.07	0.09	13.75	4.0	0.2	0.09	0.07	4.36	1.00	0.56	1.56	5.92	73.65
AF - 6	04˚ 56.010'	008˚21.241'	37	1.1	1.90	0.08	14.63	4.0	0.6	0.09	0.08	4.77	0.68	0.76	1.44	6.21	76.81
AF - 7	04˚ 56.979'	008˚21.244'	38	0.8	1.38	0.07	6.13	4.2	2.8	0.11	0.07	7.18	0.92	0.68	1.60	8.78	81.78
AF - 8	04˚ 56.992'	008˚21.228'	37	1.5	2.59	0.12	15.00	5.2	0.2	0.10	0.08	5.58	0.72	0.64	1.36	6.94	80.4
AF - 9	04˚ 57.003'	008˚21.208'	35	1.2	2.06	0.08	13.75	4.8	0.8	0.09	0.07	5.76	0.8	0.52	1.32	7.08	81.35
			Mean	**1.3**	**2.24**	**0.099**	**15.04**	**4.47**	**1.49**	**0.10**	**0.074**	**6.13**	**0.79**	**0.68**	**1.46**	**7.59**	**80.09**
			sem	**0.4**	**1.19**	**0.003**	**30.24**	**0.21**	**2.75**	0.008	0.0088	**1.71**	**0.079**	**0.032**	**0.18**	**2.78**	**31.17**
			CV%	**0.46**	**0.45**	**0.52**	**0.34**	**0.097**	**1.05**	**0.082**	**0.011**	**0.26**	**0.34**	**0.25**	**0.27**	**0.2**	**0.065**
			Range	**0.3-2.6**	**0.51-4.48**	**0.01-0.14**	**6.13-26..63**	**4-5.2**	**0.2-5.2**	**0.09-0.11**	**0.07-0.09**	**4.77-10.00**	**0.28-1.28**	**0.48-1.04**	**0.84-1.68**	**5.92-10.84**	**80.09-92.25**

Keys: ***TN =*** *Total nitrogen, Org. C = Organic carbon, Org. m = Organic matter, TEB = Total Exchangeable bases, EA = Exchangeable acidity, Sem = standard mean error, CV = Coefficient of Variation*

Table 6. Soil chemical properties of Oil palm plantation sampled at depth of 0-20cm

CODE	Lat. (N˚)	Long (E˚)	Alt (M)	Org. C (%)	Org. m (%)	TN (%)	Avail. P(mg/kg)	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	TEB cmol/kg	Al^{3+}	H^{+}	EA	ECEC	BS (%)
OPP -1	04˚ 56.447'	008˚20.946'	13	1.4	2.41	0.1	14.5	3.8	2.2	0.08	0.07	6.15	1.04	0.56	1.6	7.75	79.35
OPP -2	04˚ 56.515'	008˚20.931'	22	1.6	2.76	0.12	19.88	2.2	3.6	0.08	0.06	5.94	0.56	0.48	1.04	6.98	85.1
OPP -3	04˚ 56.488'	008˚20.893'	15	1.2	2.07	0.09	8.00	6.0	1.6	0.1	0.07	7.77	0.28	0.88	1.16	8.93	87.01
OPP -4	04˚ 56.440'	008˚20.901'	10	0.9	1.55	0.08	4.25	2.6	2.8	0.09	0.07	5.56	0.96	0.24	1.2	6.76	82.25
OPP -5	04˚ 56.476'	008˚20.934'	21	1.2	2.07	0.09	5.25	5.6	1	0.08	0.07	6.75	0.8	0.6	1.4	8.15	82.69
OPP -6	04˚ 56.453'	008˚20.919'	19	1.2	2.07	0.08	8.88	4.4	1.4	0.08	0.06	5.94	1.04	0.64	1.68	7.62	77.95
OPP -7	04˚ 56.436'	008˚20.900'	15	1.3	2.24	0.09	7.75	4.2	1.4	0.09	0.07	5.76	1.32	0.68	2	7.76	74.23
OPP -8	04˚ 56.459'	008˚20.895'	19	1.5	2.59	0.11	2.00	3.6	1.2	0.08	0.07	4.95	1.4	1.28	2.68	7.63	64.88
OPP -9	04˚ 56.485'	008˚20.891'	21	1.4	2.41	0.1	7.38	4.2	0.4	0.09	0.06	4.75	1.08	1.04	2.12	6.87	69.14
			Mean	1.3	2.24	0.096	8.65	4.07	1.73	0.086	0.07	5.95	0.94	0.71	1.65	7.6	78.06
			sem	0.043	0.13	0.12	29.79	1.52	0.96	0.0072	0.005	0.91	0.12	0.31	0.53	0.68	54.7
			CV%	0.15	0.16	0.13	0.59	0.29	0.53	0.08	0.07	0.14	0.35	0.41	0.3	0.084	0.89
			Range	0.9-1.6	1.55-2.76	0.08-0.12	2.00-19.88	2.00-4.4	0.4-3.6	0.08-0.1	0.06-0.07	4.95-7.77	0.28-1.32	0.24-1.28	1.04-2.68	6.98-8.93	77.95-87.01

***Keys: TN =** Total nitrogen, Org. C = Organic carbon, Org. m = Organic matter, TEB = Total Exchangeable bases, EA = Exchangeable acidity, Sem = standard mean error, CV = Coefficient of Variation*

Table 7. Soil chemical properties of Forestry sampled at depth of 0-20cm

CODE	Lat. (N˚)	Long (E˚)	Alt (M)	Org. C (%)	Org. m (%)	TN (%)	Avali. P(mg/kg)	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	TEB cmol/kg	Al^{3+}	H^{+}	EA	ECEC	BS (%)
FTRF - 1	04˚56.284'	008˚20.971'	15	0.8	1.38	0.08	1.50	5.2	1.6	0.11	0.09	7.0	0.28	0.2	0.48	7.48	93.58
FTRF - 2	04˚56.281'	008˚20.994'	17	1.7	2.93	0.13	2.75	6.4	1.0	0.12	0.09	7.61	0.2	0.5	0.5	8.11	93.83
FTRF - 3	04˚56.278'	008˚21.022'	19	1.4	2.41	0.11	5.38	3.0	3.6	0.08	0.06	6.74	1.44	2.4	2.4	9.14	73.74
FTRF - 4	04˚56.259'	008˚21.015'	8	1.2	2.07	0.11	2.88	3.6	2.8	0.09	0.07	6.56	1.0	1.32	1.32	7.88	83.25
FTRF - 5	04˚56.260'	008˚20.996'	4	1.4	2.41	0.11	1.13	3.8	1.8	0.08	0.06	5.74	1.56	2.36	2.36	8.1	70.86
FTRF - 6	04˚56.263'	008˚20.967'	12	1.5	2.59	0.12	1.25	3.8	1.4	0.07	0.06	5.33	2.84	4.6	4.6	9.9	53.68
FTRF - 7	04˚56.238'	008˚20.966'	10	1.6	2.76	0.13	2.00	4.6	1.8	0.09	0.07	6.56	2.48	4.04	4.04	10.6	61.89
FTRF - 8	04˚56.238'	008˚20.992'	3	0.9	1.55	0.08	6.63	4.2	2.4	0.07	0.06	6.73	0.24	0.72	0.72	7.45	90.34
FTRF - 9	04˚56.236'	008˚21.014'	4	0.9	1.55	0.07	1.50	3.6	1.6	0.06	0.05	5.31	2.44	3.64	3.64	8.95	59.33
			Mean	1.26	2.18	0.1	2.78	4.24	2.0	0.086	0.068	6.39	1.39	2.19	2.23	8.62	75.61
			Sem	0.11	0.33	0.0005	3.81	1.05	0.64	0.00037	0.00019	0.61	1.06	2.64	2.51	1.21	236.31
			CV%	0.25	0.37	0.2	0.66	0.23	0.377	0.21	0.19	0.11	0.7	0.62	0.67	0.12	0.19
			Range	0.8-1.7	1.38-2.76	0.07-0.13	1.13-5.38	3.00-6.4	1.00-3.6	0.07-0.9	0.05-0.09	5.33-7.61	1.00-2.84	0.2-4.6	0.48-4.6	8.1-10.6	61.89-93.83

Table 8. The matrix of Pearson correlation coefficient (r) between the mean of selected soil properties and some weather variables at unical teaching and research farm for 2012

	SOC	GMC	pH(H_20)	SH	RH	EVT	RF	Min.T	Max.T	T.Soil	BS	pH (Dry)
SOC	1.00											
GMC	0.026	1.00										
pH(H_20)	-0.093	-0.276	1.00									
SH	0.358	-0.104	0.391	1.00								
RH	0.044	-0.185	-0.475	-0.646**	1.00							
EVT	0.510	-0.103	0.558	0.890**	-0.595*	1.00						
RF	-0.406	0.150	-0.386	0.860**	0.687*	-0.853**	1.00					
Min.T	-0.137	0.253	-0.309	0.110	-0.536	-0.296	-0.406	1.00				
Max.T	0.293	-0.020	0.458	0.834**	-0.760**	0.906**	-0.875**	0.583*	1.00			
T.Soil	0.198	-0.212	-0.306	0.484	-0.171	0.328	-0.240	-0.240	0.0450	1.00		
BS	-0.009	-0.013	0.714**	0.312	-0.304	0.233	-0.296	-0.296	0.018	0.270	1.00	
pH (Dry)	0.105	-0.550**	0.060	c	c	c	c	c	c	c	-0.018	1.00

Table 9. The matrix of Pearson correlation coefficients (r) between mean of selected soil properties and some weather variables at unical teaching and research farm for 2015 (n=27, for 3 land uses)

	SOC	GMC	pH(H_20)	SH	RH	EVT	RF	Min.T	Max.T	T.Soil	BS	pH (Dry)
SOC	1.00											
GMC	0.026	1.00										
pH(H_20)	-0.093	-0.276	1.00									
SH	0.341	-0.104	0.400	1.00								
RH	-0.404	-0.185	-0.479	-0.743**	1.00							
EVT	0.475	-0.103	-0.648*	0.784**	-0.802*	1.00						
RF	-0.440	0.150	-0.495	0.777**	0.794*	-0.707**	1.00					
Min.T	-0.137	0.253	-0.059	0.017	-0.563	-0.202	-0.179	1.00				
Max.T	0.172	-0.020	0.473	0.938**	-0.773**	0.787**	-0.756**	0.007	1.00			
T.Soil	0.198	-0.212	-0.306	0.377	-0.681*	0.572	-0.539	-0.632*	0.350	1.00		
BS	-0.009	-0.013	0.714**	0.244	-0.584*	0.481	-0.426	-0.716**	0.280	-0.430	1.00	
pH (Dry)	0.105	0.276	0.060	c	c	C	c	c	c	c	-0.018	1.00

**. Correlation is significant at 5% level*
***. Correlation is significant at 1% level*
c. Cannot be computed because at least one of the variables is const

The means of other nutrients content of the soils of the different land uses (Arable crop farm, Oil palm plantation and Forestry) under investigation were 15.04 mg/kg, 8.65 mg/kg and 2.78 mg/kg for available P respectively. This result is similar with the report by Göl et al. [25]. The mean values of the total exchangeable bases of the land uses were 6.13 cmol/kg, 5.95 cmol/kg and 6.39 cmol/kg while mean value of the exchangeable acidity were 1.46 cmol/kg for arable crop farm. 1.65 cmol/kg for oil palm plantation and 2.23 cmol/kg for forestry and the mean of the effective cation exchange capacity obtained were 1.46 cmol/kg for arable crop farm, 7.60 cmol/kg for oil palm plantation and 8.62 cmol/kg for forestry which indicates that the ECEC values of the soils were low for both arable crop farm and oil palm plantation and medium for forestry. Finally, the base saturation means values of the soil of the three land uses were 80.09% for arable crop farm, 78.06% for oil palm plantation and 75.31% forestry which indicates that the soils have high base saturation.

3.3 The Correlation Coefficient between Some Selected Soil Properties and Some Weather Variables for 2012 and 2015

Table 8 shows the coefficient correlation between some selected soil properties and some weather variables at UNICAL teaching and research farm for 2012. Relative humidity (RH) negatively and significantly correlated with Sunshine hour, SH (r = -0.646**) which indicates that the increase in relative humidity will result in the decrease of sunshine hours while evapotranspiration (ET) was positively and significantly correlated with Sunshine hours (r = 0.890**) and moderate negatively considerably correlated with relative humidity with (r = -0.595*) while rainfall is positively significant correlated with sunshine hours (r = 0.890**), relative humidity (r = 0.687*) and negatively and significant correlated with evapotranspiration (r = -0.853**) while maximum temperature is positively and significantly correlated with sunshine hours, evapotranspiration and minimum temperature (r = 0.834**, 0.906** and 0.583* respectively) and also negatively significant with relative humidity (r = -0.760** and rainfall -0.583*. Base saturation is positively and significantly correlated with pH in water (r = 0.714**) while pH (dry) is negatively and significantly correlated with gravimetric moisture content (r = -0.550**). Finally, soil temperature negatively significant correlated with relative humidity, minimum temperature and positively significant with rainfall (r = -0.681*, 0.539* and -0.632* respectively).

Table 9 shows the coefficient correlation between some selected soil properties and some weather variables at UNICAL teaching and research farm for 2015. The results show that relative humidity is negatively and significantly correlated with Sunshine (r = -0.646**) while evapotranspiration is positively and significantly correlated with pH in water and with sunshine hour was negatively significant correlated (r = 0.648*, 0.794**, -0.707**). The maximum temperature is positive and significantly correlated with a sunshine hour and evapotranspiration (r = 0.938** and 0.787** respectively) and also negative significantly correlated with relative humidity and rainfall (r = -0.773* and -0.756**). Base saturation was positively and significantly correlated with pH in water (r = 0.714**) and negatively and significantly correlated with rainfall and minimum temperature (r = -0.756** and r = -0.716** respectively). And finally, soil temperature negatively correlated with minimum temperature (r = -0.676*).

4. CONCLUSION

Sub-humid tropical rainforest soils are high in sand fraction and low in silt and clay contents which suggest low organic matter content which acts as cementing and high impact of rainfall on the soil the particles thereby making the topsoil thin.

The studies showed that there was a positive and negative significant effect between weather variables and soil properties. pH (in water) showed a significant positive correlation with base saturation, gravimetric moisture content showed a significant negative correlation with dry soil pH ($p < 0.1$) Sunshine hours showed a negatively significant correlation with relative humidity (at $p < 0.005$ and $p < 0.1$) and positive significant correlation with evapotranspiration, rainfall and maximum temperature (at both $p < 0.005$ and $p < 0.1$). Relative humidity showed negative significant with evapotranspiration, minimum temperature and maximum temperature. Evapotranspiration showed a significant correlation with rainfall and maximum temperature, high rainfall impacts the soil properties negatively and provides soil moisture during evapotranspiration. The study also revealed the negative relationship between rainfall and maximum temperature and a positive and negative relationship between minimum temperature and soil temperature respectively.

Therefore for optimum and continuous utilisation of soils of the sub-humid tropics of Cross River State, adequate educational enlightenment should be provided to the local farmer on good farming practices such as crop rotation, cover cropping, agroforestry, wet and dry mulching to help conserve the soils and thereby protecting from the direct impact of weather variables.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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