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Soil physico-chemical properties as affected by flood and erosion in Abakaliki, Southeastern Nigeria

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Abstract

The aim of this study was to determine the physical and chemical properties of soil as affected by flood and erosion in Abakaliki Southeastern Nigeria. Sites selected for the study were: Control (arable land), fallowed floodplain, cultivated floodplain and erosion site. Five auger and core replicate soil samples were collected from each site at the depth of 0 – 30 cm and analysed for particle size distribution, bulk density, total porosity, moisture content, dispersion ratio, modified clay ratio, erosion ratio, erodibility factor, soil loss, lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), ammonium (NH_4^+), nitrate (NO_3^-), sulphate (SO_4^{2-}) and organic matter. Results from the study showed that the experimental sites were sandy loams which are easily vulnerable to erosion as a result of its properties. Physical properties indicated that the order of susceptibility to erosion was arable land < fallowed floodplain < cultivated floodplain < erosion site. The results of chemical properties showed that cations such as NH_4^+ were higher in floodplains than arable land whereas anions such as NO_3^- and SO_4^{2-} were higher in arable land than floodplains. This phenomenon might be attributed to the fact that unlike NH_4^+ which binds strongly to clay micelle, NO_3^- and SO_4^{2-} are anions and can be easily leached beneath root zone (0-30 cm) because of their negative charges. Moreover, the erosion site had the poorest fertility and productive status when compared to other sites. The results also, showed that the floodplains have inherent capacity to boost crop productivity and the nutrients leached during flooding can be recovered through fallowing the floodplains for some periods before using them for crop production.

Keywords: Erosion, Deposition, Floodplain, Leaching and transportation

Introduction

The interactions of human activities with severe climatic factors have resulted in land degradation such as soil erosion (Isikwue et al., 2012). Soil erosion by flood is a major problem threatening the social and economic lives of the people of Abakaliki, Ebonyi State Nigeria. Increasing demand for land as a result of population increase and food scarcity has made farmers in Abakaliki to farm in marginal lands such as lands susceptible to erosion and flooding (Quansah, 1997; Sanchez et al., 1997). Water erosion is defined as loosening, removal and transport of soil material from one place to another by water (Isikwue et al., 2012). Erosion involves detachment, transportation and deposition.

Flood is defined as a very large amount of water that has overflowed from a source such as a river, a pond or a broken pipe to cover a previously dried area. It occurs when soil and vegetation cannot absorb all the water; water then runoff the land in quantities that can not be carried in stream channels or retained in natural ponds and constructed reservoirs such as dams and levees (Njoku, 2013). Flood can result in shortage of crop yields as a result of drowning and suffocation of crops in floodplains (Powell, 2009). It also contributes positively to soil properties through the provision of nutrients that may be lacking in the soil (Stephen, 1993; O'Connor et al., 2004). Wetting of the floodplains by floods releases immediate nutrients that were left over from the last flood and those that result from the rapid decomposition of organic matter that has accumulated during the flood. Njoku et al. (2011) observed that total porosity and moisture contents were higher in a soil after flooding than before flooding whereas bulk density of soil was lower after flooding than before flooding.

Soil erodibility is the susceptibility of soil to erosion and it depends on various soil properties such as textures, soil aggregation, shear strength, moisture content, permeability, organic content, chemical content, soil profile, surface stoniness, detaching/ transportation force, etc. (Ezeabasili, 2014). Igwe (2001) stated that dispersion ratio was a good index for predicting erodibility in some soils of southeastern Nigeria. Therefore, this study aimed at determining soil physico-chemical properties as affected by flood and erosion in Abakaliki Southeastern Nigeria.

Material and Methods

Study area

The study was carried out at floodplains and erosion site along Ebonyi River in Abakaliki southeastern Nigeria. These floodplains are among the major sources of dry season vegetable crops for Ebonyi people especially those residing at Abakaliki urban. Abakaliki lies at latitude 5^o 35'N – 6^o 45'N and longitude 7^{0}45'E – 8^{0}30'E in the derived savannah of southeastern Nigeria. The two distinct seasons within the study area are rainy season which lasts from April to October and dry season extending from November to March. The minimum and maximum temperatures of the area are 27^{0}C and 31^{0}C, respectively. The relative humidity of the area is between 60 to 80 percent. The area has an annual rainfall range of 1500-2000mm, with a mean of 1800mm. The soil of the area is hydromorphic in nature and belongs to the order Ultisol classified as typic Haplustult (Federal Department of Agriculture and Land Resources, 1985). The dominant grasses of the area are guinea grass (*Panucum maximum*), spear grass (*Imperata cylindrical*), elephant grass (*Peniseteum purperum*), shrubs and economic trees.

Site selection and soil sampling

After visiting and inspecting the various floodplains and erosion sites in the study area, the following sites were selected: Control (Arable land), fallowed floodplain, cultivated floodplain and erosion site. Five replicate soil (auger and core) samples were collected at each site. Auger soil samples were collected at the depth of 0 – 30 cm while core samplers of 150.56 cm^3 were used to collect undisturbed soil sample. Both the auger and core soil samples were well prepared, labelled and taken to laboratory for analysis at the department of Soil Science and Environmental Management, Ebonyi State University, Abakaliki Ebonyi State Nigeria.

Laboratory analysis

Undisturbed core soil samples were weighed and oven dried at 105ºC for 24 hours. They were then weighed again to get the oven dry weight and used for the determination of selected physical parameters such as bulk density, total porosity, moisture content, dispersion ratio, modified clay ratio, erosion ratio, erodibility factor and soil loss. Similarly, auger soil samples were used for the determination of particle size distribution and selected chemical parameters such as Pb, Cd, Cu, Zn, NH_4^+, NO_3^- and SO_4^{2-}.

Determination of physical parameters

Bulk density was determined by the method of Blake and Hartage (1986). Total porosity was calculated from bulk density using the formular: Tp = 100 (1 – Db/Dp). Where: Dp is particle density assumed to be 2.65 gcm^{-3}; Db is bulk density; Tp is Total porosity (Obi, 2000). Aggregate stability was determined as described by Kemper and Rosenau (1986). Moisture content was obtained using the method of Obi (2000).

The indices of erodibility were calculated using the relationships in equations (i)-(iv) (Hudson, 1995).

i. Dispersion Ratio (DR) =

$$\frac{\%\ \text{silt} + \%\ \text{clay in undispersed soil}}{\%\ \text{silt} + \%\ \text{clay after dispersion in water}}$$

ii. Modified Clay Ratio (MCR) = $$\frac{\%\ \text{sand} + \%\ \text{silt in soil}}{\%\ \text{clay} + \%\ \text{organic matter}}$$

iii. Erosion Ratio (ER)=

$$\frac{\text{Dispersion ratio}}{\text{Colloidal content}} \times \text{moisture equivalent ratio}$$

iv. Erodibility Factor (K) = $$\frac{\%\ \text{sand} + \%\ \text{silt in soil}}{\%\ \text{clay}} \times \frac{1}{100}$$

Soil loss = A = 2.24RK
Where A = soil loss converted to tons/ha/yr by multiplying by 2.24.
R = Rainfall factor and given as 0.5H
H = Mean annual rainfall

Determination of chemical parameters

The NH_4^+ and NO_3^- contents of the soil samples were determined using colorimetric method (O'Dell, 1993). The sulphate content of soil samples was determined using the turbidimetric method (Tabatabai, 1974). The soil contents of heavy metals (Pb, Cd, Cu and Zn) were determined from the soil samples using atomic absorption spectrophotometer after digestion in concentrated HNO_3 (Clayton and Tiller, 1979).

Data analysis

Statistical analysis of the data was carried out using the General Linear Model of SAS software for Randomized Complete Block Design (SAS Institute Inc, 1999).

Results and Discussion

Physical properties of soil as affected by flood and erosion

Table 1 shows the particle size distribution of the soils. The soils studied were sandy loam and has low and high content of clay and sand, respectively. Soils with high content of sand and silt with low clay content are erodible to erosion. Chouliaras (2000) reported that most erodible soils are silts and fine grain sands and that high erodibility of silty and sandy soils are as result of size and weight of the grains and to their low cohesion, since these grain surfaces are not electrically charged. Hence, sandy and silty grains are easily detached and transported by runoff.

According to Isikwue (2012) different soils respond differently to the identical kinetic energy of raindrops or the shear stress exerted by moving fluid and their responses depend on their mechanical makeup and chemical composition.

Physical properties of soil as affected by flood and erosion are shown in Table 2. There was a significant ($P < 0.05$) difference among all experimental sites for bulk density, moisture content, total porosity, aggregate stability and mean weight diameter. Erosion site (D) recorded the highest bulk density of $1.76gcm^{-3}$. This bulk density of erosion site was higher than the bulk density of control, fallowed floodplain and cultivated floodplain by 16, 23 and 21%, respectively. The bulk density of the study sites was higher than the average standard of $1.33gcm^3$ as given by Isikwue et al. (2012). Higher bulk density makes it difficult for plant roots to penetrate the soils, and this reduces infiltration and increases overland flow and results to erosion. The total porosity of the arable land, fallowed floodplain, cultivated floodplain and eroded land were 44.15, 48.68, 47.17 and 33.59%, respectively. Low porosity of these soils showed that the soil are dense and contain low volume of voids relative to the volume of solids. Sand which is the predominant of sandy loam are more porous and less cohesive due to their divided individual soil particles. This lack of cohesion within the soil particles make them prone to the erosive forces (Isikwue et al., 2012). The order of increase in aggregate stability was erosion site < cultivated floodplain < fallowed floodplain < control. The lower the value of aggregate stability, the higher the vulnerability of soil to erosion. The moisture content of arable land, fallowed floodplain, cultivated floodplain and erosion site were 15.26, 21.32, 20.13 and 8.97%, respectively. The lower moisture content weakens the cohesiveness between the particles hence making soil easily dispersible by erosive agents such as water and more susceptible to erosion. These results collaborated with those of Andreassian et al. (2004) who indicated that a drier soil was generally more susceptible to water and wind erosion than a wet soil.

Erodibility indices and predicted loss of the soil

Table 3 shows significant ($P < 0.05$) differences in erodibility indices and predicted soil loss among the sites studied. The order of increase in dispersion ratio was control < cultivated floodplain < fallowed floodplain < erosion site. Isikwue et al., (2012) reported that soils with dispersion ratio greater than 0.15 are erodible in nature. Similarly, Chakrabarti (1990) showed that susceptibility to erosion is significantly related to the dispersion ratio in his study of soils of eastern Nepal. Therefore, it was inferred from the results that the soils from the study area are susceptible to erosion. The lowest modified clay ratio (MCR) of 4.17 was obtained at control while modified clay ratio of other sites ranged between 6.71-11.14. These ratios are considered low as compared to those of stable soils like loamy soils. Low values of MCR are an indication of the low clay content of the soils in the study area. The order of increase in erosion ratio was control < fallowed floodplain < cultivated floodplain < erosion site. These observed erosion ratios were too high when compared to standard value by Khera and Kahlon

(2005) who showed that soils with erosion ratio > 0.10 are erodible in nature. The lowest erodibility factor of 0.049 was observed in control and it was lower than erodibility factor in fallowed floodplain, cultivated floodplain and erosion site by 81, 76 and 190%, respectively. The lowest erodibility factor of control could be attributed to high clay contents which can provide higher binding forces helps in resisting detachability of soil by water. The predicted soil loss was also lowest at control (10.98 tons/ha/yr) while the predicted soil loss at other sites ranged between 19.26 – 31.36 tons/ha/yr with erosion site recording the highest value. This could be attributed to highly silty and sandy nature of the soils in fallowed floodplain, cultivated floodplain and erosion site. Silty and sandy soils are known for lacking in cohesion as their particles are loose hence requiring little force to drag and be transported by runoff. The results are in agreement with findings of Chouliaras (2000) that most erodible soils are silts and fine grain sands. High erodibility of silty and sandy soils results from larger size and weight of the grains and their low cohesion. Moreover these grain surfaces are not electrically charged. Therefore, sandy and silty grains are easily detached and transported by overland flood.

Chemical properties of soil as affected by flood and erosion

Chemical properties of the soil as affected by flood and erosion are as shown in Table 4. There was non-significant ($p < 0.05$) differences in Pb and Cd contents of the sites. However, sites significantly differed in Cu, Zn, NH_4^+, NO_3^- and SO_4^{2-} contents. The order of increase in Cu and Zn was erosion site < control < cultivated floodplain < fallowed floodplain. The higher Cu and Zn in floodplains (both cultivated and fallowed) mighty be attributed to nutrient carried from erosion site and deposited on floodplains, thereby making the floodplains to be more fertile and productive than arable land. Similar findings were revealed by Powell (2009) who observed that despite the fact that flooding results in shortage of foods due to drowning and suffocation of crops, it makes floodplains more fertile by providing nutrients that are deficient in the soils. Erosion site recorded the lowest NH_4^+ of0.14 mgkg^{-1} and were lower than NH_4^+ in control, fallowed floodplain and cultivated floodplain by 357, 414 and 443%, respectively. The order of increase in NO_3^- and SO_4^{2-} was control < cultivated floodplain < fallowed floodplain < control. Unlike NH_4^+, NO_3^- and SO_4^{2-} contents were lower in floodplains than arable land despite deposition of nutrients from highlands on floodplains. This phenomenon might be attributed to the fact that NO_3^- and SO_4^{2-} are anions and can be easily leached beneath root zone. Conversely, NH_4^+, being a cation, is strongly bound to clay micelle thereby resistant to leaching. The order of increase in organic matter was erosion site < control < cultivated floodplain < fallowed floodplain. Nathan (2002) observed that flooding generally increased the availability of plant nutrients to crops. Also, Stephen (1993) and O'Connor et al. (2004) have reported that wetting of the floodplains releases immediate nutrients that were left over from the last flood and those that result from the rapid decomposition of organic matter that has accumulated during the flood.

Table 1. Texture of the soils studied

Site	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	Texture
Control	426	404	170	Sandy loam
Fallowed floodplain	484	415	101	Sandy loam
Cultivated floodplain	488	408	104	Sandy loam
Erosion site	646	288	66	Sandy loam
F-LSD (P<0.05)	NS	NS	NS	

Table 2. **Physical properties of soil as affected by flood and erosion**

Site	Bulk density (gcm^{-3})	Total porosity (%)	Aggregate stability (%)	Moisture Content (%)
Control	1.48	44.15	10.01	15.26
Fallowed floodplain	1.36	48.68	8.89	21.32
Cultivated floodplain	1.40	47.17	8.63	20.13
Erosion site	1.76	33.59	6.37	8.97
F-LSD (P<0.05)	0.098	2.352	0.931	1.27

Table 3. **Erodibility indices and predicted soil loss of the soil studied**

Site	Dispersion ratio	Modified clay ratio	Erosion ratio	Erodibility factor.	Soil loss ($tonsha^{-1}yr^{-1}$)
Control	0.53	4.17	0.35	0.049	10.98
Fallowed floodplain	0.65	6.79	0.45	0.089	19.94
Cultivated floodplain	0.63	6.71	0.48	0.086	19.26
Erosion site	0.76	11.14	0.75	0.142	31.36
F-LSD (P<0.05)	0.006	0.96	0.009	0.008	2.36

Table 4. Chemical properties of soil as affected by flood and erosion

Treatment	Pb	Cd	Cu	Zn	NH_4^+	NO_3^-	SO_4^{2-}	Organic matter
	($mgkg^{-1}$)							(%)
Control	0.63	0.05	30.32	5.01	0.64	0.34	9.01	2.36
Fallowed floodplain	0.57	0.07	38.01	6.98	0.72	0.26	6.23	3.14
Cultivated floodplain	0.61	0.06	32.08	5.19	0.76	0.25	5.07	2.96
Erosion site	0.67	0.07	21.07	3.98	0.14	0.11	4.56	1.78
F-LSD (P<0.05)	NS	NS	1.01	0.23	0.02	0.01	0.36	0.10

Conclusion

The results showed that the floodplains have inherent capacity to increase the productivity of our crops and the nutrients leached during flooding can be recovered through fallowing the floodplains for some periods before using them for crop production. The results also, showed that erosion site had the poorest fertility and productive status when compared to all the sites studied. Therefore, this study advised farmers to be using floodplains for crop production since flood contributes positively to soil properties through the provision of nutrients that may be lacking in the soil and to be careful to prevent the drowning and suffocation of crops on floodplains. Similarly, farmers are discouraged from using erosion sites for their crop production.

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