Effect of River Flooding on Soil Nutrient Enrichment Along River Benue Floodplain at Makurdi, Benue State, Nigeria

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Abstract

This study focused on the effect of river flooding on soil enrichment along the River Benue floodplain at Makurdi, Benue State, Nigeria during the 2019 dry season. The work was carried out along the Northern and the Southern banks of the River. Soil samples were collected from 10 different locations, along the River Benue floodplains from Mu River Bank down to Agboughul River Bank of Makurdi Local Government Area. Five (5) samples were collected at 0-10cm and 10-20cm depth along the floodplains. Four (4) samples were collected on the floodplain and one (1) was collected off the floodplain and used as control. From this work it is observed that the floodplain soils on both sides of the River Benue are richer in nutrients than their respective controls.

INTRODUCTION

Agriculture is one of the most important components of life in our society. Farmers and ranchers produce the food and fiber we use every day. Soil is a critical part of successful agriculture and is the original source of the nutrients that we use to grow crops.

Soil serves as the natural habitat of organism and it is the medium through which plants obtain their nutrients. It regulates plants growth, water contents, recycles raw materials etc. Achieving and maintaining optimal levels of soil fertility is of paramount importance if agricultural land is to continuously sustain crop production (Oklo *et al*., 2021).

Soil is normally considered as the fine earth which covers land surfaces as a result of the in situ weathering of rock materials or the accumulation of mineral matter transported by water, wind, or ice. The distinctive feature of soil is that to this weathered mineral material is added organic material. This organic material may be both living and dead. The dead organic matter will include little altered and freshly added dead plant roots and leaf and other plant litter, dead fauna, and organic material in various stages of decomposition from little modified relatively fresh materials to the complex decomposed material called humus (Steven *et al.*, 2016).

Soil is important as a medium for plant growth and for the support of much animal and human activity. The soil acts as a reservoir for nutrients and water, providing the plants' needs for these requirements throughout their growth. The soil may also provide an environment for the break-down and immobilization of materials added to the surface (in addition to the aforementioned plant and animal remains) such as fertilizers and pesticides, and waste products such as sewage sludge, animal wastes and slurries, and composed refuse materials. The soil is a complex dynamic system in which the interactions of the biological, chemical, and physical processes results in the transformation of materials, possibly rendering initially harmful materials less dangerous and immobilizing others as a result of the interactions between these added materials and the organic and inorganic soil constituents (Bannick and Herwig, 2010).

The soil tends to lose its value, nutrient, and structures as times goes on. This is often due to continuous usage, deforestation, farming, urbanization, use of continuous chemicals, pesticides, erosion, flooding and many more hence the need for soil amendments to replace its lost productive capacity.

Soil enrichment is all about boosting the soil quality. Fertile soil is a very important component for growing healthy and green lawns and landscapes. Soil enrichment improves root penetration and soil water retention, making regular watering more effective. It reduces damaging soil salts from the root zone and improves soil aeration and also reduces the accumulation of thatch (biomass) (Kizito, 2019).

The unusual or above surface-water flows that move over the riverbank and inundate the nearby highlands may be regarded as flood. Flood has been the part of life of the people because of its intimate connection with agricultural production system (Eychaner, 2015).

Information in literature on the effect of flooding and its impact on soil enrichment along the River Benue Makurdi is very little and this has reduced the use and the potential of the soil for agricultural purposes effectively.

With the increased regularity of flooding of the River Benue banks, especially at Makurdi, it is important to carry out this research to assess the positive impact of flooding as a factor of soil enrichment and how this can help in accelerating agricultural activities along the River bank. This work seeks to look at the effect of flooding on soil enrichment in River Benue at the Makurdi section, a span of 5 kilometers ranging from Abua (Mu sub flood plain) along Gboko road through the town to Agboughul on the Naka road axis. The objective of this research work was to access the effect of river flooding on soil enrichment on the River Benue floodplains at Makurdi, Benue State.

MATERIALS AND METHOD

This study was carried out at Northern and Southern River Benue Flood Plain at 0-10 and 10-20cm deep each on both sides of River Benue Makurdi. On the Northern side of the River Data was collected at Katungu River Bank Lat. 7.743317 Long. 8.544121, Golf Course River Bank Lat. 7.74265 Long. 8.55427, College of Advanced and Professional Studies (CAPS) River Bank Lat. 7.71414 Long. 8.57700, JOSTUM Water Works River Bank Lat. 7.713973 Long. 8.59906, as well as it control which was collected close to the Animal Science Farm of the Joseph Sarwuan Tarka University (JOSTUM) 4km off the Flood Plain Lat. 7.793277 Long. 8.615896, and on the Southern part samples were collected at Agboughul River Bank Lat. 7.754427 Long. 8.53006, Wurukum Abattoir River Bank Lat. 7.729639 Long. 8.55549, Brewery River Bank Lat. 7.718015 Long. 8.581889, Mu River Bank Lat. 7.713754 Long. 8.620707 as well as their control which was collected close to Bawu Farm 5km off the Flood Plain.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Average Temp. (^{o}c)	27.8	28.9	31.3	29.7	28.7	27.3	27.1	26.8	27.0	26.6	27.2	24.0
Rainfall (mm)	0	26.0	1.4	173.0	85.1	216.2	186.6	319.9	208.9	320.9	48.1	0
Wind speed (Km/hr)	39.62	48.80	58.80	52.80	44.62	41.78	34.64	30.17	27.60	22.23	24.06	25.50
Relative humidity (%)	47	48	70	76	78	81	84	86	86	86	79	53

The experimental area is in the southern Guinea Savanna Agro ecological zone of Nigeria with annual rainfall of about 1,250mm and a mean temperature of 25-30^{0}c Ojanuga (2006).

Table 1: Meteorological Data of Makurdi in 2019

Source: *Nigerian Meteorological Services Agency, Nigerian Air Force Base Makurdi.*

Materials

- Cutlass for land clearing and scooping of soil sample
- Masking tape for sample labelling
- Metric rule for soil depth measurement
- Polythene bags for soil sample collection

Soil Data Collection

Soil samples were collected at two depths (0-10cm and 10-20cm) on both the Northern and Southern part of River Benue Flood Plain. They were packed in polythene bags and labelled appropriately then taken to the laboratory for analysis to determine the soil physical and chemical propreties.

Methodology

Ten (10) soil samples were randomly picked in 5 different locations on the northern part of River Benue Flood Plain on the same day at Katungu River Bank, Golf Course River Bank, beside College of Forestry and Fisheries UAM, College of Advanced and Professional Studies (CAPS) River Bank and UAM Water Works River Bank. Another ten (10) samples from 5 different locations were also taken on the southern part of the flood plain at Agboughul Area after Wadata, Wurukum Abattoir Flood Plain, Brewery Flood Plain, River Mu Area Flood Plain and Bawu Farm House Area of Fiidi. A total of 20 soil samples were collected from 10 different locations

Laboratory Analysis

Soil analysis was carried out at the Advanced Analytical Soil Testing Laboratory of the Department of Soil Science, Joseph Sarwuan Tarka University, Makurdi. The soils were air dried; gently crushed using mortar and pestle and passing through a 2mm sieve. The sieved sample were collected and packed for laboratory analysis. The Bouyoucos Hydrometer method (1951) was used to determine the particles size distribution of the sample. The soil pH water

(1:1) was determined using the pH meter. The wet oxidation method of Walkley and Black (1934) was used to determined the Organic Carbon Content of the samples. Total Nitrogen was determined by the Macro Kjeldahl Method (Jackson, 1965). The cation exchange capacity (CEC) was determined by Neutral Ammonium Acetate Method. Bray – 1 Method was used to determine the extractable phosphorus (Bray and Kurtz, 1945). The exchangeable cations were determined by Melhlich – 3 extraction solution (Melhlich, 1984). Base saturation was determined by dividing the sum of exchangeable bases by CEC and Multiplying by 100.

Table 2: Interpretation Guide for Evaluating Analytical Data

(a) Exchangeable Cations (Cmol/kg)

Ca^{3+}	Mg^{2+}	K^{+}	Na^{+}	Class
<2	<0.3	<0.2	0.1	Very low
2 – 5	0.3 – 1	0.2 – 0.3	0.1 – 0.3	Low
5 – 10	1 – 3	0.3 – 0.6	0.3 – 0.7	Moderate
10 – 20	3 – 8	0.6 – 1.2	0.7 – 2	High
>20	>8	1.2 – 2	>2	Very high

(b) Cation Exhange Capacity (Cmol/kg)

Range	*Class*
<6	Very low
6 – 12	Low
12 – 25	Moderate
25 – 40	High
>40	Very high

(c) Percentage Base Saturation

Range	*Class*
0 – 20	Very low
20 – 40	Low
40 – 60	Moderate
60 – 80	High
>80	Very high

(c) Hydraulic Conductivity

Range (cm/hr)	*Class*
<0.13	Very low
0.13 – 0.5	Low
0.51 – 2.0	moderately low
2.0 – 6.3	Moderate
6.3 – 12.7	Moderately rapid
12.7 – 25.4	Rapid
>25.4	Very rapid

(e) Organic Matter Rating (Metson, 1961)

Range (%)	*Class*
<2	Very low
2 – 4	Low
4 – 10	Moderate
10 – 20	High
>20	Very high

(d) Soil pH

Range	*Rating*
<4.5	Extremely acidic
4.5 – 5.0	Very strongly acidic
5.1 – 5.5	Strongly acidic
5.6 – 6.0	Moderately acidic
6.1 – 6.5	Slightly acidic
6.6 – 7.5	Neutral
7.6 – 7.8	Slightly alkaline
7.9 – 8.4	Moderately alkaline
8.5 – 9.0	Strongly alkaline
>9.0	Very strongly alkaline

(g) Organic Carbon (%)

Range	*Class*
<0.4	Very low
0.4 – 1.0	Low
1.0 – 1.5	Moderate
1.5 – 2.0	High
>2.0	Very high

(e) Total Nitrogen, Metson (1961) **(i) Available Phosphorus, Enwezor *et al.* (1989)**

Range	***Class***	**Bray 1**	**(mg/kg)**	**Bray 2**	**(mg/kg)**
		Range	***Class***	***Range***	***Class***
<0.1	Very low				
0.1 – 0.2	Low	<8	Low	<15	Low
0.2 – 0.5	Medium	8 – 20	Medium	15 – 25	Medium
0.5 – 1.0	High	>20	High	>25	High
>0.1	Very high				

Source: *National Special Programme for Food Security, Federal Ministry of Agriculture and Rural Development/FAO (2004)*

Results and Discussion

Particle size Analysis on the flooded soils, on the bank of River Benue at Makurdi

The result of the particle size analysis on Table 3 revealed that at the top soil (0-10cm) in 2019 for the flood plain soils showed that the sand fraction ranged from 52.55% at AGBRB to 60.14% at WARB, the silt content ranged from 20.11% at KRB to 22.86% at MRB while the clay content ranged from 18.46% at WARB to 26.64% at AGBRB.

Gani *et al.* (2020) studying the wukari flood plain soils had mean sand fraction ranging from 34.70 – 37.80%, silt value of 26.00% to 28.50% and clay fraction of 35.80% to 37.70%. Despite the variation in the figures as seen on Table 7, a common occurrence is the high silt contents of these soils relative to off flood plain soils as can be seen in the two controls (BFHM and UAMAF). Abednego *et al.* (2020) also studying on the Jalingo flood plains had higher values of silt and clay, 46.80% and 46.40% respectively, but Makurdi had 19.95% higher average sand content.

Soil pH

The result of soil pH of the River Benue flood plain on Table 3 indicated that the off flood plains soils were more acidic that the flood plain soils. This can also be seen on Table 4. For example, both controls of the two sides of the river had pH from 5.41 and 5.44 while the pH of the flood plains ranged from 6.15 to 6.81. This result agrees with that of Gani *et al.* (2020) that had a soil reaction that ranged from very slightly acidic to neutral. Ubuoh *et al*. (2016) had an opposite result at Abakaliki in the south-eastern part of Nigeria they had average pH of 5.9 in the flood plains as opposed to 5.38 off the flood plain.

Electrical Conductivity

The lowest electrical conductivity of the Makurdi off flood plain soils was 211µScm^{-1} as on Table 3. But the flood plain soils had higher electrical conductivity values.

Organic Matter

The effect of flooding on the soil organic matter content shown on Table 3 revealed that the flood plain soils had higher soil organic matter than the off-flood plain soils. This is also clearer on Table 5 which shows the differential status between River Benue flood plain and the off-flood plain control. The lowest value of soil organic matter in the flood plain soils was obtained at AGBRB with 2.72%, but this was also higher that the highest value obtained off-flood plain at UAMAF with 1.59%. The lowest organic matter content of the flood plain soils of Makurdi was higher than the highest value at the wukari flood plain soils as recorded by Gani *et al.* (2020). According to Metson (1961), the lowest value obtained in Makurdi and the highest can be rated as low, but this is higher than the very low soil organic matter content of the off-flood plain soils that fall the very low rating (1.52 – 1.59%).

Nitrogen and Phosphorus

The soil nitrogen contents of the off-flood plain soils (Table 3) were lower than that of the flood plains. This same trend was observed for phosphorus. But the concentration of both elements decreased with depth. Values of 5.54 – 8.91 MgL^{-1} obtained in this work can be rated low (Enwezor *et al.* 1989). Elsewhere Awanish *et al.* (2014) obtained moderate to high values on Fadama soils. Ubuoh *et al.* (2016) also had higher nitrogen and phosphorus in the flood plain soils than their control. Nitrogen and phosphorus contents of this flood plain soils ranged between low to medium.

Exchangeable Cations and Exchangeable Acidity

Exchangeable cations like potassium, sodium, magnesium and calcium were higher in the flood plains than away from it (Table 5). This observation was also seen by Ubuoh *et al.* (2016). The exchangeable acidity was higher in the flood plain soils. Potassium content ranged from low to medium, sodium was moderate, magnesium moderate to high while calcium content was low relative to their control which was very low

Cations Exchange Capacity, sodium adsorption ratio and base saturation

Cations exchange capacity was lower at the controls (Off-flood plain). The sodium adsorption ratio on the other hand was higher at the flood plain soils. The cations exchange capacity was rated low. The very low cations exchange capacity agrees with an earlier off-flood plain research in the study area by Akubo (2016).

Table 3: Result of Routine Analysis of Flooded Soils of the River Benue Flood Plain at Makurdi Section at 0-10cm in 2019

Sample	pH	EC	Sand	Silt	Clay	OC	OM	N	P	K	Na	Mg	Ca	EB	EA	CEC	SAR	BS	
Code		(μScm^{-1})	(%)	(%)	(%)	(%)	(%)	(%)	($Mg1^{-1}$)	←		($Cmol/Kg^{-1}$) →							(%)
KRB	6.81	385	56.41	20.11	23.48	1.78	3.07	0.140	6.10	0.31	0.31	2.94	3.10	6.66	1.24	7.90	0.17	84.30	
UAM RB	6.73	371	56.62	21.04	22.34	1.82	3.14	0.121	7.14	0.33	0.32	2.98	3.22	6.85	1.19	8.04	0.18	85.19	
CAPS RB	6.56	372	55.81	20.85	23.34	1.80	3.10	0.111	6.09	0.24	0.38	3.02	3.48	7.12	1.21	8.33	0.13	85.47	
GCRB	6.72	374	54.78	22.31	22.91	1.64	2.83	0.124	5.54	0.29	0.42	3.00	2.92	6.63	1.23	7.86	0.16	84.35	
WARB		6.43	402	60.14	21.40	18.46	1.98	3.41	0.351	8.91	0.52	0.61	3.84	3.56	8.53	1.43	9.96	0.27	85.64
MRB	6.41	385	54.11	22.86	23.03	1.74	3.00	0.212	5.80	0.21	0.30	3.10	2.91	6.52	1.23	7.75	0.12	84.13	
BBRB	6.15	406	54.00	21.82	24.18	1.87	3.22	0.360	7.88	0.46	0.52	3.78	3.44	8.20	1.44	9.64	0.24	85.06	
AGBRB	6.24	374	52.55	20.81	26.64	1.58	2.72	0.130	5.84	0.25	0.28	2.48	2.96	5.97	1.32	7.29	0.15	81.89	
UAMAF	5.44	301	71.48	11.97	16.55	0.92	1.59	0.091	3.46	0.16	0.11	1.80	1.42	3.49	1.06	4.55	0.12	76.70	
BFHM	5.41	211	73.83	10.22	15.95	0.88	1.52	0.086	3.04	0.11	0.09	1.69	1.01	2.90	1.07	3.97	0.09	73.05	

Key: KRB=Katungu River Bank, UAMRB = UAM River Bank, CAPSRB = CAPS River Bank, GCRB = Golf Course River Bank, WARB = Wurukum Abattoir River Bank, MURB = Mu River Bank, BBRB = Benue Brewery River Bank, AGBRB = Agboughul River Bank, UAMAF = UAM Animal Farm (Control North Bank), BFHM = Bawu Farm House (Control South Bank), EC=Electrical Conductivity, OC=Organic Carbon, OM = Organic Matter, EB=Exchangeable Bases, EA = Exchangeable Acidity, CEC = Cation Exchange Capacity, SAR = Sodium Adsorption Ratio and BS = Base Saturation.

Table 4: Status of Routine Analysis of Flooded Soils of the River Benue Flood Plain at Makurdi Section at 0-10cm in 2019

Sample	pH	OC	OM	N	P	K	Na	Mg	Ca	CEC	BS
Code		(%)	(%)	(%)	(Mg1^{-1})	←			(Cmol/Kg^{-1}) →		(%)
KRB	N	H	L	L	L	M	M	M	L	L	VH
UAM RB	N	H	L	L	L	M	M	M	L	L	VH
CAPS RB	SA	H	L	L	L	L	M	H	L	L	VH
GCRB	N	H	L	L	L	L	M	M	L	L	VH
WARB	SA	H	L	Me	Me	M	M	H	L	L	VH
MRB	SA	H	L	Me	L	L	M	H	L	L	VH
BBRB	SA	H	L	Me	L	M	M	H	L	L	VH
AGBRB	SA	H	L	L	L	L	L	M	L	L	VH
UAMAF	StA	L	VL	VL	L	L	L	M	VL	VL	H
BFHM	StA	L	VL	VL	L	L	VL	M	VL	VL	H

Key: KRB=Katungu River Bank, UAMRB = UAM River Bank, CAPSRB = CAPS River Bank, GCRB = Golf Course River Bank, WARB = Wurukum Abattoir River Bank, MURB = Mu River Bank, BBRB = Benue Brewery River Bank, AGBRB = Agboughul River Bank, UAMAF = UAM Animal Farm (Control North Bank), BFHM = Bawu Farm House (Control South Bank), EC=Electrical Conductivity, OC=Organic Carbon,

OM = Organic Matter, EB=Exchangeable Bases, EA = Exchangeable Acidity, CEC = Cation Exchange Capacity, SAR = Sodium Adsorption Ratio and BS = Base Saturation.

MA- Moderately acidic N – Neutral SA – Slightly Acidic StA – Strongly Acidic H – High M – Moderate Me – Medium L – Low VL – Very Low VH – Very High

Table 5: Differential Status between River Benue Flood Plain Soil at Makurdi Section and their Off-plain Control at 0 - 10cm in 2019

Sample	pH	EC	Sand	Silt	Clay	OC	OM	N	P	K	Na	Mg	Ca	EB	EA	CEC	SAR	BS	
NORTHERN BANK																			
KRK	1.37	84	-15.07	8.14	6.93	0.86	1.48	0.049	2.64	0.15	0.2	1.14	1.68	3.17	0.18	3.35	0.05	7.6	
GCRB	1.28	-297.26		-16.7	10.34	6.36	0.72	1.24	0.033	2.08	0.13	0.31	1.2	1.5	3.14	0.17	3.31	0.04	77.65
CAPS RB	1.12	71	-15.6	8.84	6.79	0.88	11.51	0.02	2.63	0.08	0.27	1.22	2.06	3.63	0.15	3.78	0.01	8.77	
UAM RB	1.29	70	-14.96	9.07	5.79	0.9	1.55	0.03	5.55	0.17	0.21	1.18	1.8	3.36	0.13	3.49	0.06	78.49	
UAM AF (Control A)																			
SOUTHERN BANK																			
AGBRB	0.83	163	-21.38	10.59	10.69	0.7	1.2	0.044	2.8	0.14	0.19	0.79	1.95	3.07	0.25	3.32	0.058	8.84	
WARB		1.02	191	-13.69	11.18	2.51	1.1	1.89	0.264	5.87	0.41	0.52	2.15	2.55	5.63	0.36	5.99	0.176	12.59
BBRB	0.74	195	-19.83	11.6	8.23	0.99	1.7	0.2734	4.84	0.35	0.43	2.09	2.43	5.3	0.37	5.67	0.148	12.01	
MRB	1	175	-19.72	12.64	7.08	0.86	1.48	0.126	2.76	0.1	0.21	1.41	1.9	3.62	0.16	3.78	0.027	11.08	

Key: KRB=Katungu River Bank, UAMRB = UAM River Bank, CAPSRB = CAPS River Bank, GCRB = Golf Course River Bank, WARB = Wurukum Abattoir River Bank, MURB = Mu River Bank, BBRB = Benue Brewery River Bank, AGBRB = Agboughul River Bank, UAMAF = UAM Animal Farm (Control North Bank), BFHM = Bawu Farm House (Control South Bank), EC=Electrical Conductivity, OC=Organic Carbon, OM = Organic Matter, EB=Exchangeable Bases, EA = Exchangeable Acidity, CEC = Cation Exchange Capacity, SAR = Sodium Adsorption Ratio and BS = Base Saturation.

CONCLUSION AND RECOMMENDATION

Conclusion

This work has revealed that flooding is not a complete disaster to agriculture, as considerable amounts of soil nutrients are moved from highland areas and deposited at the floodplains.

Recommendation

Due to the availability of plant nutrients in the River Benue floodplains, it is recommended that farmers within Makurdi Metropolis should take maximum advantage of the enriched floodplains for dry season crop cultivation.

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