FLOOD RECESSION, FERTILITY ASSESSMENT FOR FOOD SECURITY AND ENVIRONMENTAL SUSTAINABILITY IN NIGER DELTA, NIGERIA

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ABSTRACT

Food insecurity and environmental degradation are the recurrent problems in Niger Delta. Yearly flooding from Niger River improves the fertility of the floodplain. Farmers have utilized flood-recession farming for cultivating crops since time immemorial. Farmers in this approach produce crops in the floodplains' moist, fertile soil after the water levels have receded and harvest them before the river floods. This conventional approach to food production is vital for the preservation of the environment and the well-being of humans. The experiment was conducted between Asaba and Illah, using a stratified sampling methods. The results showed that the floodplain soil overlying the Niger River had a high potential for crop production with a high amount of available phosphorus (13.88–15.65 mg/kg), total nitrogen (16.03–21.03 gkg^{-1}), organic matter (23.3–31.1gkg^{-1}), cation exchange capacity (16.76–20.87 cmol/kg), and pH 5.5–7.0. The result showed that the soils are very good for agricultural purposes. However, to improve the flood-recession farming system and the food security of household small farmers, soil fertility management techniques in the areas should also focus on water use efficiency, agro-biodiversity conservation, soil health maintenance, climate change mitigation, and incorporating this practice into policy-making for food security.

Keywords: food security, climate change, fertility, soil moisture, floodplain.

1.0 INTRODUCTION

Flooding is the most common natural hazard in the Niger Delta, and most low-lying urban locations are prone to flooding. Food security is an issue for society in Nigeria and around the world, owing to current insecurity and high living costs. Flooding is regarded as the most troubling natural disaster globally (Komolafe *et al.*, 2015). According to Peduzzi *et al.* (2009), 'the level of flood occurrence globally is incomparable, with seventy (70) million individuals vulnerable to flooding. According to Rentschler and Salhab (2020), "19% of the global population has been directly exposed to significant risks during previous flood events."

Flooding occurs as a result of climate change, excessive rainfall, and anthropogenic activities such as inappropriate land use, soil moisture regime, dam operations, uncontrolled rapid population growth, insufficient government policy, and a lack of political will (MacLeod *et al.*, 2021; Adetunji and Oyeleye, 2013). In 2022, flooding in Nigeria were predicted (NIHSA, 2022).

The implication is that information on flooding, regardless of severity, is readily available every year. Managing floods begins with the handiness of knowledge and appropriate government policy on the usage of areas susceptible to flooding, particularly those near the Niger River. Climate change is caused by the exploitation and improper management of land resources, which results in flooding. Flood control is achieved by proper land resource management, well-planned policies, and agricultural practices. The primary characteristic of flooded areas along the Niger River is the fertility, and flood-recession farming (FRF) has the prospect of being an efficient key to meet rural communities' food security and sustain their livelihoods (Sidibe *et al.,* 2016).

The small-scale farming approach count on the remaining soil moisture and nutrients left behind by receding floods (Nguru *et al.,* 2019). Food production by this approach is critical for household nutritional security and financial revenue during the dry season when other food supplies are exhausted (Comas and MacPherson, 2001). FRF is used by many African communities to improve food productivity and livelihoods (Balana *et al.*, 2019).

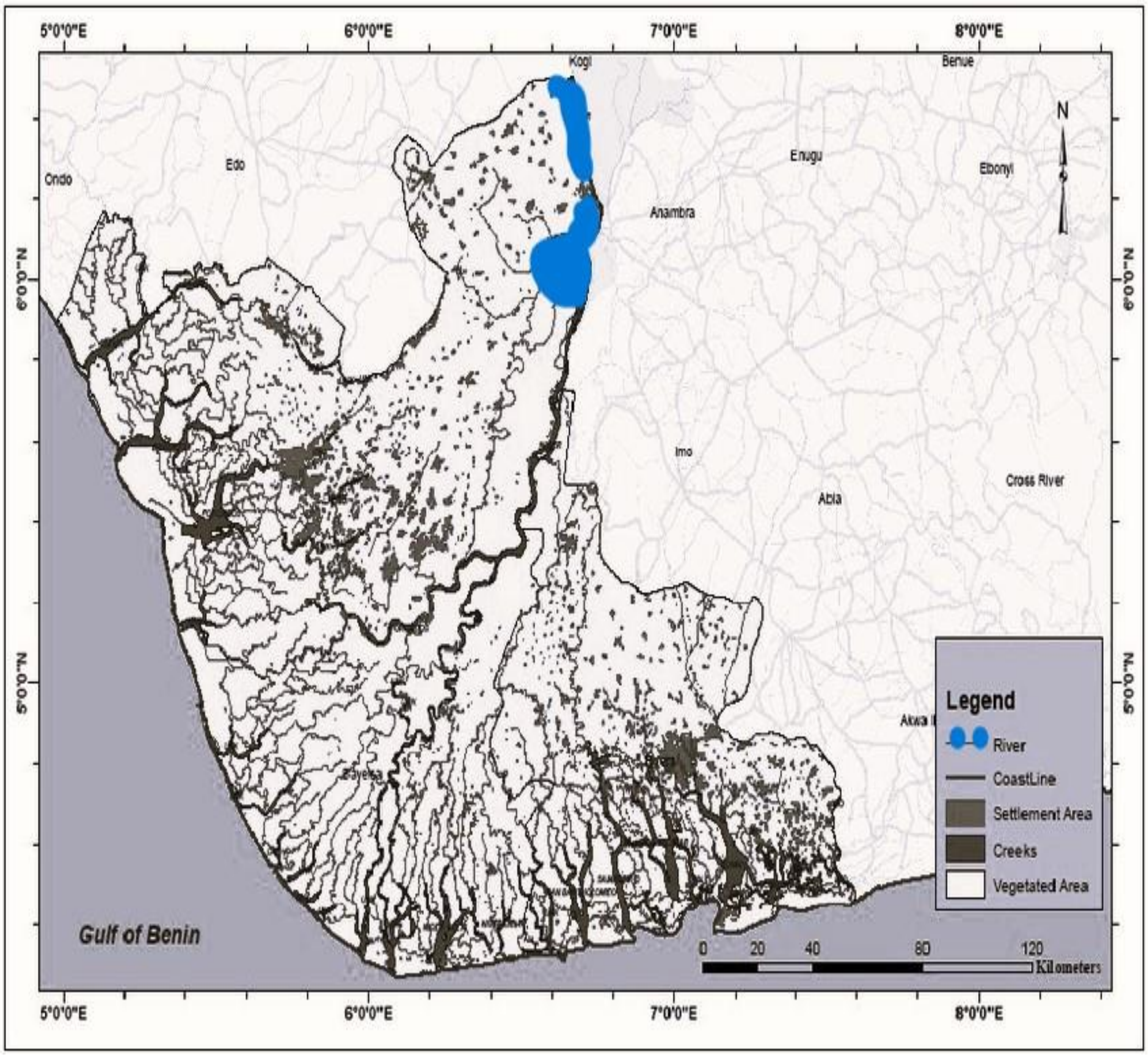
Despite its pivotal role, FRF has been poorly studied and understood. Therefore, it is required to study and document various facets of this sustainable practice (Singh *et al*., 2021). However, floodplain soils constitute a vast nutrients reserve for crop production (Akpan-Idiok and Ogbaji, 2013), and the potential of wetland soils or floodplains was also observed by Alama *et al.*, 2021 and Akpan *et al.*, 2017, based on geomorphologic aspects, classification, and characterization of wetland agro-ecosystems (Alama *et al.,* 2021; Nsor, 2017). Despite the overwhelming acceptance of the flood recession for agriculture, these soils are underutilized, and their soil qualities and agricultural potential to support crop production are unknown. However, the present study seeks to assess the soil properties of FRF soils for food security and sustainability.

2.0 MATERIALS AND METHODS

2.1 Description of the Study Area

The research was carried out on flood plain within Asaba (Latitudes 6° 10' 60.00"N and Longitudes 6° 45' 0.00"E) and Illah (Latitudes 6° 25' 26.40"N and Longitudes 6° 38' 56.40"E) Delta State, South-South Nigeria (GPS, 2022). The area lies within the humid tropical climate, characterized by two distinct seasons, the raining spell usually starts in April and ends in October, with a double peak usually in July and September, while the dry spell spans from November to March. The mean annual rainfall ranges from 1500mm to 2000mm. The rainfall distribution is bimodal, with peaks in July and September and a low period of precipitation in August. The mean temperature between Asaba and Illah is 23.8ºC, with 37.3ºC as the maximum, and relative humidity is between 70 – 89% while the mean sunshine stands at 4.8 bars and the mean monthly soil temperature at 100cm depth and the sun is 28.3ºC (Meteorological Office, Asaba 2018).

Fig. 1 Sampling Location and Area of Study



The blue point showed the Study Area

2.3 Field Study

A detailed survey was carried out using the rigid-grid method, and composite soil samples were collected from soil developed during the post-flooding event at the corresponding surface and subsurface soils, respectively. Samples were excavated at 0–30cm, respectively, at various locations labelled in airtight and clean polythene bags and taken to the laboratory.

2.4 Laboratory analyses

The Bouyoucos hydrometer method was used to determine the particle size distribution (Gee and Or, 2002). According to Udo *et al.* (2009), the pH (H2O) of the soil was determined using a glass electrode pH meter with a solid-liquid ratio of 1:2.5. The wet digestion method was used to evaluate the total organic carbon (Nelson and Sommers, 1996). The total nitrogen content of the soil was assessed by wet-digestion, distillation, and titration procedures of the Kjeldahl method, as described by Bremner (1996). Phosphorous was ascertained by Bray l method using to the procedure of (Wilke, 2005). The exchangeable bases were determined through an extraction method with 1M ammonium acetate at pH 7 (Wilke, 2005). The amounts of Ca and Mg ions in the leachate were analyzed by atomic absorption spectrophotometer, while K and Na ions were analyzed by a flame photometer. Exchangeable acidity (hydrogen and aluminium) was ascertained by the titrimetric method using 1N KCl extract. The percent base saturation of the soil was calculated as the percentage of the sum of the basic exchangeable cations (Ca, Mg, K, and Na).

3.0 RESULTS AND DISCUSSION

3.1 Physical Properties

The results showing selected physicochemical properties of soils are shown in Tables 1 and 2. The particle size distribution was sandy loam (Awnai, Mile Five, and Ngagu flood plains) in texture, while silty loam and loam were observed in the Ugbolu and Illah flood plains. Loamy soil was a common soil texture (Table 1). These were credited to homogeneity in soil development and similarity in parent material. The mean sand, silt, and clay content were 45.2, 36, and 18.8. The soil texture observed in this study also corroborates the findings of Ibanga *et al.* (2005), Nsor (2017), and Akpan *et al.* (2017), who carried out similar studies on soils of the Cross River floodplain. The similarity in texture agreed with the report of Reddy and DeLaune (2008), who reported that in floodplain soils, fresh materials are frequently added through depositions and are characterized by a mixture of clay, silt, and sand, which may perhaps have similar properties.

Table 1. Distribution of the selected physicochemical properties of alluvial floodplain soils

Location (Area)	Depth (cm)	TC	Bd (gcm^{-3})	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	pH (H_20)	OM (gkg^{-1})	N (gkg^{-1})	Av. P (Mg/kg)
Anwai FLP	0-30	SL	1.27	550	260	190	6.79	23.3	16.03	13.88
Mile Five FLP	0-30	SL	1.23	550	270	180	7.01	27.8	17.22	15.65
Ugbolu FLP	0-30	SIL	1.25	210	590	200	6.65	30.1	21.03	14.22
Ngagu FLP	0-30	SL	1.19	540	290	170	6.17	28.7	18.19	13.89
Illah FLP	0-30	L	1.21	410	390	200	6.96	25.5	17.66	14.66

Legend: TN = Total Nitrogen; OM = organic Matter; Avail. P. = Available Phosphorous; TC=Textural Class; FLP= Flood Plain

The texture observed, irrespective of location, could be favorable for crop production. Most food crops grow well in soils characterized by sandy loam and loamy sand, as these soils can potentially retain water and provide adequate aeration (Amalu and Isong, 2018).

The bulk densities generally were 1.27 g/m^3 (Awnai), 1.23 g/m^3 (Mile Five), 1.25 g/m^3 (Ugbolu), 1.19 g/m^3 (Ngagu) and 1.21 g/m^3 (Illah). The values obtained could be attributed to the long alluvial accumulation of organic residue within the agricultural horizon (0–30cm), and they are characterized by a dark brownish colour with a strong indication of agilliation. However, the bulk density values observed are within the expected range (1.1 to 1.4 cm^3) in most mineral soils, as indicated by Hazelton and Murphy (2016). Since the bulk density was within the expected values, the soil aeration and water movement within the soil structure are capable of supporting plant growth and could determine the numbers and diversity of soil microbes, thereby furnishing a versatile function in agrarian activities.

3.2 Chemical Properties

The results of the selected soils properties developed in flood-prone areas are presented in Tables 1 and 2. The interpretation of the results was based on the fertility ratings Hazelton and Murphy (2016) established for crop production. The pH results obtained from the alluvial floodplain were 6.79 (Awnai), 7.01 (Mile Five), 6.65 (Ugbolu), 6.17 (Ngagu), and 6.96 (Illah). The pH values obtained for this study indicated that the soils were slightly acidic (Hazelton and Murphy 2016). This pH value is an indication that a moderate amount of exchangeable Al^{3+} and H^+ are present to affect plant growth (Udo *et al.,* 2009). However, it was established that a pH range of 5.5–7.0 is optimal for overall satisfactory nutrient availability, but the values obtained from this study were within the acceptable limit. This showed that soils developed from alluvial floodplains along Asaba and Illah are suitable for crop production.

Table 2. Distribution of the selected chemical properties of alluvial floodplain soils

Location	**Depth**	**Ca^{2+}**	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**TEA**	**ECEC**	**BS**
(Area)	**(cm)**	→		**Cmol/kg**			←	**(%)**
Anwai Flood Plain	0-30	7.02	2.20	4.43	1.12	6.22	20.99	88.13
Mile Five Flood Plain	0-30	7.28	2.22	5.09	1.75	6.33	22.67	94.32
Ugbolu Flood Plain	0-30	8.76	4.02	5.55	1.76	7.01	25.34	85.58
Ngagu Flood Plain	0-30	7.02	2.41	5.08	1.48	6.78	25.74	87.23
Illah Flood Plain	0-30	7.78	3.55	5.67	1.61	7.32	27.99	89.17

Legend: Ca = Calcium; Mg = Magnesium; K = Potassium; Na = Sodium; TEA = Total Exchangeable Acidity; TEB = Total Exchangeable Base; ECEC = Effective Cation Exchange Capacity; %BS = Percentage Base Saturation.

Organic matter (OM) developed in alluvial flood-prone areas soil was 23.3gkg^{-1} (Awnai), 27.8gkg^{-1} (Mile Five), 30.1gkg^{-1} (Ugbolu), 28.7gkg^{-1} (Ngagu) and 25.5gkg^{-1} (Illah) and was rated moderate to high across the alluvial floodplain soil. The moderate to high values of OM across locations were ascribed to the consistent alluvial deposits of organic material and in situ parent materials developed due to pedogenic processes, the deposits brought by flood water, and increased faunal activities in the argillic horizons (Hook and Burke, 2000). The soil developed on the Ugbolu alluvial floodplain had the highest OM content compared to other floodplains; generally, it can support crop production. These findings disagreed with Traore *et al*. (2016), who affirmed that the flood plain soils of Yélimané were poorly supplied with nitrogen and OM, which are key elements for crop productivity. However, according to Noe and Hupp (2005), differences in total organic sediment accumulation between hydraulically connected and disconnected floodplains are indicative of the relationship between OM contents to floodplains. This comparison assumes that litter deposition and decomposition rates are similar across floodplains, which is unlikely given the differences in nutrient content between these locations (Fig. 1).

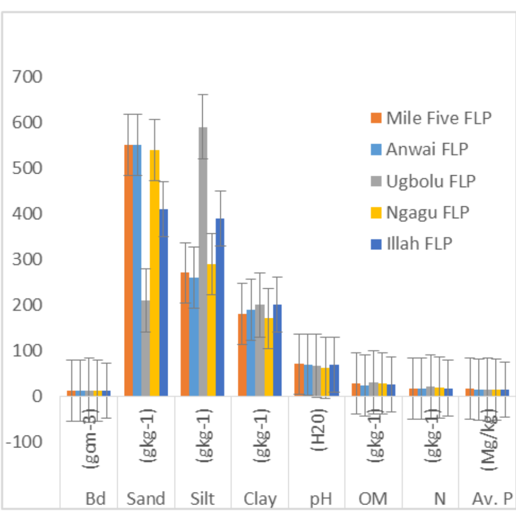


Fig. 2: Distribution of Soil Nutrient

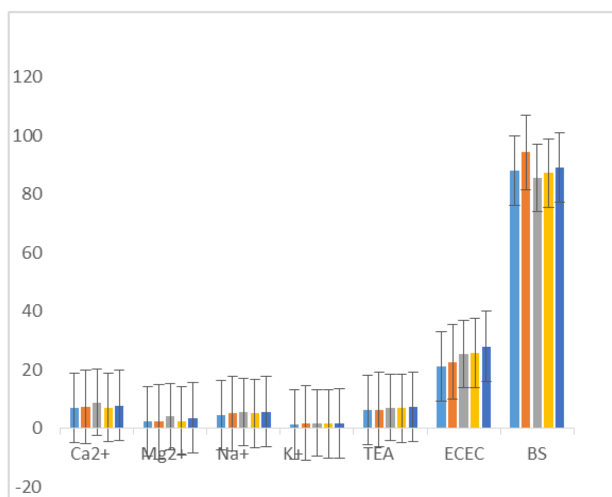


Fig. 3. Distribution of Soil Nutrient

The pH values across locations were 6.79 (Awnai), 7.01 (Mile Five), 6.65 (Ugbolu), 6.17 (Ngagu) and 6.96 (Illah) which can positively affect crop production according to Hazelton and Murphy (2016). The pH status could be accredited to the long accumulation of OM, homogeneity in the climate, and similar pedogenesis.

3.3 Total Nitrogen

Total nitrogen developed on alluvial floodplain soil was 16.03gkg^{-1} (Awnai), 17.22 g/kg (Mile Five), 21.03 g/kg (Ugbolu), 18.19 g/kg (Ngagu) and 17.66 g/kg (Illah) and was rated very high. The higher value of total nitrogen could be attributed to the high accumulation of decomposed OM from 0-35cm depth, subject to location; floodplain soils constitute a huge reserve of available nutrients for crop utilization (Akpan-Idiok and Ogbaji, 2013),

3.4 Available phosphorus

The available phosphorus (P) developed on alluvial floodplain soil was 13.88 mg/kg (Awnai), 15.65 mg/kg (Mile Five), 14.22 mg/kg (Ugbolu), 13.89 mg/kg (Ngagu), and 14.66 mg/kg (Illah) and was rated moderately across locations, with the highest observed in the Mile Five alluvial floodplain. However, the P values obtained were credited to mineral and sediment and homogeneous accumulation of parent materials. The increased P accumulation rates occurred because of the increased quantity of mineral sediment that accumulated because phosphorus dynamics in wetlands are largely controlled by interactions between PO4 32 and minerals, particularly Fe and Al, (Lowe *et al* 2018). The affirmative suggestion amongst mineral sediment and P accumulation in floodplain wetlands was observed by Pei, 2020; Fennessy, 2018.

The present phosphorus content was within the critical limit of 8-20mgkg^{-1} stipulated for crop production; however, the values were above 8-20 mgkg^{-1} critical value, which suggests that these soils potentially can support crop production. This agreed with Sun *et al.*, (2018), Yang (2021), Arenberg, and Arai, (2019.) who reported that floodplain soils are relatively P-rich and growth experiments conducted using wheat on soils of floodplain showed that plant growth was not P-limited.

The values of calcium (Ca) developed on alluvial floodplain soil were 7.02cmol/kg (Awnai), 7.28cmol/kg (Mile Five), 8.76cmol/kg (Ugbolu), 7.02cmol/kg (Ngagu) and 7.78 cmol/kg (Illah). The moderate values of Ca across locations were credited to the yearly accumulation of OM and animal residue by flood water. This agreed with Lishan, and Regasa, (2022) who reported moderate values of exchangeable Ca contents to biological accumulation with biological activity and accumulation from plant residues. The exchangeable Ca contents of study area soil were categorized as moderate (FAO, 2006). However, the study area was characterized by moderate contents of exchangeable Ca, which was an indication FRS can support crop production. Secondly, magnesium (Mg) values were 2.20cmol/kg (Awnai), 7.28cmol/kg (Mile Five), 4.02cmol/kg (Ugbolu), 2.41cmol/kg (Ngagu) and 3.55cmol/kg (Illah). The high to moderate values of mg observed across locations could be attributed to the yearly accumulation of organic matter and animal residue by flood water. These findings are congruent with Wubie, and Assen (2020) and Hounkpatin, *et al.* (2022) who reported that an increase in soil nutrients for instance Mg could be credited to the organic matter accumulation in soil related to floodplain. The sodium (Na) values were 4.43 cmol/kg (Awnai), 5.09cmol/kg (Mile Five), 5.55 cmol/kg (Ugbolu), 5.08 cmol/kg (Ngagu) and 5.67 cmol/kg (Illah) observed across location were moderate an indication that the exchangeable Na studied was not a limiting factor on crop productivity and not surplus that may trigger soil sodicity, which in turns hamper the agricultural practices. Potassium (K) values were 1.12 cmol/kg (Awnai), 1.75 cmol/kg (Mile Five), 1.76 cmol/kg (Ugbolu), 1.48cmol/kg (Ngagu) and 1.61cmol/kg (Illah) and generally high according to Halzeton and Murphy (2007). These findings agreed with the report of Attoe *et al.* (2016) and Abam and Orji (2019) who reported a higher value of exchangeable K in floodplain soils.

3.5 Effective Cation Exchange Capacity (ECEC)

The ECEC values developed on alluvial floodplain soil were 20.99cmol/kg (Awnai), 22.67cmol/kg (Mile Five), 25.34cmol/kg (Ugbolu), 25.74cmol/kg (Ngagu) and 27.99cmol/kg (Illah) and was rated low. This could be ascribed to being strongly weathered, with slight or no content of weathered constituents in sand and silt fractions and having predominantly Kaolinite in their clay fractions. This finding agreed with that of Akpan *et al.* (2017) who worked on wetland soil in Calabar and observed low levels of ECEC.

3.6 Base Saturation

Base saturation (BS) in soils developed on alluvial floodplain soil were 88.13% (Awnai), 94.32% (Mile Five), 85.58% (Ugbolu), 87.23% (Ngagu) and 89.17% (Illah) and was rated high. Soil developed on Anwai alluvial floodplain had the highest BS compared to other floodplain. These findings agreed with Akpan *et al.* (2017) who obtained high base saturation in floodplains

4.0 CONCLUSION

The result has indicated that floodplain soils are usually prone to flood and parent materials showed significant differences in physiochemical properties studied in key fertility indices (i.e. OC, N, P, Ca, ECEC, BS). Floodplain soil overlying the river Niger area had high potential for crop production as it contains a moderate amount of exchangeable Mg, and a high amount of available P, total N and organic carbon and is high in base saturation and low in exchangeable acidity and thus rated moderate in some key fertility indicators. This soil can be exploited for rice, vegetables cultivation and other arable crop with little application of N and K fertilizers. The floodplain soil developed in River Niger flood-prone area was rated high in fertility. However, soil fertility management options in the areas should focus on crop and flood management practices to improve crop production.

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