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Research Article

Impact of Flooding on Soil Enzymes Activities in Selected Lowlands and Riverine Areas of Imo and Anambra States, Nigeria

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Abstract

Flooding influences soil biochemical properties and enzymatic activities in floodplain ecosystems. This study assessed the impact of flooding on drainage and key soil enzyme activities such as catalase, lipase, urease, and phosphatase in some communities in Imo and Anambra states Nigeria. Soil samples were collected from six distinct high risk flood locations using soil auger. At each location, soil samples were gridded and collected with depths; 0 - 15 cm, 15 - 30 cm and 30 - 45 cm, representing top soil, sub soil and bottom soils respectively. Two control samples were also collected from high elevation towns within the Local Government Areas, not affected by flood. Morphological result revealed that inadequate drainage results in anaerobic conditions that facilitate changes in microbial activity and enzyme regulation. Results of enzyme activities showed spatial variations across the communities. Catalase activity ranged from 0.7433 ± 0.09 to 1.0933 ± 0.26 µmol kg^{-1}, with the highest levels recorded in Ekeugba and Amafor, indicating enhanced oxidative stress responses in frequently flooded sites. Lipase activity exhibited the widest variability 429.36 ± 366.38 to 721.35 ± 44.84 µmol kg^{-1}, suggesting differential organic matter turnover and lipid hydrolysis among the locations. Urease activity, an indicator of nitrogen mineralization, was highest in Akili-Ozizor 141.80 ± 50.36 µmol kg^{-1} and lowest in Ihiala 79.13 ± 34.70 µmol kg^{-1}, reflecting differences in nitrogen cycling potential. Phosphatase activity, which governs phosphorus mobilization, peaked in Atani 162.28 ± 37.93 µmol kg^{-1} and was lowest in Odekpe 90.95 ± 32.17 µmol kg^{-1}.

***Keyword**: Flooding; Soil Microbial Enzymes; Catalase; Lipase; Urease; Phosphatase; Southern Nigeria*

Background of Study

Climate change resulting from global warming is linked to human activities, leading to many consequences one of which is flooding. It is one of the major re-occurring environmental challenges in Nigeria [1,2].

Flooding is one of the major environmental challenges of the twenty first century. This is predominant in most wetlands of the world [2]. In Nigeria, the major cause of flood has been identified to be excessive rainfall [3,4]. However, flood usually occurs due to persistent downpour of rain for a long period of time, which leads to capacity overflow, arising from inadequacy or blockage of the drainage system [5]. When a soil is flooded, anaerobic conditions occurs, microorganisms use the available soil oxygen to survive. Free oxygen level in the soil is however dependent on the duration and severity of flood within the period [6,7]. Oxygen depletion is usually the most important environmental factor that triggers growth inhibition and injury in flooded plants [6,7].

Enzymes are important activators of the life processes of soil however; they are known to be a suitable indicator of healthy soils. Soil enzymes play an important role in maintaining soil ecology, physical and chemical characteristics, fertility and in the overall process of decomposition of organic matter in the soil system [8,9]. Soil enzyme activity can be used to rapidly obtain pertinent results on changes in soil conditions and is a dependable indicator of the biological condition of the soil [10,11]. Research in the field of soil enzymatic activity mainly focuses on the relationship between the enzyme activity and various parameters of soil environment, such as moisture, temperature, soil aeration, pH, texture, organic carbon content and quality of humus components, macronutrients and content of clay minerals.

Aim of the Study

The aim of this research is to determine the impact of flood on soil enzyme activities in Akili-Ozizor, Atani, Odekpe, Ihiala in Anambra state and Abacheke, Mmahu, Ekeugba, Amafor in Imo State respectively.

Materials and Methods

Study area/location

The study areas, Ohaji- egbema, Ihiala and Ogbaru in (Southeastern) Nigeria, is made up of five Igbo speaking States which includes; Abia, Anambra, Ebonyi, Enugu and Imo. These States constitute one of the six geo-political zones in Nigeria. It is located between latitudes 4° 20′ to 7° 10′ north of the equator and longitudes 6° 35′ to 8° 25′ east of the Greenwich Meridian with a land size of about 28,983 km^2. The region is bounded to the north by Benue and Kogi states, to the south by Rivers state, to the east by Cross River state and to the west by Delta state.

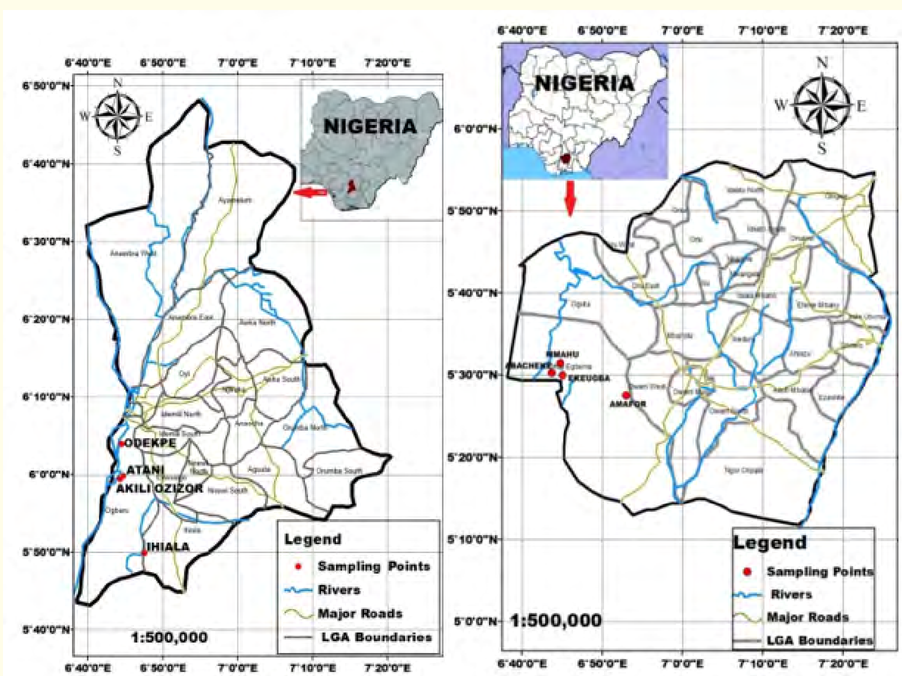

Figure 1: *Maps of Nigeria showing the Geographical and Sampling Points in Ohaji-Egbema L.G.A. of Imo State and Ihiala and Ogbaru L.G.A. of Anambra State. Source: Garwin Ltd USA (2024).*

Figure 2: *Showing sample collection points at Ekeugba, Mmahu, Abacheke and Amafor in Ohaji-egbema L.G. A. of Imo State.*

Figure 3: *Showing sample collection points at Ihiala, Odekpe, Akili-ozizor and Atani in Ogbaru L. G.A. of Anambra State.*

Climate

Southeastern Nigeria lies within tropical wet-and-dry climate or Aw climate based on Koppen's climate classification. It usually experiences an average of eight months of rainfall and four months of dry season. The two major seasons experienced in this region are; the rainy season (March to October) and the dry season (November to February). Heaviest rainfall usually occurs in July and September while December records the driest month while the month of March records the hottest weather. Mean annual rainfall ranges from 1800 mm to 2000 mm. It experiences high temperatures all year round with an average value of 27°C while the average relative humidity ranges between 60 - 70% and 80 - 90% in January and July respectively. Floods in south eastern Nigeria, are greatly influence by the rainfall pattern, and are usually experienced between July and October which is also the harvest season for most crops.

Field studies

Soil samples were collected from six distinct high risk flood locations in two southeastern states (Imo and Anambra) Nigeria, using soil auger. At each location, soil samples were gridded and collected with depths; 0 - 15 cm, 15 - 30 cm and 30 - 45 cm, representing top soil, sub soil and bottom soils respectively. Two control samples were also collected from high elevation towns within the Local Government Areas, not affected by flood.

The sampling sites were geo-referenced using Reciever Garwin Ltd Kansa USA for accurate map generation. A total of eight (8) soil samples were collected in the month of October 2024, a transition period from rainy session to dry session, the reason for the period is simply to regulate leachate migration as well as provide a stable state of the soil.

The soil samples were air-dried in a clean well – ventilated laboratory [12] homogenized by grinding, passed through a 2 mm (10 mesh) stainless sieve and stored in labeled plastic cans ready for analysis. However, the use of soil auger for sampling and subsequent air-drying and sieving were adopted in other to preserve the quality of the sample. The soil auger allowed for the collection of consistent soil cores, promoting uniform sample depth and minimizing contamination from other layers. In other to reduce moisture content and as well preserve the chemical composition of soil, air drying method were used while 2 mm sieve mesh helps to remove debris and larger stones thereby promoting homogeneity of samples.

Experimental procedure

Determination of drainage: Drainage was determined by visual observations

Assay of enzyme activity

Catalase activity was assayed following the method of Luck [13]. Lipase activity was assayed according to the method of Schinner., *et al.* [14]. Urease activity was assayed according to the method of Tabatabai and Bremner [15] while phosphatase activity was assayed according to the method of Tabatabai and Bremner [16].

Statistical analysis

Data generated were analyzed statistically using SPSS statistical software package (Version 23.0). All data were presented as the mean and standard deviation value of three replicate, where multiple comparison were done using post hoc test to compare multiple means to determine which pair of means were significantly at ($p < 0.05$) from each other.

Result

Table 1 and 2 presents the drainage characteristics of soils in some communities in Imo and Anambra states. Poorly/inadequate drainage dominated in floodplains of Akili-ozizor, Atani, Odekpe, Abacheke, Mmahu, Ekeugba while both control regions exhibited well drainage.

Locations	Depth (cm)	Drainage
Akili-Ozizor	0-15	PD
Akili-Ozizor	15-30	PD
Akili-Ozizor	30-45	PD
Atani	0-15	PD
Atani	15-30	PD
Atani	30-45	PD
Odekpe	0-15	PD
Odekpe	15-30	PD
Odekpe	30-45	PD
Ihiala (control)	0-15	WD
Ihiala (control)	15-30	WD
Ihiala (control)	30-45	WD

Table 1: *Drainage characteristics in Akili-ozizor, Atani, Odekpe, Ihiala in Anambra state.*

Locations	Depth (cm)	Drainage
Abacheke	0-15	ID
Abacheke	15-30	ID
Abacheke	30-45	ID
Mmahu	0-15	WD
Mmahu	15-30	WD
Mmahu	30-45	WD
Ekeugba	0-15	ID

Ekeugba	15-30	ID
Ekeugba	30-45	ID
Amafor (control)	0-15	WD
Amafor (control)	15-30	WD
Amafor (control)	30-45	WD

Table 2: *Drainage characteristics in Mmahu, Abacheke, Ekeugba, Amafor Communities in Imo state.*

Table 3 and 4 presents the activities of enzymes in the studied areas. Highest catalase mean values were obtained in Ekeugba (1.0933 umol/kg) and Amafor (1.0867 umol/kg) in Imo state while the lowest values were obtained in Odekpe (0.8267 umol/kg) and Atani (0.7567 umol/kg) in Anambra state. Lipase activities were relatively stable in Anambra soils ranging from (672.19-721.35 umol/kg) while in Imo soils, varied significantly. Urease values ranged from (141.79) in Akili-ozizor to (79.12 umol/kg) in Ihiala. Phosphatase values recorded its highest value in Atani (162.2800 umol/kg), followed by Mmahu (150.1000 umol/kg) while least value was recorded in Odekpe (90.9467 umol/kg).

Sample Locations	Catalase (umol/kg)	Lipase (umol/kg)	Urease (umol/kg)	Phosphatase (umol/kg)
Akili-Ozizor	0.8067 ± 0.41^{a}	720.2033 ± 65.13^{b}	141.7967 ± 50.36^{a}	94.2067 ± 81.71^{a}
Atani LGA	0.7567 ± 0.20^{a}	721.3533 ± 44.84^{b}	133.0700 ± 64.41^{a}	162.2800 ± 37.93^{a}
Odekpe	0.8267 ± 0.21^{a}	672.1900 ± 102.87^{ab}	134.7033 ± 32.41^{a}	90.9467 ± 32.17^{a}
Ihiala	0.7433 ± 0.09^{a}	673.3367 ± 38.24^{ab}	79.1267 ± 34.70^{a}	116.3400 ± 25.17^{a}

Table 3: *Soil enzyme activities in Akili-ozizor, Atani, Odekpe, Ihiala in Anambra state.*

Values represents mean ± SD of triplicate values while columns with different superscript alphabets are statistically significant ($p < 0.05$).

Sample Locations	Catalase (umol/kg)	Lipase (umol/kg)	Urease (umol/kg)	Phosphatase (umol/kg)
Abacheke	0.8467 ± 0.03^{a}	610.6200 ± 22.77^{ab}	103.8567 ± 54.71^{a}	126.6467 ± 22.31^{a}
Mmahu	1.0033 ± 0.19^{a}	429.3633 ± 366.38^{a}	102.9467 ± 42.02^{a}	150.1000 ± 29.75^{a}
Ekeugba	1.0933 ± 0.26^{a}	616.3667 ± 67.67^{ab}	140.7667 ± 25.87^{a}	113.1300 ± 19.69^{a}
Amafor	1.0867 ± 0.20^{a}	684.3667 ± 59.44^{ab}	107.4333 ± 70.69^{a}	139.3667 ± 14.41^{a}

Table 4*: Soil enzyme activities in Mmahu, Abacheke, Ekeugba, Amafor communities in Imo state.*

Values represents mean ± SD of triplicate values while columns with different superscript alphabets are statistically significant ($p < 0.05$).

Discussion

Flooding significantly threatens the biochemical dynamics of soils. The morphological data (Table 1) indicates that soils from inundated regions, displayed poor drainage (PD) and consistence unlike the well-drained (WD) control soils in Ihiala and Amafor. Inadequate drainage results in anaerobic conditions that facilitate changes in microbial activity and enzyme regulation [17]. Soil enzymes are crucial for nutrient cycling and the breakdown of organic matter, serving as sensitive indicators of soil health and microbial function. In tropical flood-prone regions, like Anambra and Imo States in southeastern Nigeria, periodic flooding alters soil's physicochemical characteristics, significantly affecting microbial enzymatic activities.

Catalase activity ranged from 0.74 µmol/kg in Ihiala to 1.09 µmol/kg in Ekeugba, with relatively higher activities recorded in Ekeugba 1.09 µmol/kg, Amafor 1.09 µmol/kg, and Mmahu 1.00 µmol/kg. Although statistical differences across sites were not significant ($p < 0.05$), the variation reflects the influence of organic matter input and microbial activity. Catalase is a redox-sensitive enzyme that decomposes hydrogen peroxide into water and oxygen, thereby protecting microbial cells from oxidative stress [18]. Higher catalase activity in Ekeugba and Amafor may indicate higher microbial activity linked to organic matter decomposition, whereas lower activity in Ihiala suggests reduced oxidative microbial processes. Flooding often induces anaerobic conditions, which can suppress catalase expression due to lower oxygen availability [19].

Lipases catalyze the hydrolysis of lipids into fatty acids and glycerol, playing a critical role in carbon cycling [20]. Lipase activity showed marked variability across the sites, ranging from 429.36 µmol/kg in Mmahu to 721.35 µmol/kg in Atani. Atani and Akili-Ozizor exhibited the highest lipase activities (>720 µmol/kg), while Mmahu recorded the lowest. Elevated lipase activity in Atani and Akili-Ozizor could be attributed to higher organic inputs, such as plant residues and microbial biomass, which provide substrates for lipid hydrolysis. In contrast, the depressed lipase activity in Mmahu suggests limited substrate availability or flooding-induced suppression of microbial populations. These differences demonstrate the sensitivity of lipase to land use, organic matter deposition, and hydrological regimes.

Urease activity ranged from 79.13 µmol/kg in Ihiala to 141.80 µmol/kg in Akili-Ozizor. This variation indicates differences in nitrogen turnover across the floodplains. Urease hydrolyzes urea into ammonia and carbon dioxide, influencing soil nitrogen availability [21]. The relatively high urease activity in Akili-Ozizor and Ekeugba suggests enhanced nitrogen cycling, possibly due to higher urea-derived inputs from fertilizers or organic amendments. Conversely, the significantly lower activity in Ihiala points to reduced nitrogen mineralization, which could constrain plant growth. Urease is strongly influenced by pH, organic matter, and moisture conditions [22].

Phosphatase activity varied significantly, with the highest value recorded in Atani 162.28 µmol/kg and the lowest in Odekpe 90.95 µmol/kg. Phosphatase is responsible for hydrolyzing organic phosphorus compounds into inorganic phosphate, thereby enhancing phosphorus availability in soils [23]. The high activity in Atani suggests strong microbial phosphorus mineralization capacity, consistent with moderate organic matter content and relatively favorable pH. In contrast, Odekpe and Akili-Ozizor recorded the lowest phosphatase activities, which may be associated with soil acidity or limited organic P substrates. Flooding tends to alter phosphorus dynamics by promoting Fe and Al oxide formation that immobilizes Phosphorus, thereby driving microorganisms to upregulate phosphatase activity in more favorable sites. This is in agreement with the report of [19].

Conclusion

Based on the findings above, flooding significantly affected drainage characteristics and enzyme activities in soils in Anambra and Imo states. These changes have direct implications which affect nutrient availability, microbial health and soil fertility. Anambra soils showed moderate enzymatic suppression compared to Imo state with greater variability, including severe inhibition (e.g. Lipase in Mmahu) and strong recovery (e.g. Catalase in Amafor).

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