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ASSESSMENT OF THE WATERSHED PROPERTIES OF IYI-ABI STREAM FOREST IN ASABA, DELTA STATE, NIGERIA

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ABSTRACT: *This study was conducted to assess the potential properties of Iyi-abi stream forest watershed in flood management of the Asaba metropolis. Three locations were mapped out at the tail-water (TW), midcourse (MC) and headwater (HW) axes of >150 stand/ha, < 150 stand/ha and approximately 150 stand/ha in the closed, high and low canopy cover of the watershed respectively. Twenty-one (21) soil samples were augered from 0-40cm depths at gridded intersection points within each location and then bulked in three (3) replicates for determination of water aggregate stability, hydraulic conductivity, particle and bulk densities, porosity, pH, CEC, P and N-levels. Data collected were subjected to ANOVA, significant means (p>0.05) separated with DMRT and coefficient of variation was used to estimate soil variability along the watershed. Results showed that particle density was HW > MC >TW (1.87±0.56 g/dm^3) and bulk density was MC < TW (1.40±0.08 g/cm^3) < HW. Mean water stable aggregates was TW (22.50) > MC (18.50) > HW (15.10) with the highest hydraulic conductivity (3.58±0.66 cm/hr), water dispersal energy (10.5 J/g), CEC (3.24 ± 0.33 meq/100g) and organic matter content at tail-water (TW). Thus, underpinned the efficiency of the watershed in tail-water axis as most significant in the flood control and therefore, the need to protect the stream forest from further attenuation by adoption into the urban forest landscape development scheme in the metropolis for eco-friendly environment.*

KEYWORDS: watershed, forest litters, soil aggregates

INTRODUCTION

Watersheds are active natural ecological forts, often situated to protect edaphic lines against weaknesses, sustain critical ecosystem services and mitigate the infrastructural impacts as environmental offsets (Eliot *et al*, 2009; Vesterdal and Leifeld, 2010; Thompson, 2013). Forest vegetative covers of the leaves and the various branches act as break at the different heights and inclination on the trunk to reduce the speed of rainfalls that impact on the soil structures to create percolations. Standing forest increase soil macro-aggregate due to rhizosphere C depositions that provide mucilage in the root regions and bind soil particles internally against lines of weakness in a complex hydraulic system (Denef and Six, 2003; Denef *et al*, 2004). These combined impacts of component standing trees is significant for increased soil aggregate stability due to increment in annual litter return and higher photosynthetic period in older stand forest plantation that biochemically protect organic C (Lawal 2013). Thus, restricted anthropogenic traffic in forests capably produce better structural aggregates that are stable and resistant to water as a result of minimal impact on the forest soil and often show better capacity to abate the otherwise erosion in time and the flood in space. Furthermore, the roots system associated with riparian vegetation reinforces stream bank soil, decreasing bank erosion rates and root network disruption following loss of standing forest tree species dwindles soil aggregate stability that lead to erosion.

Therefore, soil erosion, run-offs and flooding potentials can be indexed by the level of aggregate stability (Coate *et al*, 1998; Bronick and Lal, 2005; Borie *et al*, 2006) and potential of forest roots to stabilize soil aggregates as well as reduce run-offs (Lal, 2006). Litter soil erosion control in active forest ecosystem have been reportedly attained by limiting sediment detachment and enhanced soil stabilization by routing flow during rainfall into litter layer (Wade *et al*, 2012) to reduce velocity and transportation within the forest floor layers. Consequently, infiltration of water into the soil matrix varies according to the roughness of forest floor layer, root distribution and forest stand density under some stable soil characteristics (Osuji, *et al,* 2010).

Hammer (2017) reported significant changes in stream flows due to the interference from unplanned urban infrastructures on existing watershed that led to problems which created drainage system instability as measured by the rapidly eroded stream banks, damaged stream side vegetation and widened stream channels. This is because as land use gradually modifies stand forest vegetation, the rate of infiltration becomes significantly altered due to aggregate restructuring which lowers sorptivity and transmissivity (Haghighi *et al,* 2010; Taylor *et al,* 2009) to reduce retention capacity and manage overland flow that lead to flooding and soil erosion.

The 'lost life' of active dynamic forest ecosystem replaced in the forest watershed basin mostly contributes to the reduced 'shelf life' of engineering approaches where not complimented ecologically. According to Grischek and Bartak (2016) development of stream infrastructure to provide vital socio-economic services which often come at the cost of impacts to the stream forest ecosystem, can pose a potential liable cost in terms of safety of residents and maintenance costs. It is against this backdrop that urban forestry and landscaping approach that builds development around existing natural forest estates, is becoming fast trending practices in urban and semi-urban centers of growing conurbations in Nigeria in pursuit of Green cities. This premium on *in-situ* and naturally occurring watershed forest far outweighs the artificial arts of landscaping especially in littoral states and cities due to potential lines of edaphic weaknesses as in the Niger Delta region of Nigeria. This therefore requires the incorporation of existing forest patches, particularly watersheds in the development plans of sprawling urban centers.

However, due to the increasing loss of forest to development and urbanization, watersheds properties are lost with attendant problems that require engineering approach. Unfortunately, the cost benefit analysis of these engineering approach to forest watershed basins have often been poorly extrapolated as other essential components of the watershed are not taken into cognizance in the computation.

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The watershed forest surrounding Iyiabi stream is currently experiencing anthropogenic interferences annually as a result of the newly constructed airport in the Asaba capital territory. Over the years, urbanization has caused changes with the destruction of the watershed forest which have potentially infringed on its hydrological framework that includes dwindling capacity in the natural filtering capacity of river systems (such as channelization of headwater streams, loss of floodplains and wetlands) and regulation of flows due to the construction of residential buildings around its fringes impoundments (Meybeck, 2018). Invariably, the city master plan has not taken this critical stream forest and its capacity to drain flood water into consideration. It is against this backdrop that this study was conducted to examine the functionality of the remnant riparian Iyi-abi watershed forest soil properties as potential erosion control and flood basin for the growing city of Asaba North-end in Oshimili South LGA of Delta State.

Description of study area

The study area is Asaba, capital city of Delta State, Nigeria with co-ordinates of $6^0$11'52.23" N $6^0$43'42.48" E and a land area of 268km^2. The city forms a connector between the western, eastern and northern Nigeria through the Niger River and has a sub-humid tropical climate with an average annual temperature of 27.2^{0}C. It maintains an average tropical temperature of 32^{0}C during dry seasons while August has the lowest average temperature of the year at 25.5^{0}C with annual average temperature variation of 3.5^{0}C (NiMets, 2019).Its precipitation is approximately 1959mm of falls per annum and an average of fertile rainfall of 2,700 millimeters during the rainy season. The least amount of rainfall occurs in December (11mm). The variation in the precipitation between the driest and wettest months is 302mm (Koppen, 2005).

The natural vegetation zone of Asaba is generally classified as northeastern savanna (NDEBUMOG, 2013). It is characterized by bushes in form of grasses and interspersed trees, with shrubs. Due to anthropogenic activities and need for residential houses, many of the forests have been cleared felled to give way for infrastructural development in pursuit of the status of a State capital since in 1991. The remnant secondary forest vegetation flourishes in Asaba metropolis as landscaping units in parchments along the major urban roads. The population of Asaba was estimated at 149,603 and a metropolitan population of over half a million people and cosmopolitan population of predominantly non-indigenous people (NPC, 2006).

The Iyiabi stream forest in Asaba was naturally constituted to act as the western drainage canal to compliment and support the River Niger on the eastern axis. Ecologically, it would appear that the original stretch of the stream forest from Okpanam by NNPC fuel station through the Asaba International airport by Nelson Mandela Park to Achalla–Ibusa by Federal College of Education Technical. It is located to drain one-third (1/3) of the city from the western Okpanam through the western Asaba to the eastern Ibusa into the River Niger at Achalla-Ibusa in Oshimili North Local Government Area. The topography collaborates this as it runs parallel with another stream forest which runs from Edo-Ogwashi through Azagba-Ogwashi through Umueze-Ibusa to Oko and then to River Niger.

However, due to urbanization and growing population, massive infrastructural development, there has been significant fragmentation of the watershed forest by the construction of the Asaba International Airport, infrastructures around the NNPC fuel station by the Nelson Mandela Park, Cornerstone Model School in Okpananm and the constructed warehouses that abruptly terminated the Iyiabi stream by the Federal College Technical Asaba. The loss of approximately 40-60% of this stream forest tract is beginning to redefine the potential of its remnant in the current challenges of flooding as a result of frequent rainfall *vis-a-vis* climate change concern in Asaba.

METHODOLOGY

The rigid grid systematic survey was used to cut transverses at intervals of 30m in the horizontal and vertical axes of 30ha riparian watershed forest. This was delineated into three units of 10 ha at the tail-water, mid-course and head-water axes respectively using the level of degradation based on number of trees stand per ha. The highly degraded area (< 150 stand/ha), low degraded area (=150 stands/ha) and closed canopy (> 150 stand/ha) were basically located in the headwater (HW), midcourse (MC) and tail-water (TW) axes respectively following the level of anthropogenic activities along the watershed.

A total of twenty-one (21) soil samples were collected with a soil auger per location at the intersections of the transverses within each 10ha area from a depth of 0 - 40cm at the tail, mid-course and headwater axes. These were then bulked into 3 replicates for the determination of physical, aggregate stability and chemical properties while core samplers were used to collect samples for bulk density determination.

Bulk density was estimated as the mean of oven dried mass to volume of soil (Grossman and Reinsel, 2002). Total porosity was calculated as described by Gee and Orr (2002). The pH was measured in both water and 1N KCl potentiometrically at the soil-liquid ratio 1:2.5 soil: water suspension. The cation exchange capacity (CEC) was determined according to Hossner (1970). Soil organic carbon by Walkley and Black wet oxidation method as described by Nelson and Sommers (1986) and organic matter was extrapolated by multiplying the value of organic carbon by a factor of 1.725 (van Bermelens factor); Nitrogen was estimated by the Kjedhal method and available phosphorus calorimetrically after Bray-1 extraction (Agbenin,1995).

Mean-weight diameter of dry (MWD_d) and wet (MWD_w) aggregates was determined as described by Nimmo and Perkins (2002) by shaking 0.05kg previously sieved dry soil, through a-4mm mesh for 10minutes (10 cycles per minute) on top of a nest of sieves (2.00, 1.00, 0.50 and 0.25mm) to estimate the mass of aggregates on each sieve that was resistant to breakdown. The retained aggregate fractions were collected, weighed, remixed and pre-soaked for 10minutes on the topmost 2mm-sieve nest and then raised-lowered through a vertical distance of 4cm for 15 times per minute. Water stable aggregates (WSA) was computed as percentage aggregates that passed through the 2mm sieve in 5minutes after shaking at the rate of 60 oscillations per minute to those that passed after 60 minutes at room temperature (Malquori and Cecconi,1962). Specific

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dispersion energy of water drops (D) was determined as the equivalent kinetic energy of the total number of water drops needed to break 1.00g of a soil aggregate for ease passage through a-1mm sieve (Wustamidin and Douglas,1985).

Data collected were analyzed using ANOVA and significant means separated with the Duncan multiple range test (DMRT). The variability of soil properties along the watershed was evaluated with co-efficient of variation.

RESULTS

The mean weight diameter of dry aggregates ranged from 4.44-4.85, 5.41-6.10 and 7.96-8.73 while mean-weight diameter of wet aggregates was 3.28-4.01, 4.01-5.00 and 5.14-5.60 for the high degraded, low degraded and closed canopy watershed respectively (Table 1).
The water stable aggregates ranged from 6.24-6.71%, 7.41-8.45% and 12-12.41% for the high, low and closed canopy watershed respectively. Water dispersal energy was 3.11-3.58 J/g, 3.32-3.82J/g and 9.46-10.5 J/g for the high, low and closed canopy watershed respectively.

Table 1: Aggregate stability characteristics of forest soils along Iyi-abi watershed

Stand Density (Stand/ha)	MWD_d	MWD_w	WSA (%)	D (J/g)
High degraded watershed	4.63	3.28	6.24	3.43
(=150 stand/ha)	4.44	3.35	6.71	3.11
	4.85	4.01	6.33	3.58
Low degraded watershed	5.41	4.22	7.41	3.63
(< 150 stand/ha)	5.83	4.01	8.22	3.32
	6.10	5.00	8.45	3.82
Closed canopy watershed	7.96	5.22	12.10	9.54
(> 150 stand/ha)	8.67	5.14	12.41	9.46
	8.73	5.60	12.00	10.5
Mean	6.29	4.43	8.87	5.60
CV (%)	3.66	5.24	3.43	1.75
Ranking	Low	Low	Low	Low

The particle density was significantly different ($p > 0.05$) and was highest at the headwater (2.76±0.33 g/dm^3) while least in the tail-water (1.87±0.56 g/dm^3). The midcourse had a particle density of 2.31±1.05 g/dm^3 (Table 2).

The porosity was in the order tail-water (28.13±2.47%) > midcourse (21.31±0.79%) > headwater (18.74±0.93 %). Bulk density was highest at the headwater (1.48±0.04 g/cm^3) and midcourse (1.42±0.05 g/cm^3) which was not significantly different from the tail-water with a bulk density of 1.40±0.08 g/cm^3.

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Saturated hydraulic conductivity values ranged significantly ($p < 0.05$) along the watershed stream forest. It ranged from 1.33-3.58 cm/hr with covariance of 55.10, 57.59 and 66.94% in the midcourse, headwater and tail-water respectively. The least hydraulic conductivity (1.33± 0.15 cm/hr) was recorded in the mid-course of the watershed.

Table 2: Variability of forest soil physical properties along Iyi-abi watershed

Properties	Tail-water		Mid-course		Head-water	
	x + SD	CV (%)	x + SD	CV (%)	x + SD	CV (%)
Particle Density (g/dm^3)	$1.87±0.56^c$	24.26	$2.31±1.05^b$	48.13	$2.76±0.33^a$	46.20
Porosity (%)	$28.13±2.47^a$	17.31	$21.31±0.79^b$	11.00	$18.74±0.93^c$	45.30
MC (%)	$19.17+1.02^a$	13.10	$14.76+0.57^b$	9.64	$13.55+0.13^{bc}$	11.72
Bulk Density (g/cm^3)	$1.40±0.08^b$	15.45	$1.42±0.05^{bc}$	7.18	$1.48±0.04^a$	1.64
Hydraulic Cond (cm/hr)	$3.58±0.66^a$	66.94	$1.33±0.15^c$	55.10	$2.05±0.12^b$	57.59

Means with the same superscript on the same row are not significantly different ($p > 0.05$)

The pH varied significantly ($p > 0.05$) at the three locations along the watershed forest (Table 3). The highest pH (4.98±0.19) was recorded at the tail-water. There was no significant difference between the pH at tail-water and midcourse (4.82±0.13). The headwater recorded the least pH (4.43±0.16) which was significantly different from tail-water and midcourse. The highest organic carbon (4.10±0.09 %) was recorded at the tail-water axis while the least (1.73±0.03%) was at the headwater. There was no significant difference between the organic carbon at the midcourse and tail-water. But there was significant difference between the organic carbon level at tail-water and midcourse.

Organic matter varied significantly ($p > 0.05$) at the three locations along the watershed. The highest and least were at tail-water (7.20±0.16%) and headwater (3.00±0.45%) respectively. The midcourse showed an organic matter level of 3.80±0.03%.

The cation exchange capacity, CEC, varied significantly ($p > 0.05$) between tail-water, midcourse and headwater (Table 3). There was significant difference between tail-water and midcourse while there was none between the midcourse and headwater. The highest CEC (3.24±0.33meq/100g) and least (2.03±0.28 meq/100g) were recorded at the tail-water and midcourse respectively.

With respect to the phosphorus level, there was no significant difference at the tail-water and midcourse axes. There was significant difference between the tail-water and headwater. Highest P-concentration (2.20±0.15g/kg) was at the tail-water.

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Table 3: Variability of forest soil chemical properties along the Iyiabi watershed

Properties	Tail-water		Mid-course		Head-water	
	x + SD	CV (%)	x + SD	CV (%)	x + SD	CV (%)
pH $_{(H2O)}$	4.98±0.19[a]	11.51	4.82±0.13[ab]	5.26	4.43±0.16[c]	9.39
Org. C (%)	4.10±0.09[a]	28.14	2.20±0.17[b]	35.94	1.73±0.03[bc]	58.32
Org. M (%)	7.20±0.16[a]	12.47	3.80±0.03[b]	38.98	3.00±0.45[c]	48.40
CEC (me/100g)	3.24±0.33[a]	56.55	2.03±0.28[bc]	43.39	2.27±0.82[b]	52.51
Av. P (g/kg)	2.20±0.15[a]	18.58	2.07±0.07[ab]	12.20	1.84±0.11[c]	12.78
Nitrogen(g/kg)	0.14±0.11[b]	79.74	0.35±0.26[a]	-21.96	0.13±0.04[b]	53.32

Means with the same superscript on the same row are not significantly different (p>0.05)

DISCUSSION

The coefficient of variation of a soil properties ranged from low (< 15%), medium (15-35%) to high (> 35%) as categorized by Shukla *et al* (2004). The aggregate stability index was generally low along the watershed even though the MWDw recorded the highest value. The higher variability among the physical characteristics compared to the chemical along the watershed may not be unconnected with the different levels of vegetative degradation which has capability to influence the forest floor layer (0-5cm). The low-medium variability of the various parametric indices observed in the tail-water axis compared to mid-course and headwater axes along the watershed revealed the potential stability status of soil aggregates and inclination to combating flooding and erosion. This result corroborates the water stable aggregates and the commensurate high mean dispersal energy recorded in the closed canopy watershed portions at the tail-water axis that may be due to the high influx rate of organic materials (Osuji and Onweremadu, 2007; Beare and Bruce,1993).

The hydraulic conductivity was highly variable (>35%) with the highest value at the tail-water. This may not be unrelated with the regular infusion of litters through constant decomposition to reduce crusting and service the transmissivity pathway within the high canopy forest stand (Waniyo *et al*, 2012). Also, the reduced percolation rate which is proportionally related with forest crown cover may have enhanced reduction in disturbances for complete decomposition process of inherent vegetative matter. The highest moisture content at the tail-water was not unexpected because of the high vegetative cover. But the generally low coefficient of variation (CV <15%) of the moisture content indicated the uniformity of watershed forest floor layer (0-5cm) as probably underlain with organic matter that consistently held water, although highest at the tail-water axis. This assertion agrees with Prescott and Grayston (2013) that coarse forest fragments are noted for higher soil temperature and less moisture content due to the high rate of exposure, low crown density and high litter decomposition rate. Bulk density and moisture content recorded low CV values indicating certain homogeneity, especially at the midcourse and headwater probably due to forest floor crusting.

The most water stable aggregate was recorded within closed canopy cover while the least less high degraded watershed area. This may be as a result of the protection provided by the observed mat of organic matters which is a function of the forest cover that buffers soil aggregates over time against any external force. This finding agrees with Bronick and Lai (2005) that structural stability of soil is greatly enhanced by the presence of organic matter to resist the breakdown of aggregates. The mean diameter weight of both dry and wet aggregates within the relatively closed canopy forest as shown by the higher mean weight diameter of aggregates in water than the high and low degraded watershed portions also substantiates the findings. This is because the influx of different land-use and frequencies of practices that led to the reduction in forest covers along the watershed may have accounted for the breakage and cleavages of intact underlying soil aggregates in these degraded portions to increase potential for soil erosion (Sarah, 2005; Osuji *et al*, 2010)

The result of specific dispersion energy revealed that soil under the high canopy forest stand at tail-water were more resistant to force of dispersion than the degraded forest stands. This showed lower percolation of soil under vegetative cover probably due to the overall impact of component vegetative cover in breaking speed of rainfall overtime. Higher litter deposit and subsequent mineralization which may be more than the other portion along the watershed could equally have contributed to the greater specific dispersion energy at the tail water (Susan *et al*, 2014). Hence implicates structural stability of aggregates and likely better potential to combating erosion due to flooding at the tail water axis.

The significant differences in saturated hydraulic conductivity along the watershed, with the degraded midcourse recording the least conductivity implies restricted water transmissivity through the soil in this portion and invariably could lead to soil surface water accumulation and run-off (Bormann and Klassen, 2008). The midcourse demonstrated better capacity than the head water axis, this may not be unconnected with its higher organic matter content over time which act as readily available source of micro-organisms for creating active medium that elicits exudates from roots to bind disintegrated aggregates (Ahukaemere *et al*, 2012).

CONCLUSION

The forest soil properties of Iyiabi stream forest reflected the capability of the watershed to control flooding and avert erosion in the west-end axis of Asaba capital city. The relatively intact portion in the tail axis is notably high in saturated hydraulic conductivity compared to the midcourse which may be prone to erosion. Further degradation by encroachment and reclamation for development of urban infrastructure may lead to the attenuation and probable loss with serve ecological problems. Therefore, managing the entire stretch of the watershed by adopting it as an urban green belt through regulatory framework will go a long way in restoring the degraded portions for sustainable ecosystem services delivery especially in soil surface water control during the rains in the already concrete impervious west-end of Asaba capital city.

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