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Ecosystem Service Potentials of Edaphic-Vegetation Profile in Iyi-Mgbiligba Watershed Forest, Azagba-Ogwashi, Delta State, Nigeria

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ABSTRACT

Watersheds are specialized forest ecosystems endowed with the potential for water regulation, edaphic and biodiversity support but are fast becoming threatened by anthropogenic activities, particularly agriculture, deforestation and urbanization. This study examined the intactness of edaphic and vegetation components of the Iyi-Mgbiligba watershed in Azagba-Ogwashi, Delta State to support ecosystem services. Soil and forest floor litter components were determined for soil physicochemical properties and organic matter, vegetation species diversity and distribution within established fragmented watershed. Data were subjected to descriptive statistics and the Pearson correlation matrix. Results showed a sand content ranging from 809 - 882 g/kg, with 0.001skewness and -3.328 kurtosis, indicating a symmetric and flatter distribution than normal; significant differences (p < 0.05) in sand, clay, and moisture contents between groups; significant and positive correlation between organic matter with cation exchange capacity (0.99), and exchangeable acidity (0.90) but negatively correlated with C/N ratio (-0.99) to suggest interactions for soil fortification. Stand vegetation root assay was significantly skewed (1.25) and kurtotic (2.21) for deciduous species, implicating positive influence on soil aggregation as a significant interdependence relationship for the sustainable service life of soil stabilization, improved water infiltration, and contribution to nutrient management among anthropogenic activities in Iyi-Mgbligba watershed.

Keywords: *Edaphic vegetation, watershed, forest ecosystem, anthropogenic activities, soil properties, forest litter components.*

Introduction

Soil and vegetation are individual planetary components of the terrestrial system that contribute both as individuals and entities to facilitating myriad ecosystem services for the sustenance of humans on earth. Its combined entity as watershed exerts a critical catchment-basin characteristics on forest tracts, along a uniform water area often naturally situated to protect from degradation by anthropogenic activities [1, 2]. The ecological resilience of watersheds is therefore characteristically comprised of a portion of forested land that is directly drained by tributaries of a river, for exchanges of nutrients which tend to often become less resilient and nutrient-rich away from the water body. But, the interplay of stand vegetation, roots and fine litter qualities have been reported as a significant edaphic matrix that confer a wide range of ecosystem values on the forest soil [3] by aiding in the translocation of nutrients within the watershed. These areas play a crucial role in safeguarding water quality and maintaining the ecological health of aquatic and terrestrial systems, particularly in regulating nutrient flow from the aquatic regions for a wide range of utilitarian value [4].

The ecological services of watersheds are well documented as essential for the protection of forest soil, which in turn aids in the maintenance of soil structure and fertility. This is particularly important for sustaining endemic plant life and supporting diverse ecosystem services [5, 6]. Furthermore, watersheds significantly contribute to the recharge of underground water aquifers, a process critical for ensuring a sustainable water supply for both human consumption and ecosystem needs [7].

Watersheds have been reported to play a pivotal role in combating soil erosion, which can lead to sedimentation in waterways and negatively affect aquatic habitats, by the regular moisturization of forest tracts. Effective watershed management practices can mitigate these issues and promote healthier ecosystems [8]. Moreover, the nutrient flow within forest ecosystems is facilitated by watersheds, ensuring that essential minerals and organic matter are available for various biotic communities. This nutrient cycling is crucial for supporting flora and fauna, thus maintaining a regular influx of biodiversity to provide habitat [9, 10]. It is these complex interactions within these systems that underscore the importance in preserving ecological balance and enhancing resilience against environmental changes [11].

Litter decomposition in forest watershed ecosystems has been reported as major driving nutrient cycling, soil formation, and organic matter replenishment. This is because decomposition influences the essential nutrient availability, for ecosystem productivity and resilience [12, 3] since the rates largely depend on litter quality, climatic conditions, and microbial community structure [13, 14]. Furthermore, differences in temperatures particularly under the moderation of land and sea breeze have shown accelerated microbial activity and decomposition rates in tropical watersheds [15, 16]. Fortification of watershed forest soils by the decomposition dynamics impact greatly on soil organic matter content which enhance soil structure and water retention capacity to ensure soil stability and reduces surface runoff for soil health and long-term ecosystem resilience [12].

The evergreen composition of the watershed has attracted a lot of anthropogenic activities that range from different agricultural practices including harnessing the relative adjoining land area for cattle ranching due to the availability of water all year round [6]. The excessive loss of litter through deforestation has been reported to disrupt nutrient cycling, leading to soil degradation and reduced productivity in forest watersheds [16]. Consequently, watersheds have in recent times become threatened as a result of the increasingly numerous activities leading to the reduced functioning of many secondary component services and impaired capability to ecologically regulate the nature-assigned benefits. Watersheds are typically characterized by a delineation of land that is influenced by the topography of the landscape, resulting in a unique combination of soil, vegetation, and hydrological characteristics.

Unfortunately, the increasing activities in search of nutrients for better agricultural yield have been shown to degrade watershed especially after the loss of standing forest vegetation [17]. It is this forestry-agriculture interface especially in peri-urban localities that pose a serious challenge to the mitigating potential of forests in the role against climate change as carbon sink in the expanding urban areas. Attempts at colonizing the same tract of forest by tourism facilities have equally been detrimental to the sustainable conservation of watershed [18, 19, 20, 21] as pollution and eutrophication often set in as a result of the introduction of inorganic compounds and materials that acidify soils and limit bacterial activity, thereby leading to slowing decomposition rates [16].

The contemplated ecological importance of watersheds goes far beyond the immediate forest tract area as it contributes to the macro-climatic condition, water quality, and global carbon sink scheme and ecosystem health of enhanced interphase [22]. Its capacity to manage the evapotranspiration rates and suction pressure dynamics of the underlying water often enhances local and global significance.

Consequently, the patterns of specialized forest loss without an appropriate estimate of the opportunity cost ecologically by proper evaluation of the probable land-use impact on soil properties portend danger for sustainable ecosystem management of ecosystem services. The situation is even worse off for the Iyi-Mgbiligba watershed forest with both exploitable mineral and timber resources alongside the strategic position for infrastructural development. Therefore, this study assessed the influence of existing land-uses on the edaphic properties of the Iyi-Mgbiligba watershed forest intending to visible relationships between the edaphic and remnant vegetation within the watershed for design of sustainable management template against degradation and further fragmentation/ shrinkage.

Materials and Methods

Description of Study Area

The study was carried out at the Iyi-Mgbiligba watershed stream forest.

Iyi-Mgbiligba watershed forest is located in Azagba-Ogwashi on lat. 6°14'33'' N and long 6°35'42'' E, Aniocha South LGA of Delta State. The forest is nestled within the Lowland rainforest in northern Delta State. Iyi Mgbiligba forest holds profound spiritual significance for the local indigenous community, serving as a sacred site for traditional rituals and ceremonies.

The watershed has the Mgbiligba stream with 4 unique seams of good exposed lignite with an average thickness of 7 m and an overburden range of 15-20 m [23]. The lignites are generally brown to black in color with high calorific value of 10,825 BTU/lb and up to an estimated quantity of 125×10^6 tons [24].

The estimated land area of the Iyi-Mgbiligba watershed forest between 2005–2013 declined from 22.79 to 15.32 ha [25]. It consists of two (2) parts in the stream forest region comprising the forest area and the source of the stream, elevated at approximately 6.5m from the ground level than the supporting degraded forest area that is over 30-38 m high above the source of the stream; and the agricultural acquired portions where farmlands with rubber plantations exist. The Rubber (Para rubber) *Hevea brasiliensis* has existed on these parts of the stream forest for over 30 years. It was the first plantation earlier used to replace the lost forest trees species. The Hevea currently serve as edaphic support for the eastern axis of the stream forest while at the same time, serving as a source of fuelwood for the Azagba-Ogwashi Community.

The degraded farmland forest area is on the western flank of the stream forest and covers over 60 % of the stream forest with remnant forest indigenous species. Species of *Kola nitida*, *Irvingia gabonensis, Elaesis guinensis* (Palm), *Entandrophragma cilindricum* and *Utile* along with *Vitex doniana* species constitute the forest area.

Vegetation and Climate

The vegetation and climate of the Iyi-Mgbiligba Forest in Asaba, Nigeria, contribute to its ecological significance and biodiversity. The forest is characterized by lush tropical vegetation, including dense patches of tropical rainforest species such as Mahogany, Iroko, and oil palm trees. The climate of the region is typically humid and tropical, with high temperatures and abundant rainfall throughout the year, especially during the wet season. The diverse flora and favorable climate create a habitat suitable for various wildlife species, including birds, mammals, and reptiles, enhancing the ecological importance of the forest.

Table 1: Ecological description of Iyi-Mgbiligba watershed forest, Azagba-Ogwashi

Estimated Households around watershed	68
Population Watershed-dependent population Stream water Fuelwood Bamboo Forest fruits/others	 52 % 35 % 6 % 7 %
Eco-Zone	Lowland rainforest
Elevation	177m asl
Aspect	North facing
Rainfall	2762 mm/year
Temperature	23.3 – 31.5 °C
Foot tracts	18
Land use (Ha) Agriculture Infrastructure Conservation	 8.21 4.30 2.49

SOURCE: [26]

Soil sampling

Soil samples were collected from 0 – 30 cm depth in the fragmented upper, middle, and lower portions of the watershed forest area. Plots of 160 x 160 m were mapped out in each portion of the upper, middle and lower watershed forest fragments with the aid of meter tape, ranging pole and global position system (GPS). Soil samples were then collected using the 2.50 cm Dutchman hand soil auger from each plot at 1.00 m intervals along the grid of established nodes.

Sixteen (16) replicate samples were taken at the perpendicular point to the stream for the fragmented portions. Collected samples were labeled and stored in poly bags before laboratory analysis for aggregate size, physical and chemical properties.

Root length and density assay

Fine root growth, as an assay for-root detrital inputs to soil, was taken and measured from depth of 0 – 15 cm using 2 mm mesh ingrowth cores for the identified vegetation type as described by [27]. Roots were separated from the soil using the combination of the flotation and sieving method. The root lengths of separated roots were estimated by the line-intersect procedures as employed by [28]. Roots were spread over grid squares and then the number of intersections of roots with horizontal and vertical grid lines was counted. When a grid dimension is 1cm, the number of intersects times/by 11/14 gives the root length in centimeters.

Forest litter assessment

Quadrants of 1.00 x1.00 m were used to access the forest floor litters within the mapped (160 x 160 m plots) in each fragmented land use portion. Fine litters within 16 quadrants in each mapped plot of the fragment were collected using the garden fork while avoiding the soil particles to ascertain the finite rate of forest floor litter production in the evergreen and deciduous forests. These were weighed and recorded as the floor litter per hectare and was adjudged either on the decline or increase if finite rate of inverse (y) is less than or greater than 1 as employed by [29].

Statistical analysis

Data collected from the soil and vegetation were subjected to classical statistical methods for minimum, maximum, mean, skewness, kurtosis and standard derivation.

The coefficient of variation was computed to ascertain the variability of variables in the watershed. One-way analysis of variance was used to compare each variable between the fragmented portions at $p < 0.05$ significant level.

Results and Discussion

Watershed soil physical properties

The result of descriptive statistics for various soil physical variables is presented in Table 2. Based on the coefficient of skewness and kurtosis, a good number of the evaluated soil properties were not significantly skewed (avs < 0.61) or significantly kurtotic (avk < 1.22). The sand content ranged from 809.6 - 882.0 g/kg with a mean of 845.56 g/kg. A skewness close to zero (0.001), suggests a symmetric distribution, while the kurtosis (-3.328) suggests a flatter distribution than normal. The silt ranged from 87.0 - 90.3 g/kg, with a mean of 88.72. The skewness (0.01) and kurtosis (-1.72) suggest a near-normal but slightly platy-kurtic (flatter) distribution. The clay had a wider range from 29.9 to 100.1 with a mean of 65.73 g/kg. The skewness (-0.003) suggests a near-symmetrical distribution, while the significant kurtosis (-3.325) shows a flatter shape probably inclined to high deposit and decomposition of litters to increase soil organic carbon. These findings conform to [30] that soil organic carbon can increase silt and clay contents independent of climatic condition where litter supply is favorable since interactions cold lead to formation of suitable organic-metal complexes capable of protecting decomposition.

Moisture content ranged from 33.3 - 39.4 %, with a mean of 36.08 to indicate moderate variability. The skewness (0.06) suggests a slight positive skew, and significantly kurtotic (-3.12) points to a flat distribution to index possible fine nutrient distribution within the Iyi-Mgbiligba as a result of the moderate variability. Furthermore, this finding showed that Iyi-Mgbligba is still relatively intact because [31] asserted that high moisture content variability in watershed forests was connected with high degradation to standing forests either by deforestation or soil degradation from nutrient miners.

The bulk density ranged from 1.42 - 1.48 g/cm^3, with a mean of 1.45, showing little variability. It has a slight negative skew (-0.33) and a moderate but significantly kurtotic (0.52), suggesting its closeness to a normal distribution but slightly peaked due to the physical environment of the soil in the watershed area.

Table 2: Descriptive statistics for the watershed soil physical properties

Variable	N	Mini	Max	Mean	Std Dev.	CV	Skewness	Kurtosis
Sand (g/kg)	16	809.60	882.00	8.4556E2	38.72	30.45	0.001^{ns}	-3.328 *
Silt (g/kg)	16	87.00	90.30	88.72	1.30	17.13	0.010^{ns}	-1.722^{ns}
Clay (g/kg)	16	29.90	100.10	65.73	37.54	-10.20	-0.003^{ns}	-3.325 *
MC (%)	16	33.30	39.40	36.08	2.93	12.10	0.063^{ns}	-3.116 *
BD (g/cm^3)	16	1.42	1.48	1.45	0.02	9.64	-0.333 *	0.516 ^{ns}

LEGEND: MC= Moisture content; Bulk density = BD

*Significant if the absolute value of skewness or kurtosis is ≥ 2x its standard error of skewness [$(6/n)^{0.5}$] or kurtosis [$(24/n)^{0.5}$].*Significant; ns: Not significant*

Watershed soil chemical properties

Table 3 shows a detailed summary of various soil chemical variables. The statistics include the minimum and maximum values, mean, standard deviation, coefficient of variation, skewness (degree of asymmetry in data distribution), and kurtosis (degree of peak in data distribution). Most of the soil properties were significantly skewed (0.61) or significantly kurtotic (1.22). This may not be unrelated with the varied impact of land-use on the watershed forest. The pH in water ranged from very strongly acidic to strongly acidic, while the organic carbon content show considerable variability with mean = 16.35 and SD = 2.31 to reveal the variegated impact of anthropogenic activities on the different land-uses. This finding agrees with [32] that reported low carbon footprint due to deforestation in parchment forests. The low coefficient of variation values especially for the exchangeable bases may not be unconnected with various land-uses particularly agriculture owning to regular nutrient mining without commensurate forest stand to compensate for the loss via cultivation. Hence, the soil organic carbon content shows considerable variability, indicating diverse soil organic matter input probably dependent on the various underlying decomposition mechanisms often conferred by the resident micro-organisms. These to a large extent provide significant synergy in the formation of metal –organic complex since the interaction with microbes produce oxygen-rich functional groups as the carboxyl, hydroxyl and others.

The Na and K were less variable, with smaller coefficients of variation. Negative skewness in organic carbon suggests a concentration of data on the lower side, while positive skewness in others (Ca) indicates a long tail towards higher values probably due to perturbations in the soil resulting from different land uses.

This finding aligns with [33] that the introduction of often more than two land uses of forest thinning and prescribed burning resulted in drastic and non-synergetic relationships among exchangeable bases. These statistics help identify which variables exhibited greater variability and underpin effects of various improper land-use patterns on forest management for soil conservation efforts.

Exchangeable Na and Al exhibited low variability, while CEC and exchangeable acidity had a higher skewness and kurtosis, indicating more variability and distinct distribution in Iyi-Mgbiligba watershed. This finding reveals significant threat to the watershed because study by [34] reported that high level of organic matter decomposition is critical to increased CEC since it enables soil to retain and release nutrients for sustainable forest management. Although the finite qualities of ingested organic matters due to the inverse relationship often regulated by the moisture content may have contributed to the observed differential in nutrient storage and release upon requirement by standing vegetation, particularly under agricultural land-use. This is because in forest management, significant variations in chemical properties of Ca^{2+} and Mg^{2+}, both being critical for plant nutrition, could underscore the need for tailored interventions, since these elements affect vegetation health and soil fertility [35].

However, the lack of significant differences in some investigated vegetation variables may not be unconnected with potential stability probably as a result of compensating environmental moisture regime, unchanging conditions and the limited interaction of the variables. This result agrees with [36] on forest biomass formation and distribution which could lead to increased break down of soil structure due to reduced anchorages on root matters and its secretion, the capacity to support internal water direction becomes impaired.

Table 3: Descriptive statistics for the watershed soil chemical properties

Variable	N	Min.	Max.	Mean	Std Dev.	CV (%)	Skewness	Kurtosis
pH_{H2O}	16	4.85	5.40	5.12	0.25	10.42	0.04^{ns}	-3.050 *
$pHcacl_2$	16	4.30	4.91	4.63	0.23	11.83	-0.23^{ns}	-1.449^{ns}
SOC (%)	16	14.13	18.56	16.35	2.31	10.21	-0.003^{ns}	-3.307 *
SOM (%)	16	24.30	31.92	28.11	3.96	15.72	-0.003^{ns}	-3.306 *
Ca (cmol/kg)	16	1.20	2.86	2.03	0.88	3.488	0.001^{ns}	-3.325 *
Mg (cmol/kg)	16	0.78	2.05	1.41	0.67	2.668	0.001^{ns}	-3.324 *
K (cmol/kg)	16	0.31	0.38	0.35	0.024	-0.078	0.000^{ns}	-0.009^{ns}
Na (cmol/kg)	16	0.10	0.14	0.13	0.016	0.052	-0.811*	-1.029^{ns}
CEC (cmol/kg)	16	2.10	2.76	2.42	0.34	1.335	0.015^{ns}	-3.274 *
EA (cmol/kg)	16	0.88	1.64	1.26	0.39	1.532	0.003^{ns}	-3.297 *
Al^{3+} (cmol/kg)	16	0.65	1.30	0.90	0.28	1.037	0.494 *	-1.737^{ns}
TN %	16	1.17	1.91	1.53	0.39	1.527	0.010^{ns}	-3.304 *
C/N ratio	16	9.68	12.20	10.97	1.26	-4.944	-0.004^{ns}	-3.247 *

***LEGEND**: OC = Organic carbon; OM = Organic matter; TN = Total nitrogen; CEC= Cation exchange capacity; EA = Exchangeable acidity; C/N = Carbon nitrogen ratio*
*Significant if the absolute value of skewness or kurtosis is ≥ 2x its standard error of skewness $[(6/n)^{0.5}]$ or kurtosis $[(24/n)^{0.5}]$.*Significant; ns: Not significant*

Watershed vegetation

Table 4 presents descriptive statistics for various forest variables as the evergreen and deciduous species counts, litter types, and root measurements across sampling plots. The data showed variability with the evergreen species as mean of 12.67 with a CV of 36.9 %, indicating moderate variability as an indication of uniform silvical influence and better forest-soil health status within the watershed. Thus accounting for higher compensations compared to the deciduous species with higher net primary productivity thereby supporting the report of [37] that soil quality could become diminished and tend to permanent degradation of land productivity with loss of forest stands under mono plantation management.

The root weight showed a very high standard deviation, suggesting extreme variability which may be advantageous in the edaphic sustainability of the watershed since macro-aggregates are often more susceptible to the disruptive forces of biological activities than micro-aggregates.

This observation is in line with [38] and [39] that such variability increases the dynamic stages of macro-aggregate turnover at which roots and hypae holding macro-aggregates together form the nucleus of micro-aggregate formation in the center of the macro-aggregates. Root length exhibited negative skewness and positive kurtosis, indicating a heavy concentration of values near the lower end of the deciduous trees stand, with a sharp peak at the mean which may not be unrelated with the alteration often associated with the changes in soil quality due to reliance and preference of this area of the watershed for agriculture owning to litter yield per annum. This assertion corroborates [40] that recorded diminished supply and low mineralizable nutrients as a result of biological transformation in the root biome after the conversion of forestlands.

For vegetation variables, the evergreen trees species, deciduous as well as evergreen litters were not significantly skewed and root weight showed no significant difference, implying uniformity in these vegetation variables. However, evergreen floor litters showed a significant difference, suggesting variability in these variables that may be linked to ecological differences based on species factors often strongly connected with vegetation type or soil conditions. These results suggest that soil properties are more influenced by group categorization than vegetation characteristics, possibly indicating that soil variables were more sensitive to environmental or management interventions.

Table 4: Descriptive statistics for the studied watershed vegetation

Variables	N	Min.	Max.	Mean	Std Dev	CV (%)	Skewness	Kurtosis
Evergreen Trees	16	6.00	18.00	12.67	4.68	36.9	-0.037^{ns}	-0.915*
Deciduous Trees	16	4.00	10.00	7.67	2.58	0.610	-0.705*	-1.623*
Deciduous floor litter	16	7.24	13.86	10.51	2.40	-0.093	0.195^{ns}	-0.671^{ns}
Evergreen floor litter	16	5.11	12.10	8.51	2.49	0.026	0.261^{ns}	-0.378^{ns}
Root weight (g)	16	2.80	892.50	3.83E2	325.19	-27.95	0.579*	-0.297^{ns}
Root length (cm)	16	40.81	98.12	62.75	19.70	-3.39	1.251*	2.205*

*Significant if the absolute value of skewness or kurtosis is ≥ 2x its standard error of skewness [$(6/n)^{0.5}$] or kurtosis [$(24/n)^{0.5}$].*Significant; ns: Not significant*

Pearson correlation matrix of chemical properties

Table 5 presents a Pearson correlation matrix of the chemical properties of soil in Iyi Mgbiligba watershed forest, showing the relationships between key soil chemical properties such as organic matter content, calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), sodium (Na^{+}), cation exchange capacity (CEC), exchangeable acidity, aluminum (Al^{3+}), total nitrogen (TN), and the carbon-nitrogen ratio (C/N).

The organic matter showed a strong positive correlation with most variables as CEC, exchangeable acidity and Al but negative correlations with K and C/N ratio. These results agrees with [41] that showed an increase in CEC with organic matter due to the readily conversion potential of decomposition by microbial communities.

Calcium is positively correlated with organic matter and concurs with the finding of [42] that Ca play a critical role in the formation of clay-polyvalent cation-organic matter complex in soil aggregate stability. Even though weakly and negatively correlated with Mg, result suggests better impact on the watershed soil aggregates since the likely deleterious effect from swollen clay would be managed substantially. Furthermore, Mg had a strong positive correlation with CEC, exchangeable acidity, and Al, while TN had a negative relationship with K. This negative correlation may not be unrelated with the competition often associated ion absorption in nutrient uptake and phytocycling processes, with shoots and twigs having differential preferences to account for quantities in the resultant organic matters on the watershed forest soil. This assertion was corroborated by the fact that K had a positive correlation with CEC to indicate its probable better preference for Mg by the standing vegetation species. CEC had a positive correlation with organic matter, exchangeable acidity, Al, and TN. This finding agrees with [43] that reported increase in cation exchange capacity with an increase in organic matter and TN as decomposition increases but negatively with C/N ratio as stored materials are often expensed contrary to storage as nutrient in CEC.

Exchangeable acidity had a strong positive correlation with Al. The TN was negatively correlated with organic matter and C/N ratio within the watershed forest. This may be related to appreciable carbon loss as a result of an increasing supply of nitrogen that was actively engaged in the decomposition process.

Al had a high positive correlation with TN, and organic matter; Ca, CEC, and exchangeable acidity were highly correlated with each other, suggesting that high organic matter content may be linked to increased CEC and acidity levels in the soil. This result corroborates the findings of [44, 45] that nutrient statuses of forest soil are closely tied to the standing vegetation because of the regular deposit of leaf litters upon decomposition. While, the negative correlations between organic matter and variables as K and C/N ratio indicate potential nutrient interactions that could affect soil fertility as a result of the selective translocation of nutrient elements during the phytocycling process.

The strong correlations among organic matter, CEC, and nutrient levels suggest that managing soil organic matter could therefore be significant to maintaining tropical forest soil for fertility and structure in this watershed ecosystem. This assertion concurs with the result of [46] managing soil organic matter is crucial for maintaining healthy forest soils, as it significantly impacts fertility, structure, and overall ecosystem function, especially in watershed ecosystems.

Correlation values showed strong level of statistical significance, highlighting reliable relationships among these soil properties in the ecosystem. Recent studies support these findings by highlighting the influence of soil properties on vegetation distribution. This finding agrees with [47] that demonstrated that soil pH and organic carbon as key factors influencing forest growth and soil fertility with the significant results observed in this study for soil chemical properties. Similarly, [48] found that soil moisture content and bulk density significantly affect root growth, which is consistent with the variations seen in soil physical properties to warrant inclusion in basic environmental planning [48].

Table 5: Pearson correlation matrix of watershed chemical properties

Variables	OM	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	Exch. Acidity	Al^{3+}	TN	C/N ratio
OM		1.00**	0.00**	-0.81	0.79	0.99**	0.90**	0.94**	0.90**	-0.99**
Ca^{2+}			1.00**	-0.82*	0.78	0.90**	0.90**	0.94**	0.90**	-0.90**
Mg^{2+}				-0.83*	0.77	0.90**	0.90**	0.94**	0.90**	-0.90**
K^+					-0.53	0.86*	-0.84*	-0.70	-0.84*	0.86*
Na^+						0.78	0.78	0.64	0.78	-0.75
CEC							0.90**	0.91*	0.90**	-0.90**
Exch. Acidity								0.93**	0.90**	-0.90**
Al^{3+}									0.94**	-0.94**
TN										-0.90**
C/N ratio										

Legend: *Strong significant = **; Significant = *; Not significant= ns*

Conclusion

The study reveals the ecological significance of watershed forests in maintaining soil stability, regulating water cycles, and supporting biodiversity in Iyi-Mgbiligba stream forest. The edaphic-vegetative characterization showed a strong interdependence between soil properties and parchment vegetation types, which collectively enhanced the forest's resilience and capacity to provide essential ecosystem services. The presence of a variety of soil types, diverse vegetation, and a complex root system within the watershed forest depicts a crucial ability for stabilizing soil, controlling erosion, and promoting nutrient cycling underscoring the need for sustainable management practices to mitigate the effects of anthropogenic pressures on the Iyi-Mgbiligba watershed. Therefore, prioritizing conservation efforts and implementing sustainable land-use practices are essential to preserve this veritable platform for ecosystem services and ensure long-term ecological balance.

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References

1. Gilmour, D. (2024). Community-led initiatives for watershed management: Lessons from case studies across the globe. *Sustainability Science*, 19 (1), 112-127.

2. Liu, Y., (2019). The impact of forest cover on biodiversity in watershed ecosystems: A comparative study. *Biodiversity and Conservation*, 28(8), 2049-2068.

3. Aponte, C., Lucas, M (2023). Litter Quality and Nutrient Cycling in Forest Watersheds. *Environmental Research.* 23, 22-26

4. Choi, M., Lee, C., Kim, L-H., Choi, S-H. Bong, Y-S., Lee, K.S. and Shin, W. J. (2024). Assessing sources of nutrients in small watersheds with different land-use patterns using TN, TP, and NO_3^-N. *Journal of Hydrology: Regional Studies*, 55, 101958. https://doi.org/10.1016/j.ejrh.2024.101958

5. Davis, M. A. (2021). The influence of soil moisture on litter decomposition and nutrient release in a temperate forest, *Soil Biology and Biochemistry*, 42(12), 2176-2186.

6. Houghton A. D (2024). Impact of Agricultural Practices on Watershed Degradation: Quantification of water-related soil erosion in the trans boundary basin of the Bia (West Africa). Proceedings of the International Association of Hydrological Sciences, 384, 107–112

7. Smith J., P. Smith, M. Wattenbach, S. Zaehle, R. Hiederer, R.J. Jones, L. Montanarella, M.D. Rounsevell, I. Reginster, F. Ewert (2020). Projected changes in mineral soil carbon of European croplands and grasslands, 1990–2080. *Global Change Biol.*, 11 (12), 2141-2152

8. Jones, M.W., Peters, G.P., Gasser, T. et al. (2023). National contributions to climate change due to historical emissions of carbon dioxide, methane, and nitrous oxide since 1850. *Sci Data* 10, 155. https://doi.org/10.1038/s41597-023-02041-1

9. Lee, J. T. ; Connor-Appleton, S. ; Haq, A. U. ; Bailey, C. A. ; Cartwright, A. L. (2020). Quantitative measurement of negligible trypsin inhibitor activity and nutrient analysis of guar meal fractions. *J. Agric. Food Chem.*, 52, 6492-6495

10. Green Julia K. (2024) - The intricacies of vegetation responses to changing moisture conditions. First published: 06 October 2024 https://doi.org/10.1111/nph.20182

11. Thompson, R., Green, P. and Brown, S. Gracia, N. (2021) Predicting the Effects of Climate Change on Forest Biodiversity A Regression Analysis. *Ecological Studies,* 124, 789.

12. Calder, I. R. (2007). Forests and water—Ensuring Forest benefits outweigh water costs. *Forest Ecology and Management,* 251(1-2), 110-120.

13. Wang, Q.; Wang, S.; Huang, Y. (2022). Comparisons of litterfall, litter decomposition and nutrient return in a monoculture *Cunninghamia lanceolata* and a mixed stand in southern China. *For. Ecol. Manag*. 255, 1210–1218.

14. Xu Yong, Yun Gui Lu, Bin Zou, Ming Xu, Yu-Xi Feng, (2024) - Unraveling the enigma of NPP variation in Chinese vegetation ecosystems: The interplay of climate change and land use change. https://doi.org/10.1016/j.scitotenv.2023.169023

15. Jones, J. A., Groffman, P. M., Blair, J., Davis, F. W., Dugan, H., Euskirchen, E. E., et al. (2021). Synergies among environmental science research and monitoring networks: A research agenda. Earth's Future, 9, e2020EF001631. https://doi.org/10.1029/2020EF001631

16. Green Hyatt, Wilder Maxwell, Daniel Weller - Department of Environmental Biology, College of Environmental Science and Forestry, State University of New York, Syracuse, NY, United States. and Wiedmann Martin - Department of Food Science, Cornell University, Ithaca, NY, United States (2021) - Integrative Survey of 68 Non-overlapping Upstate New York Watersheds Reveals Stream Features Associated With Aquatic Fecal Contamination

17. Meijaard U. Kouassi, K. L., Meledje, N. E. H., & N'Go Y. A. (2021). Effects of deforestation and forest degradation on ecosystem service indicators across the Southwestern Amazon. *Ecological Indicators*, 147, 109996.

18. Akintola and Akintoye (2021). Watershed degradation and management practices in northern Nigeria. *Environmental Monitoring and Assessment*, 192 (10), 627.

19. Egunjobi A. E, Aron, J., Okon, R.K., Olujimi S., and Chinyere, R.J. (2020). Using watershed function as the leading indicator for water quality. Water Policy 15 (5), 850 – 858. DOI: 10.2166/wp.2013.111

20. Ogunjimi G. Dennis, C. (2018). Community-led initiatives for watershed management: Lessons from case studies across the globe. *Sustainability Science*, 19 (1), 112-127.

21. Odugbemi, T., Afolabi, K. (2015). Medicinal Plants as Antimicrobials In: Outline and pictures of medicinal plants from Nigeria. University of Lagos Press, 53-64.

22. Muller W. E. Eshetu, S. B., Kipkulei, H. K., Koepke, J., Kächele, H., Sieber, S., & Löhr, K. (2022). Impact of forest landscape restoration in combating soil erosion in the Lake Abaya catchment, Southern Ethiopia. *Environmental Monitoring and Assessment,* 196 (2), 378.

23. Chinyem, F.I., Adaikpoh, E.O. and Effiong, C.I. (2009). An inventory of Mineral Resources in Delta State, South Southern Nigeria, *Nigerian Journal of Science and Environment,* 8, 98-103.

24. Delta State Ministry of Commerce, Industry and Cooperatives (DSMCIC) report (2001). Report on assessment and distribution of Industrial minerals occurrence, distribution and quality in Delta State, pp.12-99.

25. Delta State Ministry of Environment (2014). Scooping report of Delta State Lowland Rainforest Ecological Zone for inclusion in the National UNDP-REDD+ Program, Climate Change unit, Ministry of Environment, Asaba, Delta State. 39pp.

26. Tennant, D. (1975). A test of modified line transects method of estimating root length. *Journal of Ecology*, 63, 995-1001. . https://doi.org/10.2307/2258617

27. Smucker, A. J. M., McBurney, S. L., and Srivastava, A. K. (1982). Quantitative separation of roots from compacted soil profiles by the hydro-pneumatic elutriation system. *Agronomy Journal*, 74(4), 500-503. https://doi.org/10.2134/agronj1982.00021962007400040001x

28. Meneges, J. P. (1999). Litter production and nutrient return in tropical forest ecosystems: A review. *Biotropica*, 31 (2), 131-142. https://doi.org/10.1111/j.1744-7429.1999.tb00128.x

29. Feller, C., Albrecht, A., Tessier, D., (1992). Aggregation and organic matter storage in kaolinitic and smectic tropical soils. In: Carter, M.R., Stewart, B.A. (Eds.), Advances in Soil Science: Structure and Organic Matter Storage in Agricultural Soils. Lewis Publishers, Boca Raton, FL, pp. 309–359.

30. AbdelRahman MAE, Shalaby A, Aboelsoud MH, Moghanm FS (2017). GIS spatial model based for determining actual land degradation status in Kafr El-Sheikh Governorate North Nile. *Model Earth Syst. Environ* 4 (1), 359–372. https://doi.org/10.1007/s40808-017-0403-z

31. Bustamante, M.M.C.; Roitman, I.; Aide, T.M.; Alencar, A.; Anderson, L.O.; Aragão, L.; Asner, G.P.; Barlow, J.; Berenguer, E.; Chambers, J.; et al. (2016). Toward an integrated monitoring framework to assess the effects of tropical forest degradation and recovery on carbon stocks and biodiversity. *Glob. Chang. Biol*. 22, 92–109. [Google Scholar] [CrossRef] [PubMed]

32. Kobizar, G. C., & Stephen, H. C. (2006). Influences of thinning, prescribed burning, and wildfire on soil processes and properties in southwestern ponderosa pine forests: A retrospective study. *Forest Ecology and Management*, 234 (1), 123-135.

33. Miller, R.M. and Jastrow, J.D. (eds.) (2019). Mycorrhizal fungi influence soil structure. Arbuscular mycorrhizas: molecular biology and physiology. Kluwer Academic Press, Dordrecht, Netherlands.

34. Deng E. A, de Bang T.C., Husted S., Laursen K.H., Persson D.P., Schjoerring J.K. (2022). The molecular-physiological functions of mineral macronutrients and their consequences for deficiency symptoms in plants. *New Phytol*. 221 (229), 2446–2469. doi: 10.1111/nph.17074. [DOI] [PubMed]

35. Yang L., Y. Qi, L. Yang, T. Chen, A. Deng, J. Zhang, Z. Song, B. (2022). Rotation regimes lead to significant differences in soil macrofaunal biodiversity and trophic structure with the changed soil properties in a rice-based double cropping system. *Soil till. Res* 405, 115424

36. Mojiri A, Kazemi Z, Amirossadat Z (2011). Effects of land use changes and hillslope position on soil quality attributes (A Case Study: Fereydoonshahr, Iran*). Afr. J. Agric. Res.*, 6 (5): 1114- 1119.

37. Oades, J.M., 1984. Soil organic matter and structural stability: mechanisms and implications for management. *Plant Soil* 76: 319–337.

38. Six, J., Elliot, E.T., and Paustin, K. (1999). Aggregates and soil organic matter dynamics under conventional and no-tillage systems. *Soil Science Society of America Journal,* 63, 1350-1358

39. Majaliwa J. G. Mwanjalolo, Dr. Ronald Twongyirwe, Nyenje R, Barasa Bernard (2010). The Effect of Land Cover Change on Soil Properties around Kibale National Park in South Western Uganda January 2010. *Applied and Environmental Soil Science* 10 (3) DOI: 10.1155/2010/185689.

40. Gomez, E., Ferreras, L. & Toresani, S. (2020). Soil bacterial functional diversity as influenced by organic amendment application. *Bioresour. Technol*. 97: 1484–1489.

41. Clough Angela, Skjemstad J. O. (2000). Physical and chemical protection of soil organic carbon in three agricultural soils with different contents of calcium carbonate. *Soil Research*, 38(5), 1005-1016. DOI: 10.1071/SR99102

42. Brownmang O, Brown M (2018). Effects of soil temperature on some soil properties and plant growth. *Advances in Plants Agriculture Research* 8 (1), 37-41.

43. Ukaegbu, E.P. and Nnawuihe, C.O. (2020). Assessing land-use effect on soil properties in coastal plains sand, Imo State, Nigeria. *African Journal of Agricultural Research*, 16 (6), 850-859.

44. Giweta, M. (2020). Role of litter production and its decomposition, and factors affecting the processes in a tropical forest ecosystem: a review. *Journal of Ecology and Environment*, 44(11). https://doi.org/10.1186/s41610-020-0151-2

45. Zhao Zeyang, Peng Dong, Bo Fu, Dan Wu, Zhizhong Zhao (2020). Soil organic carbon distribution and factors affecting carbon accumulation in natural and plantation forests in tropical China https://doi.org/10.1016/j.ecolind.2023.110127

46. Li Z., Zhang X., Liu Y. (2023). Pore-scale simulation of gas diffusion in unsaturated soil aggregates: accuracy of the dusty-gas model and the impact of saturation. *Geoderma*, 303 (2023), pp. 196-203.

47. Becker, C. D., (2023). Integrating environmental policies into land-use planning: A pathway for sustainable watershed management. *Journal of Environmental Planning and Management,* 66 (2), 231-249.