

Reviving Nature: Strategies for Ecosystem Restoration in a Deteriorated Southwestern Nigeria's Forest Reserve

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Abstract- Forests are always depleted by human activities. The study focused on the deterioration of the Ikeji-ipetu forest reserve, Osun State. Concurrent methods of data collection were used in this study. Sampled plots of 10 m×10 m was delineated in the forest reserve, the woody species were identified, and the woody tree variables such as height and circumference were measured using an altimeter. The woody tree species were classified into different categories using the Integrated Taxonomic Information System (ITIS). The qualitative method employed was focus group discussion sessions of five elderly people between 45 years and above from one of the communities nearest to the Forest Reserve. The secondary data included a map on a scale of 1:50,000 and satellite imageries ArcGIS 10.1 of 1986 to 2016 of the study area. The study revealed the most abundant woody species was *Gmelina arborea* (29.9%). The Landsat TM of 1986 showed that the undisturbed land was 88% and that of 2016 (74.86%) with a difference of (13.14%). The average nitrogen value was 22.75 mg/l in forest land and 13.66 mg/l in cultivated land. Data were analyzed using descriptive statistics and content -analysis. A re-afforestation scheme was such as forest regrowth, and regeneration, sustainable resources management practices, and implementation of policies and regulations against illegal logging were some of the few restoration strategies suggested.

Keywords: Ecosystem restoration, Forest reserve management, Environmental conservation, Sustainable development, Biodiversity preservation.

I. Introduction

Forest ecosystems are marked by an intricate interplay of living organisms, including trees, herbaceous plants, animals, fungi, and microorganisms, interacting with their physical environment, such as soil, water, and climate. These ecosystems provide an array of goods and services critical to human well-being, including timber, fuel, clean air, and water, as well as recreational opportunities and important ecological functions like carbon sequestration and habitat preservation (Maier et al., 2021).

Still, global environmental problems, increasing urbanization, industrialization pressures, and dominant market mechanisms have put the forest ecosystem in jeopardy and obstructed the long-term sustainable provision of forest ecosystem services (Mbamali et al., 2012). Protecting and managing these vital ecosystems is crucial for maintaining biodiversity and ensuring that future generations can enjoy their myriad benefits. The deterioration of the forest environment is through the damage accomplished directly or indirectly on the resources such as air, water, soil, forest, animals, and so on. According to Ogunbode et al. (2021), the environment consists of the totality of the physical, chemical, biological, social, economic, and cultural components to which man relates, adapts, and utilizes to satisfy his needs. The environment consists of water, land, and air with their respective resources. Therefore, when the natural environment (habitats) and resources are destroyed, the environment is automatically depleted. This deterioration of the environmental quality can be from excessive concentrations of pollutants and other activities and processes such as improper land use and natural disasters (Inyang, 2019). According to the United Nations International Strategy for Disaster Reduction (ISDR), environmental deterioration is the reduction of the ability of the environment to meet the social and ecological objectives and needs of the people (ISDR, 2004).

Environmental deterioration is a serious issue that threatens the health of the ecosystem. One of the most critical aspects of environmental deterioration is the destruction of forests, especially trees and animals. According to Food and Agriculture Organization of the United Nations (2020a), the rate of deforestation between 2015 and 2020 was estimated at 10 million hectares per year. The primary forest area worldwide has decreased by over 80 million hectares since 1990. And since 1990, it is estimated that 420 million hectares of forest have been depleted through conversion to other land uses. Bustamante, (2016), asserted that, the major causes of forest deterioration are unsustainable exploitation such as excessive harvesting of forest, overgrazing, wildfires, and the spread of invasive species or pests. It is estimated that more than 2000 million hectares of the world's forest have been tampered with and this resulted in a serious global environmental, social and economic issue (Stanturf, 2014). In Nigeria, according to Global Forest Watch (2024), deforestation stand at 163 Kha/year, with 12% of forest cover lost between 2001 and 2022.

The destruction done to the forest also includes land, soil, and water. Forests typically serve a crucial role in maintaining biodiversity, regulating climate, and providing essential ecosystem services such as clean air and water. Forest deterioration is a

critical issue that poses significant threats to the wellness of the ecosystem (Folorunso and Folorunso, 2022). Forests are also the habitat of various animals. However, human activities such as deforestation, illegal logging, and unsustainable land use practices have led to widespread forest deterioration, resulting in severe environmental consequences. Some fauna and flora have been decimated, while some are on the verge of extinction. Climate change has occurred due to the excessive cutting of valuable trees.

Environmental deterioration in forests through unsustainable land use practices, such as using forest land for agricultural purposes without proper planning and management, also increases forest deterioration. This often results in the loss of valuable forest resources such as medicinal plants, food and fruits, and genetic diversity. This also upsets the fragile equilibrium of the ecosystems (Ogundipe et al., 2020).

According to Bamidele and Erameh (2023), habitats of numerous plant and animal species are endangered through deforestation, it also contributes to climate change by releasing excessive carbon dioxide into the atmosphere. Additionally, it can lead to soil erosion, loss of water quality, loss of soil nutrients, and disruption of local and global weather patterns in the area. Illegal logging is another significant contributor to forest deterioration. This commonly entails the extraction of trees without proper authorization and adherence to sustainable forestry practices. This also includes the cutting of immature trees. Oyetunji et al. (2020), asserted that the structures of the forest ecosystem were directly affected by human interactions like farming, excessive logging, illegal logging, construction of buildings, mining of resources, and gravel excavation. All these anthropogenic activities have led to the deforestation and deterioration of the forest ecosystem.

Regardless, restoring ecosystem is crucial in addressing forest degradation. The Society for Ecological Restoration (2023) opined that, ecosystem restoration involves facilitating the recovery of degraded ecosystems and preserving intact ecosystems, thereby maintaining ecological balance and promoting biodiversity. It is a process that combat climate change, and support all ecosystem services and local economies as well.

The revitalization of ecosystems is important for restoring the wellness of the ecosystem, particularly in areas experiencing significant deterioration. In many forest reserves in Nigeria in particular, the adverse effects of environmental changes and human activities have caused a reduction in biodiversity and overall ecological stability (Pona, 2021). Strategies for ecosystem restoration play a vital role in addressing these challenges and promoting rehabilitation and sustainable practices that enhance the resilience of these fundamental ecosystems. And a harmonious coexistence between natural habitats and human development will be enhanced. These strategies will be of benefit to the diverse plant and animal life that are found in these areas. It will also enhance the well-being of nearby communities, paving the way for a sustainable future for both the ecosystem environment and its residents (that is, plants, animals, and other organisms). Sustainable land use is one of the key factors in reshaping ecosystem. It involves managing land resources in a way that balances current trend with long term ecological, economic, and social considerations, ensuring that future generations can meet their own need while maintaining a healthy environment (Aznar- Sanchez, et al., 2019).

This study, therefore, explores various tree species, determines different land use activities and land cover changes, and the implications of ecosystem deterioration to the soil in Ikeji Ipetu Forest Reserve, Osun state with a specific focus on the environmental deterioration of this forest reserve (Figure 1).

II. Materials and Methods

This study was conducted at the Ikeji-ipetu forest reserve. The forest reserve is located between Ikeji - Arakeji and Ipetu - Ijesa in Osun State, with latitude 7.400000N and longitude 4.933333E. Settlements nearby are Orita Reserve, Alonge, Temidire Majaro, Fajuike, Lofinnika, S. B Ojo Orisumbare, Ikeji-Arakeji, and others, with a population range of 70 to 3,700. The major occupation of the people is farming. The local population focuses primarily on tree crop farming. Among the tree crops cultivated in the area are cocoa, kola nuts, and oil palm trees. The prevalent food crops include yam, cassava, rice, cocoyam, bananas, and plantains. The climate in the study area is characterized as humid tropical, featuring well-defined dry and wet seasons, which supports both cash and food crop farming. The wet season lasts from March to late October, with a bimodal rainfall pattern having its peaks in July and September.

The study area features soils that are moderately too strongly leached, with low to medium humus content, weak to neutral surface layers, and moderately to strongly acidic sub-soils (Smyth and Montgomery, 1962). The vegetation is predominantly evergreen, consisting of woody species such as Teak (*Tectona grandis* L.f.), Gmelina (*Gmelina arborea* (Benth.) Staff), Oganwo (*Khaya ivorensis* A.Chev.), Ayunre (*Albizia zygia* (DC.) J.F. Macbride), and Iroko (*Milicia excelsa* (Welw.) C.C.Berg), among others.

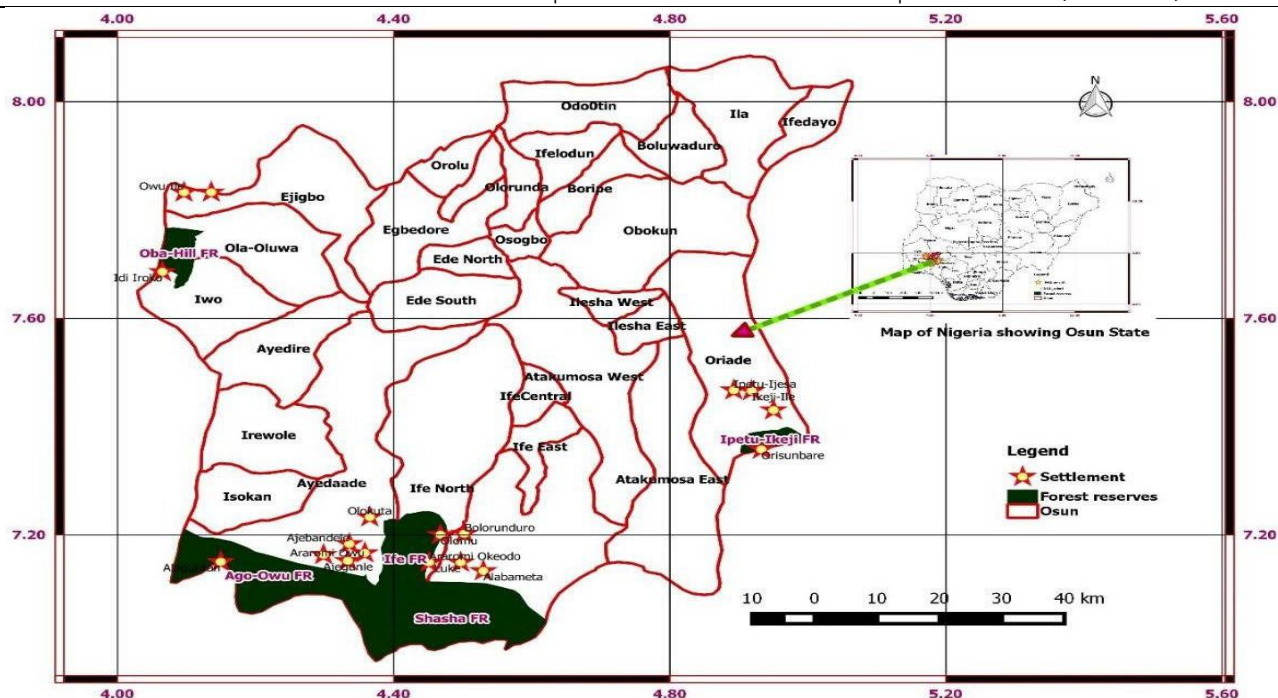


Figure 1. Map of Osun State, Nigeria showing the forest reserve

A concurrent method (that is both quantitative and qualitative data collection) was adopted. The quantitative methods included the use of the Global Positioning System to take the coordinates of the five sampled plots of 10 m×10 m randomly demarcated from the edge of the major road to the interior of the forest reserve. The woody species were identified and counted, and variables such as height and circumference were measured using a clinometer, measuring tape and calculator while the circumference was measured with the use of a circumference tape. The branches of a woody tree that might serve as an obstacle were considered. The horizontal distance D from a point was measured and recorded using measuring tape. The angle was measured by holding the clinometer at a level aiming at the top of the woody tree. The angle of elevation was recorded as “A”. The height was calculated using the formula;

$H = D \times \tan(A)$ with the use of a calculator;

Where H is the Height,

D is the Distance, and

A is the angle of elevation.

The circumference tape is wrapped around the trunk of a woody tree to measure its circumference. This measurement was then used to calculate the diameter of the tree. The woody tree species were classified into different tree taxonomic categories. Soil samples were collected from two different points at a depth of 0 to 20cm. Soil samples were collected from two spots: one from the forested/undisturbed area and the second sample from the disturbed area within the study area. Field observations were conducted to investigate human activities in the study area. The qualitative method was a focus group discussion session of five elderly people, aged 45 years and above, from two of the nearest communities. The secondary data included a map of the study area on a scale of 1:50,000 and satellite imageries using ArcGIS 10.1 from 1986 to 2016 of the study area. Data was analyzed using descriptive statistics such as frequency tables. Focus group discussion (FGD) evidence was analyzed using content analysis.

III. Results and Discussion

Floristic composition of Ikeji-ipetu forest reserve

The most abundant woody species in Ikeji- Ipetu forest reserve were *G. arborea* (29.9%) followed by *T. grandis* (18.2%). The frequencies of *Terminalia superba* and *Ficus exasperata*, and *Cinnamomum cassia* were (6.5%) and (3.9%), respectively. The woody species that belong to the family Verbanaceae (47.4%) were the most abundant, followed by Euphorbiaceae (6.5%) and Lauraceae, Moraceae, and Caricaceae (3.9%) in the study area (Table 1). The status of the woody

species revealed that some of the woody species are endangered, meaning, their numbers have decreased substantially. These findings concur with Marsh (2021), who defined endangered species as any animal or plant at risk of disappearing entirely from the environment. In this study, the endangered woody species included *T. grandis*, *G. arborea*, *A. zygia* DC Macbride, *T. superba*, and *C. cassia*. The woody species with endemic status were *Khaya senegalensis*, *Newboulda laevis*, *Gliricidea sepium*, and others. Woody species such as *Ficus mucoso*, *Alstonia boonei*, and *Luffa acutangula* were on the verge of extinction. Extinction of a particular animal or plant species occurs when no individuals of that species remain alive anywhere in the world.

Consequently, a species is considered on the verge of extinction when its population is extremely small.

Marsh (2021) opined that efforts to protect the animals and plants that have been on the endangered list should be taken by all stakeholders. There is a need to work together to protect and sustainably manage the forests, preserving the health of our planet and ensuring a sustainable future. so that the health of our planet can be preserved and ensure a sustainable future. Tsoraeva et al. (2020), opined that continuous agricultural practice on forest land has resulted in plant and animal species loss, loss of natural terrain, among others. Sakadzo and Nyasha (2021) also asserted that increasing pressure on the land ecosystems for building purposes, the need for fertile agricultural land, and the search for more forest products and services such as timber have increased disturbances and eventually leading to deforestation and deterioration.

No.	Species	Botanical name	Family	Abundance (%)	Status
1	Teak	<i>Tectona grandis</i>	Lamiaceae	18.2	Threatened
2	Gmelina	<i>Gmelina arborea</i>	Verbenaceae	29.9	Threatened
3	Ayunre	<i>Albizia zygia</i>	Malvaceae	1.3	“
4	Afara	<i>Terminalia superba</i>	Combretaceae	6.5	“
5	Cassia	<i>Cinnamomum cassia</i>	Lauraceae	3.9	“
6	Mahogany	<i>Khaya senegalensis</i>	Meliaceae	1.3	Endemic
7	Akoko	<i>Newboulda laevis</i>	Bignoniaceae	2.6	“
8	Opoto	<i>Ficus capensis</i>	Moraceae	1.3	-
9	Obobo	<i>Ficus mucoso</i>	Moraceae	1.3	Verge of extinction
10	Ahun	<i>Alstonia boonei</i> De Wild	Apocynaceae	1.3	“
11	Iroko	<i>Milicia excels</i>	Meliaceae	2.6	Threatened
12	Omo	<i>Cordia millenii</i>	Boraginaceae	1.3	“
13	Arere	<i>Triplochiton scleroxylon</i>	Sterculiaceae	1.3	“
14	Oriro	<i>Luffa acutangula</i>	Cucurbitaceae	1.3	Verge of extinction
15	Agunmoniye	<i>Gliricidia sepium</i>	Leguminosae	1.3	Endemic
16	Isin	<i>Blighia sapida</i>	Sapindaceae	1.3	Threatened
17	Epin	<i>Ficus exasperata</i>	Moraceae	6.5	Endemic
18	Ita	<i>Celtis zenkeri</i>	Ulmaceae	1.3	Threatened
19	Pawpaw	<i>Carica papaya</i>	Caricaceae	3.9	Endemic
20	Idigbo	<i>Terminalia ivorensis</i>	Combretaceae	2.6	Endemic
21	Agbalumo	<i>Spondias mombin</i>	-	1.3	„
22	Palm oil tree	<i>Elaeis guineensis</i>	Arecaceae	1.3	Endemic
23	Cashew	<i>Anacardium occidentale</i>	Anacardiaceae	1.3	„

Land use and land cover change in Ikeji-ipetu forest reserve using satellite imageries

Satellite imageries of ten-year intervals (Landsat TM 1986, 1996, 2006, and 2016) showed the land cover and changes that have occurred (Table 2). In Ikeji-Ipetu forest reserve (Figure 2), the Landsat TM of 1986 showed that the undisturbed land was 88%, cultivated was 10.00% and the built-up was 1.73%. In 1996, the undisturbed was 89.57%, cultivated/disturbed was 10.33% and the built-up was 0.09%. In 2006, the undisturbed was 94.09%, cultivated was 1.89% and the built-up was 4.00%. In 2016, the undisturbed was 74.86%, disturbed was 1.519% and the built-up was 23.618%. The undisturbed areas are areas used for the plantation of woody trees, disturbed areas are the areas used for other purposes such as farming and built-up areas are those areas where human activities such as building, construction, farming, etc., are pronounced. This result showed that the built-up areas increased from 1.73% in 1986 to a greater amount in 2006, namely 4.00%, which drastically increased to 23.618% in 2016. It meant that human activities such as excavation of sand, mining, and building of houses were on the increase in the study area has made the

forest reserve depleted. The differences in the land cover due to human activities showed that the undisturbed land incurred a decrease (-4.0212 km^2) in 2016. This indicated that the land that was formerly undisturbed had been tampered with and used for other purposes aside from being left undisturbed through human activities. The cultivated/disturbed land area was reduced by 0.0792 km^2 in 2016. This showed that the land was bare, and this correlated with the field work and observation that the forest trees had reduced in number and food crops were largely found. The people here practiced a taungya farming system in which food crops were planted in between the remaining tiny forest trees. The cultivated areas were used extensively, and woody tree species were cut down, rendering the land fallow. The built-up areas increased tremendously from 0.362 km^2 in 1986 to 4.94 km^2 in 2016. The result indicated that urbanization has taken place drastically and there was a substantial amount of development and expansion such as houses, construction of different structures, etc., that had taken up the forest land. This concurred with a report by Sakadzo and Nyesha (2021), that several woody tree species have been cut at an alarming rate for various purposes like industrialization, urbanization, and intensive farming.

Also, an accuracy assessment was carried out in which the digital numbers were correctly picked. Google Earth was adopted and was checked before picking sample points and this was also used to validate the images.

Table 2. Land use and land degradation in Ikeji-Ipetu (forest reserve)

Classes	1986 (km^2)/ (%)	1996 (km^2)/ (%)	2006 (km^2)/ (%)	2016 (km^2)/ (%)	Difference between 1986 and 1996 (km^2)	1996 and 2006 (km^2)	2006 and 2016 (km^2)
Undisturbed/Forest Land	18.455 (88.26)	18.73 (89.5)	19.67 (94.1)	15.65 (74.86)	0.2754	0.9441	-4.0212
Disturbed/Cultivated	2.093 (10.01)	2.16 (10.3)	0.39 (1.89)	0.31 (1.52)	0.0675	1.7631	0.0792
Built up	0.362 (1.730)	0.019 (0.09)	0.84 (4.07)	4.94 (23. 62)	0.3429	0.819	4.1004
Total	20.90	20.90	20.90	20.90	-	-	-

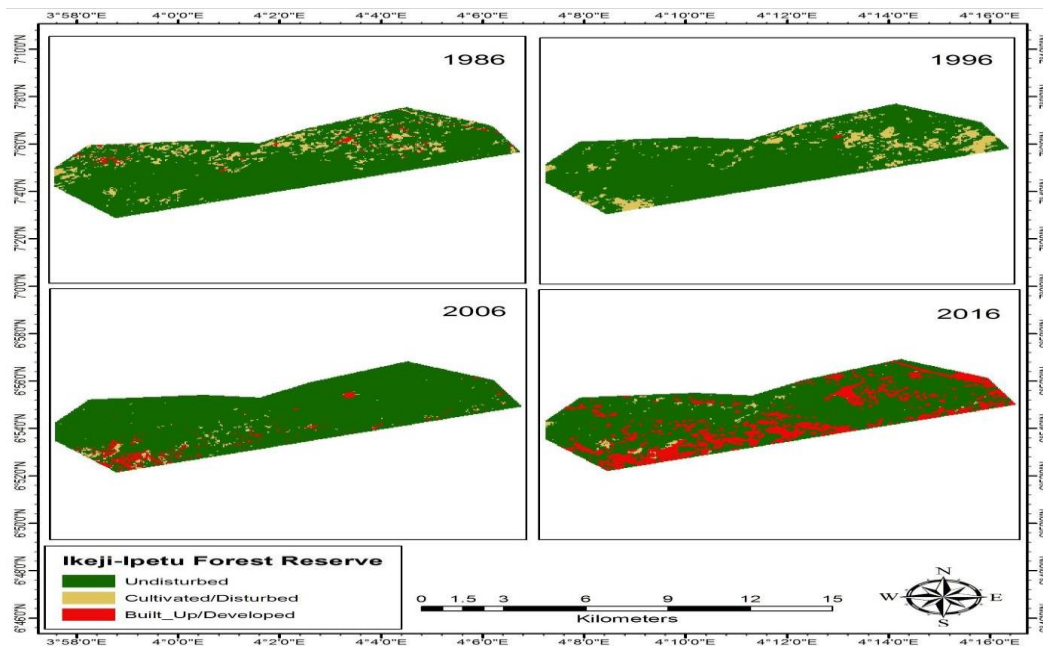


Figure 2. Land use and land cover changes in Ikeji- Ipetu Forest Reserve 1986 to 2016.

Strategies practiced to restore the ecosystem in the study area

In this study, some strategies practiced to resuscitate the ecosystem were mentioned. It was revealed that afforestation, reforestation, and invasive species management were merely mentioned. Meanwhile, soil restoration through planting of cover crops and fire management were highly mentioned by the respondents. Other initiatives are community enlightenment and

education and monitoring by the government to curb illegal activities in the study area. Sustainable land -use practices such as taungya farming was said to be in practice by the farmers. Taungya farming system is a farming practice in which farmer cultivate food crops in an already developed forest reserve. The aim is to take care of the woody tree. Wildlife habitat restoration was also mentioned to be one of the strategies utilized to preserve the study area. Furthermore, climate resilience planning was merely

mentioned. This shows that the occupants have not practiced climate resilience techniques.

Table 3. Strategies practiced to restore the ecosystem in the study area.

Variable	Highly mentioned	Mere mentioned
Afforestation	-	+
Reforestation	-	+
Invasive Species Management	-	-
Soil Restoration	+	-
Fire Management	+	-
Community enlightenment and education	+	-
Sustainable Land-Use Practices e.g. taungya system	+	-
Wildlife Habitat Restoration	+	-
Water Management	-	-
Monitoring and Assessment	-	+
Climate Resilience Planning	-	-

+ Means positive response and - means negative response

Content analysis of focus group discussion sessions

Focus group discussion sessions of five elderly people aged 45 years and above (both genders) from two of the nearest communities were conducted using an FGDs guide. This guide contained questions on human activities, utilization of the forest resources, and past events in the study area. It was written in English language but was translated and conducted in the local language of the respondents. It was conducted at the break time on their farm to allow for the total concentration of the respondents. Therefore, those people who met together on a farmland were interviewed. It was also recorded on a tape. The aim of conducting the focus group discussion sessions was to have a better understanding of the activities that have occurred such as in the area of utilization and management of forest resources. This also complements the result from a questionnaire survey. The participants aged 45 years and above were selected purposefully for this session because they are the best set of people who could give concise information about what has happened in the past.

The results of the FGDs supported the findings from the field survey. The majority of the respondents for the FGDs session mentioned that: "Taungya farming is being practiced, firewood was cut from both dry-standing and wet woody trees. Timber logging is predominant, and charcoal production is done using available woody tree species" (FGDs respondents, 45 years and above). The content analysis indicated that through all the aforementioned practices; deterioration has occurred in the study area. The respondents also mentioned some initiatives they practiced to restore this deteriorated forest. They are afforestation, reforestation, and soil restoration were practiced to restore the already deteriorated forest. Other initiatives are community enlightenment and education and monitoring by the government. Meanwhile, these initiatives to restore the deteriorated forest were merely mentioned. This implied that they did not use them extensively as shown in Table 3.

Implications of forest deterioration on soil quality

Among the deleterious human activities, the deterioration realized on the soil through the removal of trees without reforestation for extensive farming, the taungya farming system in particular, industrialization, urbanization, and other human interactions in the study area has resulted in significant damage to soil effective function leading to an imbalance of the ecosystem. Soil plays a critical role in delivering ecosystem services, which has been altered. Some of the changes that have occurred in soil quality are discussed in the following.

Changes in soil structure

The result showed the Particle size distribution (PSD) in the forested/undisturbed area was 15.22 ppm and the cultivated area was 11.34 ppm. Also, the organic matter content of the soil was low both in the forested and cultivated areas of the study area with a Least significant difference (LSD) of 2.119. Forest degradation has disrupted the natural structure of the soil, thereby leading to compaction, erosion, and reduced water infiltration (Zhang et al., 2014). This was seen in the study area. The productivity of the soil has decreased since the soil chemical properties were altered in the study area and this increased the vulnerability to environmental stresses such as drought and flooding (Table 4).

Loss of soil biodiversity

The result of this study also shows that forest deterioration due to excessive logging and cutting of tree species has led to the loss of soil biodiversity and habitat of living organisms, including microorganisms, fungi, and other soil organisms that play a crucial role in maintaining soil health. Increased rate of runoff also has significant effects on the land leading to the erosion of the soil and nutrients.

Uncertainties in soil data collection such as instrumental and analytical, sampling and interpretation errors were taken in to consideration. Robust sampling design was used. Also, suitable measurement tools were employed and data accuracy were verified through calibration, validation of equipment and methods.

Table 4. Implications of forest deterioration on soil quality.

Parameter	Treatment							
	pH (mm)	PSD (ppm)	AP (%)	EA (mol/kg)	CEC (g/cm ³)	BD (g/cm ³)	TN (mg/l)	OM (%)
Land use								
Forest	6.21	15.27	51.21 ^c	13.46	13.06 ^c	6.89 ^a	22.77 ^b	5.42 ^a
Cultivated land	6.27	11.34	63.14 ^b	13.85	17.86 ^a	4.45 ^c	13.66 ^c	3.19 ^b
LSD (0.05)	NS	NS	11.94	NS	4.806	2.411	16.704	3.223
SEM (±)	0.048	0.817	2.890	0.423	2.980	1.750	0.661	4.247
Soil depth								
0-15 cm	6.33	13.79	59.83	13.66	15.34	5.62	25.43	8.01
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
SEM ±	0.039	1.038	1.821	0.640	1.150	0.424	2.766	+2.119

The main effect means, that a column followed by the same letter is not significantly different. pH: Potential of Hydrogen, PSD: particle size distribution, AP: soil water characteristics, EA: exchangeable acidity, CEC: cation exchange capacity, BD: bulk density, TN: total nitrogen, OM: organic matter, NS: no significant difference, LSD: least significant difference, SEM: scanning electron microscope.

IV. Conclusion and Recommendations

The importance of environmental conservation initiatives and revitalization of the forest reserve in a deteriorated southwestern forest reserve in Nigeria cannot be overstated. The degradation of the forest reserve has had detrimental effects on biodiversity, ecosystems, soil quality, and the livelihoods of local communities. However, through concerted efforts to implement conservation initiative measures such as reforestation, habitat restoration, and sustainable resource management, the forest reserve has the opportunity to recover and thrive once again.

Stakeholders including government agencies and their officials, NGOs, local communities, and private entities must work collaboratively toward the conservation and revitalization of the forest reserve. Implementation of Policies and regulations should be implemented.

Another strategy for ecosystem restoration is the establishment of new forest reserves in areas where there was no forest before or reafforestation (that is, planting trees where the forest land has been fallowed for a while). Afforestation and reafforestation aim to restore previously deteriorated forest land. Soil quality should also be replenished through afforestation, planting of cover crops, and strategic farming systems assisting in the restoration of the soil because, without a diverse soil ecosystem, soil functions such as nutrient cycling and forest health will still be jeopardized.

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