ASSESSMENT OF TREE SPECIES COMPOSITION, SEEDLING DIVERSITY AND GROWTH PERFORMANCE IN A FOREST RESTORATION SITE UNIVERSITY OF BENIN, BENIN CITY. EDO STATE IN NIGERIA.

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FACULTY OF AGRICULTURE

UNIVERSITY OF BENIN

BENIN CITY,NIGERIA

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A PROJECT WRITTEN IN THE DEPARTMENT OF FOREST RESOURCES AND WILDLIFE MANAGEMENT, FACULTY OF AGRICULTURE AND SUBMITTED DEPARTMENT IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE (BSc) IN FOREST RESOURCES AND WILDLIFE MANAGEMENT OF THE UNIVERSITY OF BENIN, BENIN CITY, NIGERIA

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CERTIFICATION

We certify that this project work was carried out by OTASOWIE OSAKPAMWAN with matriculation number AGR1900320 of the department of forest resources and wildlife management, faculty of agriculture, university of Benin, Benin city.

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DEDICATION

This work is dedication to the Almighty God who gave me the grace of his help, wisdom and success throughout my study and to my lovely parents Mr. and Mrs. Otasowie Osakpamwan

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ABSTRACT

Forest degradation remains a pressing environmental issue, threatening biodiversity and ecosystem functionality worldwide. This study evaluates tree seedling diversity and growth dynamics in a forest restoration site at the University of Benin, Benin City, Nigeria. The research aims to assess species composition, growth performance, and biodiversity indices within a designated 100m x 86m sample plot. Data collection involved identifying tree species, recording their abundance, and measuring key growth parameters, including height, number of leaves, number of branches, and collar girth. The study employed descriptive statistics and diversity indices such as Shannon-Wiener, Simpson's, and Margalef's indices, while growth data were analyzed using One-Way ANOVA in a Completely Randomized Design (CRD).

A total of 194 trees, representing 28 species from 19 families, were recorded. Among these, 19 species regenerated naturally, while 9 were deliberately planted. The diversity analysis indicated that naturally regenerated species exhibited higher diversity indices (H^1 = 2.813, D = 0.947, M = 4.195) compared to planted species, highlighting the significance of natural regeneration in enhancing biodiversity. Growth analysis revealed that *Terminalia ivorensis* demonstrated the highest growth rates across all measured parameters, while *Entandrophragma cylindricuvvvvvvvvvvv m* recorded the lowest performance.

This study underscores the role of human activity in shaping forest regeneration outcomes. The findings suggest that deforestation and land-use change significantly impact species diversity, thereby affecting ecosystem stability. To promote effective forest restoration, it is recommended that reforestation efforts prioritize the selection of resilient native species, enhance conservation strategies, and conduct further research on the ecological factors influencing seedling establishment and growth. These initiatives are essential for fostering long-term forest sustainability and biodiversity conservatio

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Forests play a crucial role in sustaining biodiversity, regulating climate, and providing essential ecosystem services such as carbon sequestration, soil protection, and water purification (FAO, 2020). However, deforestation and forest degradation have significantly reduced forest cover globally, leading to habitat destruction, biodiversity loss, and the depletion of natural resources (Sloan and Sayer, 2015). The increasing demand for agricultural land, timber, and urban expansion has further exacerbated this trend, making forest restoration efforts critical in mitigating these negative impacts (Chazdon, 2008).

Forest restoration is an ecological process aimed at re-establishing tree cover, improving biodiversity, and enhancing ecosystem functionality in degraded forest landscapes (Holl and Aide, 2011). This process can involve natural regeneration, assisted regeneration, or tree planting, depending on site conditions and restoration goals (Lamb, 2018). To address these issues, various reforestation and afforestation programs have been initiated, including the establishment of forest reserves and restoration sites in different parts of the country (Nwoboshi, 2020).

Seedling diversity is a fundamental component of forest regeneration, as it influences species succession, ecosystem stability, and long-term forest resilience (Slik *et al*., 2008). The presence of diverse tree species at the seedling stage enhances forest productivity, promotes species coexistence, and increases resistance to environmental stressors such as drought and pests (Guariguata and Ostertag, 2001; Poorter *et al*., 2019). Assessing seedling diversity and growth in forest restoration sites provides valuable insights into species performance, survival rates, and competition dynamics, which are crucial for effective restoration planning (Letcher and Chazdon, 2009).

1.2 Statement of problem

The destruction of natural forests has reached alarming rates globally, with millions of hectares lost each year (FAO, 2020). In regions that rely heavily on forest resources, the degradation of forests poses significant threats to biodiversity, ecosystem services, and local economies (Chazdon *et al*., 2016). Forest loss disrupts carbon sequestration processes, alters hydrological cycles, and contributes to climate change, exacerbating environmental vulnerabilities (Lewis *et al*., 2019).

While reforestation and forest regeneration efforts have been widely implemented, the success of these initiatives remains uncertain due to the lack of comprehensive studies that assess the health and recovery of these ecosystems (Holl and Aide, 2011).

The main challenge of forest restoration is the limited understanding of species diversity and growth dynamics in regenerating forests (Letcher and Chazdon, 2009). Without proper monitoring and assessment, it is difficult to determine whether the desired levels of biodiversity and ecosystem functions are being restored (Brancalion *et al*., 2019).

Many restoration projects focus on increasing tree cover, but often, they fail to account for the ecological complexity required to sustain a fully functioning forest ecosystem (Reid *et al*., 2018). Additionally, there is a need for more precise data on tree growth rates, species composition, and the factors that influence the regeneration process, such as soil seed bank or germination, and anthropogenic pressures (Poorter *et al*., 2016).

1.3 Justification of the Study

The success of forest restoration depends on selecting appropriate tree species that can adapt to local environmental conditions and contribute to ecosystem stability (Holl *et al*., 2017). This study is essential because it will provide scientific data on seedling diversity, growth performance, and survival rates in a regenerating forest site (Ding *et al*., 2017). The findings will help in identifying tree species that exhibit high resilience and regeneration potential, which can inform future restoration and conservation strategies (Palma and Laurance, 2015).

Furthermore, understanding seedling diversity and growth trends will contribute to biodiversity conservation by promoting the use of native species in reforestation projects (Vásquez-Grandón *et al*., 2018). Research has shown that native species play a crucial role in restoring ecological functions and enhancing forest resilience compared to exotic species (Palma and Laurance, 2015). This study will also provide baseline data for monitoring the long-term success of the restoration site, allowing for periodic evaluation and necessary management interventions (Letcher and Chazdon, 2009).

While various forest restoration initiatives have been implemented, there is limited empirical data on the success of these efforts in terms of seedling diversity and growth performance, particularly within university-affiliated restoration sites (Chazdon *et al*., 2017). Many restoration projects focus primarily on tree planting without adequately assessing species survival, growth rates, and ecological interactions (Elliott *et al*., 2013). Without such assessments, it is difficult to determine which species thrive best under local environmental conditions and how restoration strategies can be improved to enhance long-term forest sustainability (Elliott *et al*., 2013).This study seeks to address this knowledge gap by assessing the diversity and growth of tree seedlings in the forest restoration site at the University of Benin (University of Benin, 2023). Understanding species composition and growth dynamics will provide critical insights for future reforestation projects and contribute to improved forest management practices in Nigeria (Adekunle *et al*., 2021).

This study provides an opportunity to study seedling diversity and growth performance in a restoration environment, offering insights into the effectiveness of reforestation strategies in the region (Adekunle *et al*., 2021).

This study addresses the gap by conducting a total inventory on a forest regeneration site. Through detailed measurement and analysis of tree species, growth rates, and forest structure, the study aims to provide critical data on forest recovery (Chazdon, 2014). The findings will contribute to improving management strategies for forest regeneration and ensuring that these ecosystems recover their full ecological potential (Lennox *et al*., 2018). Furthermore, understanding the ecological succession patterns in regenerating forests can aid policymakers and conservationists in designing more effective restoration programs that prioritize both biodiversity conservation and sustainable land-use practices (Crouzeilles *et al*., 2017).

1.4 Objectives of the Study

The primary objective of this study is to assess the diversity and growth performance of tree seedlings in a forest restoration site at the University of Benin, Benin City, Edo State, Nigeria (University of Benin, 2022). The specific objectives are to:

1. assess tree species composition of the planted and naturally regenerated species present in the forest restoration site.
2. determine the growth rate of the planted species in the restoration area.
3. evaluate species abundance and diversity in the study area

CHAPTER TWO:

LITERATURE REVIEW

2.1 Importance of Seedling Diversity in Forest Restoration

Seedling diversity is a fundamental aspect of forest restoration, playing a crucial role in ensuring ecological resilience and sustainability (Lugo, 2009). The presence of a wide variety of tree species contributes to the stability of forest ecosystems by facilitating nutrient cycling, enhancing soil fertility, and supporting a diverse array of wildlife (Lamb *et al*., 2005). This diversity acts as a buffer against environmental stressors, making forests more resistant to pests, diseases, and climate fluctuations (Gómez-Pompa and Kaus, 1992). Furthermore, species-rich forests are better equipped to undergo ecological succession, which is the natural process of vegetation recovery over time. Through this process, a greater number of plant species establish themselves, leading to increased carbon sequestration potential and overall forest productivity (Elliott *et al*., 2013).

In restoration projects, several tree species contribute significantly to forest resilience and ecosystem services. Indigenous species such as *Triplochiton scleroxylon, Khaya grandifoliola, Entandrophragma cylindricum, Terminalia superba, Terminalia ivorensis, Pterocarpus angolensis, Pterocarpus osun, and Nauclea diderrichii* play essential roles in ecological restoration (FAO, 2015). These species not only provide economic benefits through timber production but also enhance biodiversity, improve soil structure, and offer habitat for various fauna (Chazdon,2008). By incorporating diverse species into forest restoration efforts, the likelihood of long-term sustainability and ecosystem balance is greatly improved. (Rey Benayas et al., 2009).

2.1.1 Factors Influencing Seedling Growth in Restoration Sites

The growth and survival of seedlings in forest restoration sites are influenced by a combination of biotic and abiotic factors. One of the primary determinants of successful restoration is species selection, as different tree species exhibit varying levels of adaptability to environmental conditions and ecological interactions (Rodrigues *et al*., 2009). Indigenous tree species such as *Triplochiton scleroxylon, Khaya grandifoliola,* and *Entandrophragma cylindricum* are often favored due to their ability to thrive in local climatic and soil conditions. Additionally, fast-growing species such as *Terminalia superba* and *Terminalia ivorensis* are commonly used to establish early canopy cover, reducing competition from invasive plants and improving microclimatic conditions for other species (Chazdon, 2008).

Soil properties also play a critical role in seedling establishment and growth. Factors such as soil composition, moisture availability, and nutrient levels significantly impact seedling development (Elliott *et al*., 2013). High organic matter content, balanced pH levels, and active microbial communities contribute to better seedling survival rates and overall forest health (Brancalion *et al*., 2016). In degraded sites, soil amendments such as organic mulch and compost can enhance soil fertility and water retention, thereby improving seedling growth rates and resilience against harsh environmental conditions (Lal,2015; Brady and Weil, 2017).

2.2. The Role of the University of Benin in Forest Restoration

The University of Benin has played a significant role in advancing forest restoration through research, education, and community engagement (University of Benin, 2023). Through its academic and research initiatives, the institution has contributed valuable knowledge on seedling diversity, growth performance, and ecological interactions that inform best practices in restoration efforts (Dadaa, et al., 2024.). By conducting studies on species adaptability and ecological benefits, the university provides critical insights that guide reforestation programs and sustainable land management practices.

Capacity building and training programs at the university equip students, forestry professionals, and local communities with the necessary skills and knowledge in sustainable forest management, biodiversity conservation, and climate change adaptation (Adekunle *et al*., 2010). These training initiatives foster a greater understanding of ecological restoration techniques and promote the adoption of sustainable practices in land-use planning.

The university also engages in practical restoration efforts by establishing forest regeneration projects within its campus and surrounding areas. These projects serve as model sites for studying seedling survival rates, growth dynamics, and species interactions in a controlled environment (Akinyele, 2013). By integrating scientific research with on-the-ground restoration activities, the University of Benin contributes significantly to the conservation and rehabilitation of degraded forest landscapes.

2.3 Forest Inventory and Its Role in Regeneration Studies

Forest inventory is a systematic method of collecting data on tree species, their distribution, and ecological characteristics within a specific area. This process provides valuable insights into forest structure, composition, and health, which are essential for effective regeneration studies. A particular approach known as total inventory involves the exhaustive enumeration and measurement of all trees within a defined plot or area. This method is especially useful in regenerating forests, where the primary goal is to assess recovery progress, species diversity, and structural development.

The total inventory method enables researchers to obtain detailed data on species abundance, tree height, basal area, and diameter at breast height (DBH), which are critical indicators of forest growth and dynamics (Köhl *et al*., 2006). By analyzing these metrics, researchers can evaluate species dominance, competition, and overall forest productivity. Understanding these ecological parameters aids in making informed decisions regarding forest management and conservation strategies, ensuring the long-term success of restoration efforts.

2.4 Forest Regeneration Processes

Forest regeneration is the natural or assisted process by which forests recover following disturbances such as deforestation, wildfires, or logging. This process can occur naturally through seed dispersal, vegetative reproduction, and the recruitment of pioneer species, or it can be facilitated by human interventions such as planting and silvicultural practices (Chazdon *et al*., 2007). Natural regeneration is often preferred for its ability to maintain high species diversity, as it allows for the spontaneous establishment of native species that are well adapted to local conditions.

Artificial regeneration, while often more rapid and controlled, can sometimes result in reduced diversity if only a few species are planted in monoculture systems (Lamb *et al*., 2005). To enhance the effectiveness of artificial regeneration, it is important to incorporate a variety of species that reflect the natural composition of the forest. The integration of total inventory methods in regeneration studies provides essential data on seedling establishment, survival rates, and species composition, thereby guiding restoration efforts to achieve long-term ecological sustainability.

2.5 Species Composition and Ecological Significance

Species composition is a key indicator of forest health and biodiversity. The selected species for this study, including Triplochiton scleroxylon, Khaya grandifoliola, *Entandrophragma cylindricum*, and others, contribute significantly to timber production, carbon sequestration, and habitat provision. These species play crucial roles in sustaining ecological balance, supporting wildlife, and maintaining soil fertility.

Triplochiton scleroxylon, commonly known as African whitewood, is a large deciduous tree native to tropical West and Central Africa (Keay, 1989; Orwa *et al*., 2009). It typically reaches heights of up to 50 meters, with trunk diameters ranging from 60 to 150 centimeters. The bark is ashy grey or yellowish-brown, smooth in younger specimens but becoming scaly with age.The leaves are palmately lobed with 5 to 7 lobes, measuring between 10 to 20 centimeters in length and width. Flowers are saucer-shaped, featuring white petals that are reddish-purple at the base. The fruit comprises winged carpels, each about 4 to 6 centimeters long. The timber of *T. scleroxylon* is pale yellow, moderately soft, and lightweight for a hardwood. It is utilized in the production of veneer, furniture, picture frames, and mouldings. Additionally, the wood is favored by guitar makers; companies like Gibson and Fender Japan have employed it in limited edition guitars.

In traditional medicine, various parts of the tree are used to treat conditions such as edemas and serve as painkillers. The leaves are edible and are cooked as a vegetable in certain West African cuisines. Ecologically, *T. scleroxylon* serves as a host for the African silk moth (Anaphe venata), whose caterpillars feed on its leaves and spin cocoons used in silk production.

Despite its extensive use, the species is currently classified as 'Least Concern' on the IUCN Red List. However, unsustainable harvesting practices in some regions have raised conservation concerns, highlighting the need for sustainable management strategies and afforestation initiatives.

Khaya grandifoliola, commonly known as African Mahogany, is a large deciduous tree native to West and Central Africa (Orwa *et al*., 2009). It belongs to the Meliaceae family and is valued for its high-quality timber, which is used in furniture, construction, and boat building (Lemmens, 2008). The tree can grow up to 50 meters in height, with a straight bole and an umbrella-shaped crown (Keay, 1989). Its leaves are compound, with large, glossy leaflets that provide dense shade (Hall and Swaine, 1981).

African Mahogany thrives in moist, deciduous forests and riverine ecosystems, preferring well-drained soils (Orwa *et al*., 2009). It is also resistant to drought, making it suitable for agroforestry systems in semi-arid regions (Louppe *et al*., 2008). The species is known for its resistance to pests, although it is sometimes affected by the mahogany shoot borer (Hypsipyla robusta) (Newton *et al*., 1993).

Apart from timber, *Khaya grandifoliola* has medicinal uses, with its bark and leaves traditionally used to treat fever, malaria, and stomach ailments (Iwu, 1993). The tree also plays an ecological role by improving soil fertility through leaf litter decomposition (Oduor and Omondi, 2008). Additionally, its flowers provide nectar for bees, contributing to honey production and pollination services. Despite its economic and ecological significance, overexploitation and deforestation have led to population declines, necessitating conservation efforts such as controlled harvesting and reforestation programs (Jenkins *et al*., 2012).

Entandrophragma cylindricum, commonly known as Sapele wood, is a large deciduous tree native to tropical Africa (Orwa *et al*., 2009). It belongs to the Meliaceae family and is closely related to mahogany species (Lemmens, 2008). The tree can grow up to 45 meters in height, with a straight bole and a well-developed crown (Orwa *et al*., 2009).

Sapele wood is highly valued for its reddish-brown timber, which darkens with age and has an interlocked grain that produces a distinctive ribbon figure (Lemmens, 2008). Due to its durability and aesthetic appeal, it is widely used in furniture, flooring, boatbuilding, and musical instruments (Orwa *et al*., 2009). The wood has moderate natural resistance to decay and insect attacks, though it benefits from treatment for outdoor applications (Lemmens, 2008).

Entandrophragma cylindricum is mainly found in West and Central Africa, particularly in countries like Cameroon, Ghana, and the Democratic Republic of Congo (Orwa *et al*., 2009). It plays an essential role in forest ecosystems by providing habitat and food sources for wildlife. Overharvesting has led to concerns about its conservation, and it is listed as vulnerable on the IUCN Red List (Lemmens, 2008). Sustainable forest management and controlled logging practices, such as reduced-impact logging and certification programs, are crucial to preserving its population (Orwa *et al*., 2009).

Terminalia superba, commonly known as White Afara, is a large deciduous tree native to tropical West and Central Africa (Orwa *et al*., 2009). It belongs to the Combretaceae family and is widely valued for its timber and ecological benefits (Louppe *et al*., 2008). The tree can grow up to 50 meters in height, with a straight, cylindrical bole and a broad, open crown (Agyeman *et al*., 2003).

It thrives in moist, well-drained soils and is commonly found in secondary forests and plantations (Hall and Swaine, 1981). Terminalia superba is a fast-growing species, making it suitable for reforestation and agroforestry systems (FAO, 1995). Its wood is lightweight, durable, and resistant to termites, making it ideal for furniture, construction, and plywood (Orwa *et al*., 2009).

Additionally, the tree provides environmental benefits such as soil stabilization, carbon sequestration, and habitat for wildlife (Louppe *et al*., 2008). Its deep root system helps prevent soil erosion, and its fallen leaves contribute to soil nutrient cycling. It also has medicinal uses, with various parts of the tree traditionally used to treat ailments like diarrhea, wounds, and respiratory infections (Burkill, 1985). Despite its economic and ecological importance, unsustainable logging poses a threat to its population, necessitating conservation efforts such as afforestation, controlled harvesting, and the promotion of alternative timber sources (Agyeman *et al*., 2003).

Terminalia ivorensis (Ivory Coast Almond) is a large deciduous tree native to West and Central Africa (Orwa *et al*., 2009). It belongs to the Combretaceae family and thrives in tropical rainforests with high humidity and well-drained soils (Orwa *et al*., 2009). The tree can grow up to 50 meters in height and is valued for its high-quality timber, which is used in furniture, construction, and boatbuilding (Lemmens *et al*., 2012).

Its wood is light brown to golden-yellow, with a fine texture and moderate durability (Orwa *et al*., 2009). The species is also known for its role in afforestation and agroforestry due to its rapid growth and ability to improve soil fertility (Leakey, 1999). However, Terminalia ivorensis is classified as vulnerable due to overexploitation and habitat destruction (IUCN, 2021). Conservation efforts, including sustainable logging and reforestation programs, are essential to ensure its survival (IUCN, 2021).

Pterocarpus angolensis, commonly known as African Teak or Kiaat, is a deciduous tree native to southern Africa (Coates and Palgrave, 2002). It belongs to the Fabaceae family and thrives in well-drained soils in savanna and woodland ecosystems (Van Wyk and Van Wyk, 2013). The tree can grow up to 18 meters in height and is valued for its durable, termite-resistant timber, which is widely used in furniture making and construction (Louppe *et al*., 2008).

The species produces yellow flowers and distinctive winged pods that aid in seed dispersal (Schmidt *et al*., 2002). It is also an important medicinal plant, with its bark and roots used in traditional medicine for treating wounds, fever, and respiratory ailments (Arnold and Götzenberger, 2017). However, due to overexploitation and slow growth rates, P. angolensis is classified as Near Threatened on the IUCN Red List (IUCN, 2020). Conservation efforts, including sustainable harvesting and plantation establishment, are crucial for its long-term survival (Shackleton *et al*., 2015).

Pterocarpus osun, commonly known as Camwood, is a tropical hardwood tree native to West Africa (Orwa *et al*., 2009). It belongs to the Fabaceae family and is valued for its red heartwood, which is used for dye production and traditional medicine (Burkill, 1995). The tree typically grows in moist, deciduous forests and can reach heights of up to 15–25 meters (Keay, 1989).

Camwood is widely utilized for its medicinal properties, including its antibacterial and antifungal activities (Iwu, 1993). The heartwood contains bioactive compounds such as flavonoids and tannins, which contribute to its therapeutic effects (Ogunwande *et al*., 2006).

Additionally, it has economic importance in the production of dyes for textiles and cosmetics (Abbiw, 1990).

Due to overexploitation and habitat destruction, Pterocarpus osun is facing threats in some regions (Adekunle *et al*., 2013). Conservation efforts are needed to ensure its sustainable use and long-term availability (IUCN, 2021).

Nauclea diderichii, commonly known as Opepe, is a large tropical hardwood tree native to West and Central Africa (Orwa et al., 2009). It belongs to the Rubiaceae family and thrives in humid lowland forests (Lemmens, 2008). The tree can grow up to 40 meters in height, with a straight bole and a broad, rounded crown (Keay, 1989).

Opepe is highly valued for its durable and termite-resistant timber, which is used in construction, flooring, and boat building (PROTA, 2007). The wood has a yellow to orange-brown color and is known for its strength and resistance to decay (Orwa et al., 2009). In addition to its commercial value, Nauclea diderichii has medicinal uses, with extracts from its bark and leaves traditionally used to treat fever and infections (Burkill, 1985).

The species is facing threats due to deforestation and overexploitation, leading to its classification as "Vulnerable" by the IUCN (IUCN, 2020). Conservation efforts, including sustainable management and reforestation programs, are essential to ensure the survival of this valuable species (Lemmens, 2008).

2.6 Species Diversity in Regenerating Forests

Species diversity is a measure of the variety and abundance of species within an ecosystem (Hooper *et al*., 2005). In regenerating forests, diversity is a critical indicator of ecological recovery and resilience (Hooper *et al*., 2005). High species diversity is associated with improved ecosystem functions, such as nutrient cycling, carbon storage, and resistance to disturbances (Hooper *et al*., 2005). Diverse ecosystems tend to be more stable and productive, as they can better withstand environmental changes, disease outbreaks, and invasive species (Tilman *et al*., 1997).

In regenerating forests, species diversity plays a crucial role in succession dynamics, where pioneer species facilitate the establishment of late-successional species (Connell and Slatyer, 1977). This diversity-driven process enhances habitat complexity, provides resources for a wide range of organisms, and contributes to long-term ecosystem stability (Chazdon, 2008). High species richness also supports trophic interactions by sustaining pollinators, herbivores, and decomposers, all of which influence forest productivity and health (Eisenhauer *et al*., 2012).

Metrics such as the Shannon-Wiener Index and Simpson's Diversity Index are commonly used to assess species diversity (Magurran, 2004). These indices provide insights into the richness (number of species present) and evenness (distribution of individuals among species), which are important for understanding competitive interactions, niche differentiation, and succession patterns in regenerating forests (Whittaker, 1972).

Shannon-Wiener Index (H'): This index accounts for both species richness and evenness, making it useful for comparing diversity across different forest regeneration stages (Magurran, 2004). Higher values indicate a more diverse and evenly distributed species composition, which is often associated with greater ecosystem stability (Purvis and Hector, 2000).

Simpson's Diversity Index (D): This index measures the probability that two randomly selected individuals belong to different species (Simpson, 1949). A higher Simpson's Index value suggests lower dominance by a single species, indicating a more balanced ecosystem (Magurran, 2004).Additional metrics, such as species evenness and functional diversity, provide further ecological insights into forest recovery processes (Mason *et al*., 2005). Evenness indicates how equitably individuals are distributed among species, while functional diversity considers variations in species traits and their contributions to ecosystem functions (Díaz and Cabido, 2001).

Monitoring species diversity in regenerating forests is essential for conservation planning, sustainable forest management, and climate change mitigation efforts (Chazdon, 2008). By promoting diverse plant communities, forests can better adapt to environmental stressors, support biodiversity conservation, and enhance ecosystem services (Cardinale *et al*., 2012).

2.7 Growth Dynamics of Tree Species

Growth dynamics refer to the patterns of tree growth in terms of diameter, height, and volume over time (Clark and Clark, 1999). Regenerating forests often exhibit varying growth rates depending on the species, site conditions, and stage of succession (Finegan, 1996). Pioneer species such as *Triplochiton scleroxylon* grow rapidly in open conditions, while late-successional species like *Khaya grandifoliola* exhibit slower, sustained growth under closed canopies (Swaine and Whitmore, 1988).

The study of growth dynamics provides valuable information on forest productivity and biomass accumulation (Brown and Lugo, 1990). It also informs management practices aimed at enhancing forest recovery and sustainability (Lugo and Scatena, 1996). Understanding growth rates allows forest managers to implement appropriate silvicultural interventions, such as thinning, enrichment planting, and controlled disturbances, to optimize forest regeneration (Lamprecht, 1989).

Tree growth is influenced by multiple factors, including soil fertility, light availability, competition, and climate variability (Chave *et al*., 2003). In regenerating forests, early-successional species often allocate more energy to rapid height growth to outcompete neighbors for sunlight, while late-successional species invest in denser wood and deeper root systems for long-term survival (Poorter *et al*., 2005). Growth models, such as diameter increment equations and height-diameter relationships, are commonly used to predict stand development and guide sustainable harvesting strategies (Vanclay, 1994).

Monitoring growth dynamics is essential for assessing carbon sequestration potential, as tree biomass accumulation directly contributes to carbon storage in forest ecosystems (Malhi *et al*., 2004). Long-term growth studies help in understanding how forests respond to environmental changes, such as climate fluctuations and land-use shifts, thereby improving adaptive forest management strategies (Phillips *et al*., 2008).

2.8 Factors Influencing Forest Regeneration

Several factors influence the success of forest regeneration, including:

1. Soil Fertility: Nutrient-rich soils promote faster growth and higher species diversity (Lal, 2005).
2. Light Availability: Light-demanding species dominate in open canopies, while shade-tolerant species thrive under dense canopies.

3. Disturbance History: Sites with frequent disturbances may favor pioneer species, while less disturbed areas support late-successional species.
4. Climate: Temperature and rainfall patterns affect seed germination, growth rates, and species composition.
5. Competition: The interaction between species for resources such as light, water, and nutrients shapes growth dynamics and diversity.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Description of Study Site

This study was carried out at a forest restoration site located behind Blocks of flat in the University of Benin, Benin City Nigeria. The site which is located on Latitude 6° 24'16.8" N and Longitude 005°38'02.5" E has an elevation of 75m above sea level and measuring 100m x 100m (1 ha) area with a buffer zone of 4m. A sample plot measuring 100m × 86m (8600 m^2) was marked out within the one hectare planted area of the restoration site for this study. The site has a temperature range of between 27°C to 32°C for most of the year and atmospheric humidity of 75% at noon and 95% at 6.00am. The average annual rainfall is 2500mm (UNIBEN Master Plan, 1993).

3.2 Site preparation

A reconnaissance survey was first carry out to locate and determine the size of the forest restoration site after which a sample plot of 8600 m^2 was marked out using measuring tape, ranging poles, pegs and red ribbon. Ring weeding using cutlass was done around the planted tree species within the sample plot for ease of data collection. Also, the nature and characteristics of the site was recorded.

3.3 Data Collection

Two groups of data were collected in this study. Group one was data on naturally regenerating tree species: identification and species frequency. Group two was data on the planted tree species: identification, species frequency and measurement of growth parameters.

The growth parameters measured for planted tree species were height (cm) with the aid of a measuring tape, number of leaves, number of branches and collar girth (mm) with the aid of a veneer calliper. Data for both groups were collected within a period of three weeks.


Plate 1: Taking height Measurement of Seedling

Plate 2: **Measuring Sample Plot**

Plate 3:**Counting Number Of Leaves Of Seedling**

3.4 Data Analysis

Data was analyzed using descriptive statistics such as tables, charts and graphs. Tree species diversity were analyzed using the following indices; Shannon-Wiener diversity index (H), Margalef's index of species richness (M), Simpson concentration index (D). Growth data collected for planted trees was analysed using One-way analysis of variance (ANOVA) in Completely Randomized Design (CRD) while the means were separated using Duncans Multiple Range Test (DMRT).

The experimental model for CRD design is stated below;

$$Y_{ij} = \mu + T_j + \varepsilon_{ij}$$

Where: Yij = Individual observation

N = Population mean/General mean

Tj = Treatment effect

Eij = Experimental error

In this study, species richness was computed as the total number of tree species encountered in the sample plot. For the measurement of evenness/heterogeneity, Simpson and Shannon-Wiener indices was computed for the sample plot using GENSTAT version 12.1. Margalef's index was also used for the purpose of comparison.

Species Diversity Index

Species diversity index was computed using

1. Shannon-Wiener diversity index equation (McPherson and Simpson, 1999; Kent and Coker, 1992; Guo *et al*., 2003)

$$\boldsymbol{H^{'} = -\sum_{i=1}^{s} p_i\, In(p_i)}$$

Where, $\boldsymbol{H'}$ = Shannon-Wiener index of diversity

$\boldsymbol{S}$ = the total number of species in the community

$\boldsymbol{P_i} = \boldsymbol{\frac{n_i}{N}}$

$\boldsymbol{n_i}$ = total no. of individuals of all species

$\boldsymbol{N}$ = total no. of individuals of species

$\boldsymbol{p_i}$ = the proportion of S made up of the ith species

ln = natural logarithm.

2. (i) Simpson's index (D) of dominance (Simpson, 1949)

$$\mathbf{D = 1\text{-}\Sigma\, (\boldsymbol{p_i})^{2}}$$

Where, **D** = Simpson index of dominance

p_i = the proportion of important value of the ith species ($p_i = n_i/N$; n_i is the important value index of ith species and N is the importance value index of all the species).

3. Species richness [Margalef index (M)] **(**Margalef, 1958)

$$M = \frac{S - 1}{I_n N}$$

Where: **S** = total number of species,

N= total number of individual species

CHAPTER FOUR

RESULTS

4.1 Tree Species Composition

A total of 194 trees in different girth classes comprising of 28 species belonging to 19 families were recorded within the sample plot in the regeneration area (Table 1). The results show that 19 tree species regenerated naturally while 9 species were planted. *Triplochiton scleroxylon* was the most prevalent (46 trees) while *Ficus Sur, Pycnanthus angolensis* and *Eribroma oblonga* had the least represented by one individual each.

Table 1: Tree species within sample plot

S/N	FAMILY	SPECIES	ORIGIN	FREQUENCY
1	Apocynaceac	*Alstonia boonei* Engl	NR	3
		Rauvolfia vornitoria Afel	NR	8
2	Biqnoniaceac	*Newbouldia Laevis*	NR	2
		(P.Beaur)Seemann exizureau		
		Spathodia companulata F.Beaur	NR	7
3	Caesalpiniodeac	*Dialum quineense* Wild	NR	7
4	Combretaceae	*Terminalia superba*	P	21
		Terminalia ivorensis	P	16
5	Ebenaceac	*Diospyros iturensis*	NR	2
		(Gurke)Letouzey and F.White		
		Margaritaria discoidea	NR	4
		(Baill)Webster in J.Am Arb		
6	Fabaceae	*Pterocarpus osun*	P	4
7	Meliaceae	*Khaya grandifoliola*	P	5
		Entandrophragma cylindricum	P	12
8	Guttiferac	*Harungana madagascariensis*	NR	3
		Lam expoir		

9	Lecythidiaceac	*Napoleonaca imperialis* P.Beaur	NR	3
10	Loganiaceac	*Anthocleista vogelii* planch	NR	6
11	Malvaceae	*Bombax buonopozense*	P	11
12	Mimosoideac	*Albizia Zygia* (DC) J.E Machr	NR	4
		Albizia adianthifolia (schum)W.F Weight	NR	6
		Pentaclethra macrophylla Beath	NR	4
13	Maraceac	*Ficus exasperate* vahl	NR	3
		Ficus Sur forssk	NR	1
		Antiaris toxicaria lesch	NR	3
14	Myristicaceae	*Pycnanthus angolensis*	P	1
15	Papilionoideae	*Amphimas pterocarpoides* Harms	NR	3
16	Rubiaceae	*Nauclea diderrichii*	P	5
17	Steraliaceac	*Eribroma oblonga* (Mast)puerre ex A.chec	NR	1
18	Sterculiaceae	*Triplochiton scleroxylon*	P	46
19	Ulmaceac	*Trema orientalis* (Linn)Blume-Poihill	NR	3
Total		**28**		**194**

NR: natural regenerated species, P: planted species

4.2 Diversity and Species Richness

The records of species richness and diversity indices computed are shown in Table 2. The biodiversity did not vary greatly between the planted species and natural regenerated species in the study area. When the diversity indices of both groups were calculated, the natural regenerated tree species had higher diversity indices (H^{1} = 2.813, D = 0.947, M = 4.195) compared to the planted species

Table 2: Diversity of sample plot

Diversity Indices	Planted species	Natural regenerated species	Total sample plot species
Shannon-Weiner H	1.802	2.813	2.845
Simpson 1-D	0.792	0.947	0.912
Margalef	1.668	4.195	5.125
Species richness	9.000	19.000	28.000

4.3 Growth Performance of Planted Trees

4.3.1 Height growth

The average height growth of measured planted tree species is shown in figure 1. It indicates faster growth rate of *Terminalia ivorensis* with average height of 366.27cm followed by *Nauclea diderrichii* (195.22cm) *Terminalia superba* (181.20cm) while the least height of 42.68cm was recorded for *Entandrophragma cylindricum.*

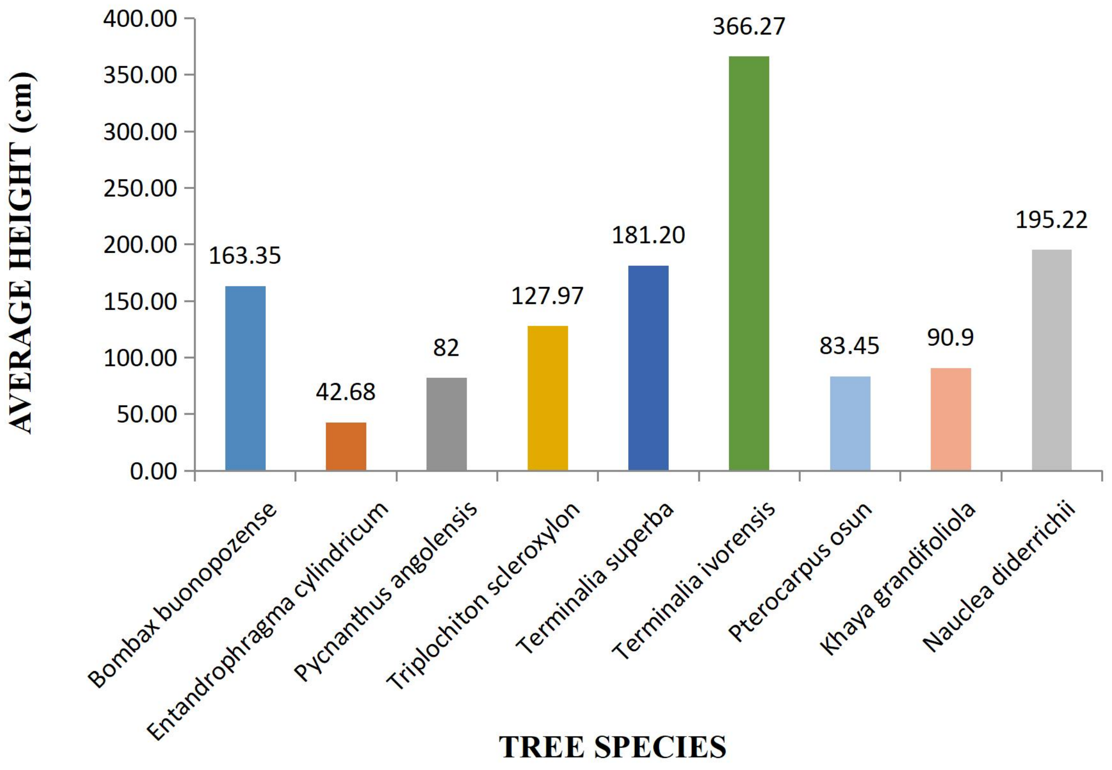

Figure 1: Average height growth of planted tree species

4.3.2 Number of leaves

The data collected for leaf production by planted tree shown in figure 2, reveals that *Terminalia ivorensis* and *Terminalia superba* produced more leaves (3,390 and 1,056 leaves respectively) compared to other species. *P. angolensis and K. grandifoliola* had equal number of leaves (17) while *E. cylindricum* had the least leaf production of 5.

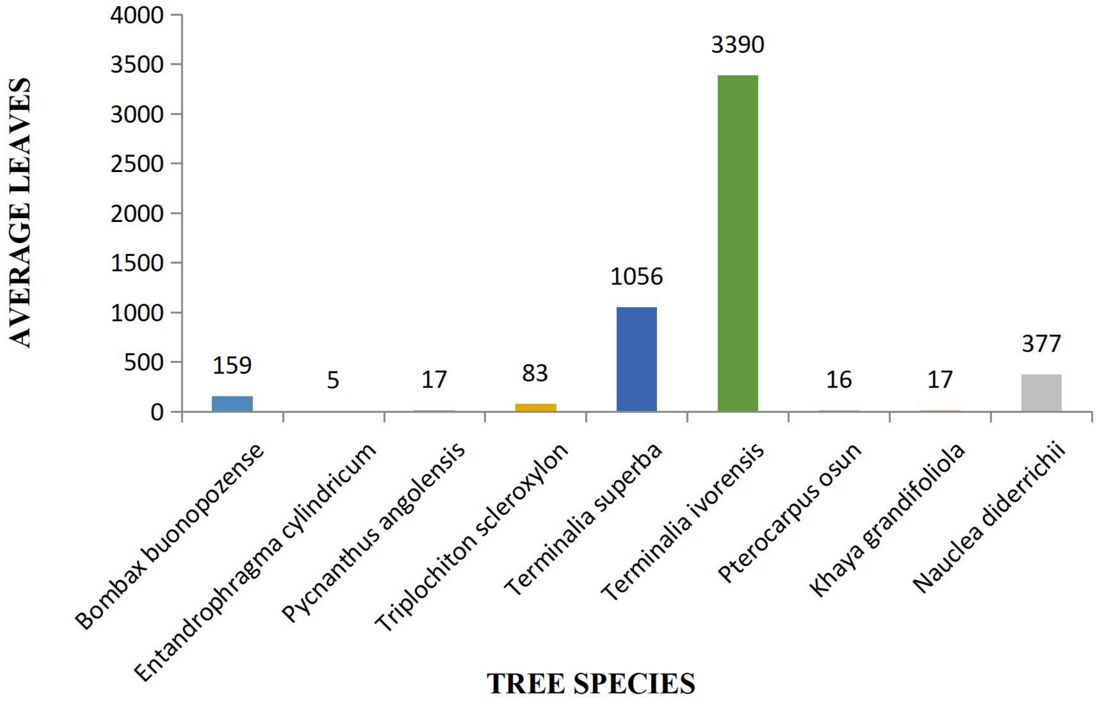

Figure 2: Average leaf of planted tree species

4.3.3 Number of branches

Figure 3 shows that the average branch proliferation of the planted tree species was high in *Terminalia ivorensis* (19.19) and was closely followed by *Nauclea diderrichii* (14.2). *T. scleroxylon* and *T. superba* recorded similar average branch production rate of 9.20 and 9.43 respectively while *E. cylindricum* had the least production.

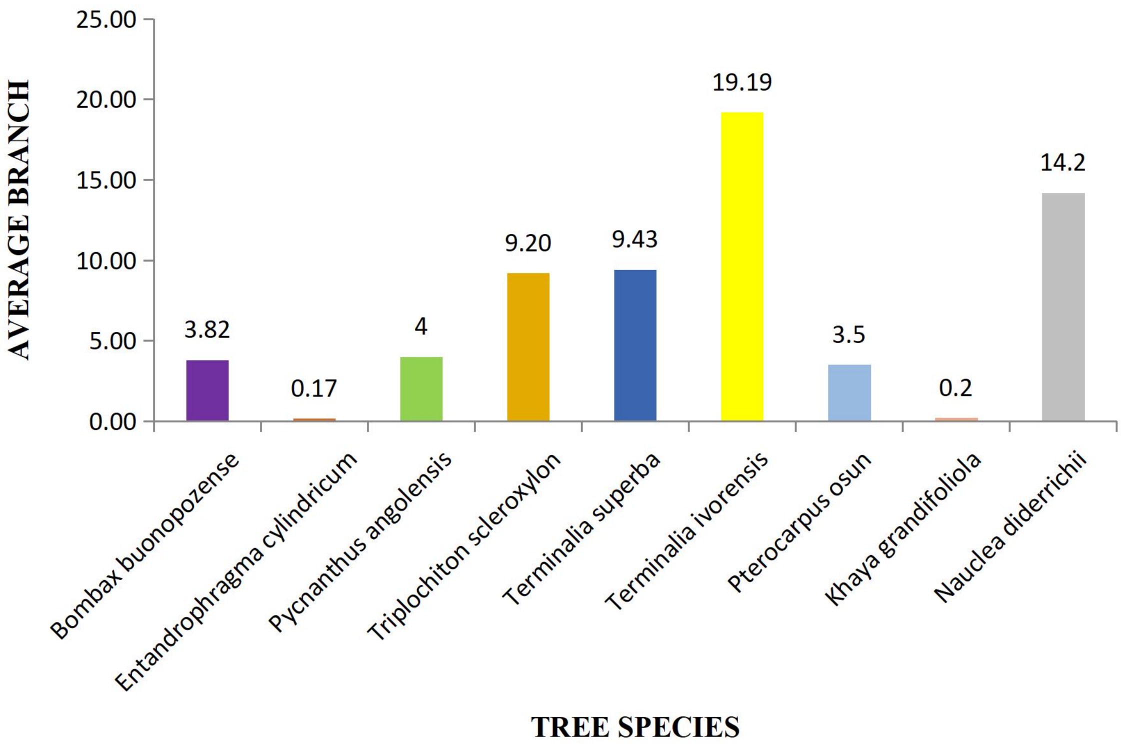

Figure 3: Average branch of planted tree species

4.3.4 Colar girth

The average colar girth increment of the planted species measured is shown in figure 4. From the figure, *Terminalia ivorensis* recorded the largest girth size of 158.6mm, followed by *Bombax buonopozense* (63.0mm), *Nauclea diderrichii* (59.7mm) and *Terminalia superba* (55.44mm). the least girth size of 17.5mm was recorded for *Pycnanthus angolensis*.

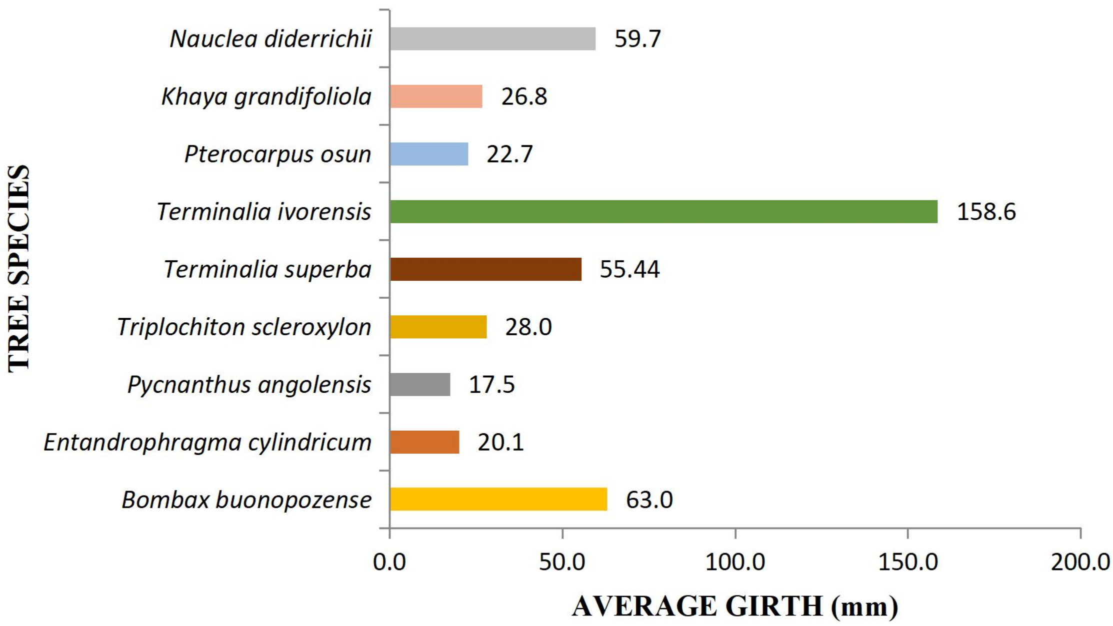

Figure 4: Average colar girth of planted tree species

The analysis of variance (ANOVA) for all measured parameters showed significant difference at $P < 0.05$ in the growth performance of the planted tree species (Appendix 2 – 5). The growth performance of *T. ivorensis* was significantly different from other species in all parameters measured as indicated by the mean separation (Table 3). *E. cylindricum* recorded the least growth performance in the measured parameters except for colar girth size where *P. angolensis* had the least

Table 3: Mean separation for measured parameters of planted trees

xcacdfcvHEIGHT		NUMBER OF LEAF		NUMBER OF BRANCH		COLAR GIRTH	
Species	**mean**	**species**	**Mean**	**species**	**mean**	**Species**	**mean**
T. ivorensis	366.3 a	*T. ivorensis*	3389.9 a	*T. ivorensis*	19.666 a	*T. ivorensis*	158.28 a
N. diderrichii	195.3 b	*T. superba*	10566.7 b	*N. diderrichii*	14.275 b	*B. buonopozense*	63.02 b
T. superba	181.2 b	*N. diderrichii*	376.9 c	*T. superba*	9.319 c	*N. diderrichii*	59.59 b
B. buonopozense	163.4 bc	*B. buonopozense*	158.1 d	*T. scleroxylon*	9.186 c	*T. superba*	55.55 b
T. scleroxylon	127.5 cd	*T. scleroxylon*	83.5 e	*P. angolensis*	4.250 d	*T. scleroxylon*	28.24 c
K. grandifoliola	90.6 de	*K. grandifoliola*	17.2 f	*P. osun*	3.478 d	*K. grandifoliola*	26.73 cd
P. osun	83.5 e	*P. angolensis*	17.0 f	*B. buonopozense*	3.154 d	*P. osun*	22.81 cd
P. angolensis	81.6 e	*P. osun*	15.6 f	*K. grandifoliola*	0.225 e	*E. cylindricum*	20.08 cd
E. cylindricum	42.6 f	*E. cylindricum*	5.1 f	*E. cylindricum*	0.159 e	*P. angolensis*	17.55 d

Means with the same letter are not significantly different along column.

4.2 DISCUSSION

From the result, a total of 194 trees covering an average density of 0.67 trees ha^{-1} were enumerated in the forest regeneration site is not much different from the findings of Thoringston *et al*. (1982) and Hubbell and Foster (1983) who reported 171 ha^{-1} and 152 ha^{-1} respectively;. However, this result differs from that of Ogunjemite (2015), who recorded 944 trees ha^{-1} in 2015 in a similar study. Also, 535/ha was reported by Sidiyasa (2001) in Wain River, East Kalimantan, while 1420/ha and 1720/ha were recorded by Campbell *et al*. (1986) and Campbell *et al*. (1992) respectively both in tropical Amazonia forest.

Composition and diversity of the residual forest in this study was significantly affected, as the practice of continuous farming and burning reduces the diversity of tree species, harming one or more main forest species. According to Vásquez-Grandón *et al*. (2018), this eventually lead to the disappearance of certain species, and low Relative importance values (RIV) of the remaining original species found in the regeneration site while Devi and Behera (2003) opined that the greater the degree of degradation, the more severe the decline in the number of tree species.

The result of the site characteristic in this study revealed the presence of non-commercial or secondary species to the detriment of principal forest species, and high density and coverage of competitive arborescent and/or shrub species. In severely altered forests, where damaging selective extraction affects the composition and structure of the forest, Vásquez-Grandón *et al*. (2018) stated that the density and dominance of non-commercial and secondary species may reach disproportionally high levels (e.g., 90% of the total stand density). In terms of regeneration, altered forests are characterized by moderate to low levels or indeed a complete absence of tree species regeneration, and/or high levels of secondary, arborescent and non-commercial species regeneration, depending on the degree of degradation.

The better growth performance of the planted tree species such as *Terminalia ivorensis, Bombax buonopozense, Terminalia superba and Nauclea diderrichii* may be attributed to their growth characterization as pioneers – quick root development and adaptability, fast growth and stem elongation.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

In summary, the structural and compositional characteristics of forest regeneration site subjected to damaging human-induced alterations (with an absence of silvicultural criteria and objectives) of varying intensity and frequency become altered to a greater or lesser extent, as does the density and diversity of the tree species regenerating within the sample plot. In other words, the site eventually came to reflect the differing degrees of alteration that has taken place.

The implication of the outcome of this study is that the regeneration site has lower species richness than most tropical rainforest sites. This difference may likely be related to the level of deforestation due to illegal logging, land clearing for farming, fuelwood exploitation, etc. Diversity of regeneration is linked to the presence or absence of adult seed trees and to the high coverage of competitive species in the understory. The presence of seed trees in degraded forests does not guarantee a successful process of seedling recruitment and seed harvesting, and in highly degraded forests, the density of seedlings of non-commercial and secondary species may represent more of the total density of tree regeneration in the stand.

From the findings of this study, the following recommendations are made:

i. further and more detailed research is needed into the structural, compositional and regeneration criteria and characteristics of degraded forest lands in order to identify a set of valid and adequate indicators to discern common patterns of degradation in forests, and thus establish a practical approach for description and analysis of a degraded forest. This research should be based on specific field studies, existing forest inventories, and permanent plots.

ii. there should be considerable motivation worldwide in reversing the process of forest degradation, especially among scientists and international organizations that focus on forests and biological conservation in general.

iii. more studies should be conducted to identify appropriate tree species used to create an operational regeneration system that details characteristics, measurements or observations of the forests (stands) under evaluation, establishing a practical means of regenerating degraded forest area

iv. local diagnosis and remedial approaches that consider the specific biophysical, social and political context will be important contributors to the global and urgent need to reverse forest degradation.

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APPENDIX

Appendix 1: Averages of growth parameter for planted trees

SPECIES	Height(cm)	Number of leaf	Number of branch	Colar girth(mm)
Bombax buonopozense	163.35	158.64	3.82	63.02
Entandrophragma cylindricum	42.68	5.00	0.17	20.10
Pycnanthus angolensis	82	17	4	17.5
Triplochiton scleroxylon	127.97	83.00	9.20	28.02
Terminalia superba	181.20	1056.90	9.43	55.44
Terminalia ivorensis	366.27	3389.81	19.19	158.58
Pterocarpus osun	83.45	15.75	3.5	22.65
Khaya grandifoliola	90.9	17.2	0.2	26.78
Nauclea diderrichii	195.22	376.6	14.2	59.68

Appendix 2: ANOVA for height of planted trees

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
SPECIES	8	298537.3	37317.2	52.04	<.001
Residual	27	19360.6	717.1		
Total	35	317898.0			

Appendix 3: ANOVA for number of leaf of planted trees

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
SPECIES	8	39478378.	4934797.	3106.16	<.001
Residual	27	42895.	1589.		
Total	35	39521273.			

Appendix 4: ANOVA for number of branch of planted trees

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
SPECIES	8	1403.602	175.450	75.05	<.001
Residual	27	63.121	2.338		
Total	35	1466.723			

Appendix 4: ANOVA for colar girth of planted trees

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
SPECIES	8	62878.16	7859.77	200.51	<.001
Residual	27	1058.38	39.20		
Total	35	63936.54			