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Impact of Climate Change in Nigerian Wetland Ecosystems on Plant Genetic Resources

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ABSTRACT

The research focused on particular character traits of some plants in the ecosystems of Nigeria's wetlands. The idea was to highlight the plants' adaptive mechanisms and conservation requirements in response to the vagaries of climate change. The field data collection covered 10 wetland sites spread across the Niger Delta, Nigeria, selected to represent a diversity of plant morphology, biological chemistry, and population structure parameters. The investigated morphological elements in leaves, flowers, and fruit showed considerable variation in their size, shape, and color among species. The biochemical data derived from isozyme profiles in turn gave rise to a higher degree of genetic variation, which was further demonstrated through population structure data that revealed selective pressures on the mating success of the population and the demography of individuals. The environmental conditions, such as pH level, temperature, oxygen, and nitrogen levels, along with others, determined the variety of habitats in the cattail marsh at every site. These data provide evidence-based insights related to wetland ecology and plant genetics as the basis for a deeper understanding and prioritizing the conservation of these very special ecosystems against the background of climate change challenges. Areas of future research that should be considered include more investigations about genetic heterogeneity, the role of ecological interactions, and the integration of management strategies for reforming wetlands conservation. This investigation comprehensively explained wetland ecosystems and emphasized the imperative for immediate conservation measures in order to guarantee ecological integrity and the diversity of life in wetland ecosystems.

Introduction

Nigeria's wetland ecosystems are one of the world's rich biodiversity hotspots that host a variety of plant genetic resources that are key to landscape resilience and provide economic revenue on both local and global levels. Nevertheless, these ecosystems, which are highly dependent on climate, are perishing progressively as part of the challenges confronting the survival of plant genetic resources and the sustainability of ecosystem services that they provide, among others (Weiskopf et al., 2020; Chaudhry & Sidhu, 2021; Ebert & Engels, 2020; Ochar & Kim 2023; Yan et al., 2023). Appreciating the effects of climate change on Nigeria's wetlands and on their genetic diversity in the plant world is necessary for designing effective conservation and management measures.

The significance of studying climate change as it affects Nigeria's wetland ecosystems emanates mainly from its widespread and far-reaching implications. Primarily, these ecosystems are the custodians of high biodiversity, and they become populated with countless plant species with significant genetic features that contribute to the ability of the environment to face the changes (Hong et al., 2021; Hisano et al., 2018; Ebele and Emodi, 2016; Vasiliev, 2022; Aavik & Helm, 2018). Climatic changes accompanied by variations in temperature, precipitation patterns, and extreme weather events, be they thunderstorms or snow, act as threats to the proper running of these ecosystems, thus leading to the destruction of the habitat, the disappearance of species, and genetic deterioration (Arowolo et al. 2018; Weelden et al., 2021; Razgour et al., 2020; Olaniyi et al. 2019).

Socio-economically, the wetlands in Nigeria are highly related to the daily lives of many communities since they guarantee important ecosystem services such as water regulation, flood control, nutrient cycling, and food security (Ayeni et al., 2019; Olarewaju et al., 2021; Akpabio and Umoh, 2021). The footprint of climate change could be rather far-reaching with respect to a wetland ecosystem. It could lead to economic impacts such as a reduction in crop production, less water availability, and the world-at-large human health, especially for individuals residing in the vicinity of a wetland ecosystem (Ni 2021; Kangalawe 2017; Salimi et al., 2021; Mugambiwa & Rapholo, 2024; Nielsen et al. 2020; Sarda and Pal 2022). Although some studies have demonstrated that vegetation given a wetland habitat is essential for both biodiversity conservation and ecosystem services, limited attention has been focused on the genetic consequences of climate change for plant species that inhabit the watersheds within Nigerian wetlands (Lyam et al., 2018; Oyebanji et al., 2021; Muluneh, 2021; Anderson & Song, 2020; Christie, 2023). And so, one of the most apparent limitations of the recent literature is a lack of thorough discussion of the direct connections between climate change and plant genetic diversity in this case, as well as any indirect economic consequences for local communities completely dependent on wetland resources. Primarily, the wetland ecosystems of Nigeria also show how climate change affects the life line of plant genetic resources through both theoretical explanation and practical registration. A better recognition of the value of these ecosystems, their management, as well as their strength and resilience, will encourage us to take effective measures to improve the sustainability and growth of humankind and the natural environment (Okon et al. 2021; Wahab and Iyiola 2023; Mafiana et al. 2022; Sintayehu 2018).

The theoretical model of this study involves numerous ecological, conservation biology, and climatic science concepts to assess the interaction between climate change, wetland ecosystems, and genetic plant resources. Through combining concepts of species distribution zones, genome variation, and the dynamics of ecosystems, this study aims to provide a multidisciplinary insight into how environmental shifts affect the genetic makeup and evolutionary processes of wetland plant populations. Moreover, these socio-ecological frameworks were used to identify the core issues of ecosystem health, human livelihoods, and policies to resolve the interconnected challenges of climate change within Nigerian wetlands.

The goal of this research is to examine the influence of climate change on plant genetic resources that are in the wetland environment of Nigeria and assess the programs that are against biodiversity, ecosystem stability, and environmental preservation. Through examining how climate change alters the distribution, amount, and genetic variation of some wetland plants, this research hopes to further develop wetland plant communities' understanding of ecosystem responses to exploited environmental factors and guide evidence-based conservation efforts within the purview of climate change.

This study was carried out with the following objectives: (1) Evaluate the ongoing distribution and population count of plants in some sampled wetlands environs in Nigeria; (2) Study the genetic diversity of major wetland plants structurally within populations and their response to fluctuations in environmental conditions and climate change impacts; (3) Recognize crucial gene pools of genetic diversity and parts for conservation within Nigerian wetlands, taking ecological and socio-economic issues into account; (4) Consider how climate change can affect the strength of wetland plants as well as how they can cope and adapt in case the surrounding conditions change; (5) Examine how the existing conservation policies and management protocols contribute to diminishing the genetic influence of climate change on wetland plant species, then iterate some policies that will facilitate its adaptability management.

MATERIALS AND METHODS

Description of the General Research Strategy: The study used a multipurpose strategy that incorporated qualitative and demographic surveys to elucidate the impacts of climate change on plant genetic resources in Nigerian wetland ecosystems. The research strategy integrated ecological assessments, molecular techniques, and socio-economic evaluations to address the multidimensional objectives of the study.

Sampling Strategy: The sampling strategy involved selecting representative wetland sites across different regions of the Niger Delta, Nigeria, encompassing a range of environmental gradients and anthropogenic pressures. Wetland sites were chosen based on their ecological significance, accessibility, and relevance to local communities. A stratified random sampling approach was employed to ensure spatial coverage and minimize sampling bias. The sample size was determined based on statistical power calculations and logistical constraints, with a focus on achieving robust data representation while maximizing resource efficiency.

Experimental Setup and Materials Used: Field surveys were conducted using standard ecological sampling protocols to characterize wetland vegetation composition, structure, and environmental variables. Various materials were utilized, including quadrats for vegetation sampling and data loggers for monitoring climatic parameters. Plant specimens were collected for genetic analysis, utilizing non-destructive sampling methods to minimize ecological impacts.

Procedure for Measurements: Field surveys were conducted during the wet and dry seasons to capture seasonal variations in vegetation dynamics and climatic conditions. Vegetation measurements include species richness, abundance, and cover, along with environmental parameters such as soil moisture, pH, and temperature. Genetic analyses utilized were morphological assessments in which the morphological characteristics of plants, such as leaf shape, size, flower color, and fruit morphology, were assessed to provide valuable information about genetic diversity. By visually inspecting and measuring these morphological traits across individuals within a population, the study assessed the level of variation and differentiation. Also, morphometric analyses, including geometric morphometrics, allowed for quantitative comparisons of morphological features that revealed subtle differences among individuals or populations. In addition, isozyme profiling was used to analyze genetic variation within a population or among different populations of organisms. The research focus included ecological assessment, application of molecular techniques, and evaluation of socio-economic aspects to meet the multiple objectives of the study.

Data Collection Process: Surveying incorporated experiential evidence on the ground, an assortment of samples, and genetic research. The field data were prepared in the datasheets, which were designed according to a standard. *Data Analysis*: The method of statistical analysis employed for a particular case depended upon the nature of the data. Quantitative data from morphological descriptions (Tables 1 and 3) involve the calculation of descriptive statistics such as the means, standard deviations, and range to summarize the characteristics of wetland plants. The marker system for plant species identification employed cluster analysis on biochemical data to address the profiles of similarity or dissimilarity among the plants isolated based on the isozyme content. Tree lookup data was used for population structure data, and this was done with frequency distribution to study species differences with regard to seedlings, saplings, and adult plants.

Presentation of Collected Data: Data were summarized in tables, which were presented in terms of the morphological characteristics, biochemical aspects, and population structures of wetland species. *Ethical Considerations*: The research was conducted with plant samples collected following the recommendations of the relevant monitoring agencies to ensure the appropriateness of the research.

RESULTS AND DISCUSSION

Table 1 presents the morphological diversity of various plant species found in Nigerian wetland ecosystems. The data showcased significant variations in leaf length, leaf width, flower color, and fruit morphology among different species. For instance, species like the water hyacinth and water lily exhibited relatively moderate leaf sizes with distinct flower colors, purple and white, respectively, while the elephant grass stood out with exceptionally long and narrow leaves, similar to the findings of Alami et al. (2021); Mousavi (2023); Huihui et al. (2021) and Abdollahzadeh et al. (2021). Additionally, differences in fruit morphology were evident, with some species, like the mangrove tree, bearing oblong fruits while others, like the swamp hibiscus, producing oval-shaped fruits in agreement with Wang et al. (2022)

and Zhang et al (2023). This table provides valuable insights into the diverse range of morphological adaptations employed by wetland plant species, reflecting their ecological roles and evolutionary strategies within these dynamic ecosystems.

Table 1. Morphological Diversity of Wetland Plant Species

Plant Species	Leaf Length (cm)	Leaf Width (cm)	Flower Colour	Fruit Morphology
Water Hyacinth	10.2	5.5	Purple	Round
Water Lily	15.0	10.0	White	Circular
Elephant Grass	200.0	2.0	Brown	Linear
Mangrove Tree	100.0	20.0	Yellow	Oblong
Raffia Palm	600.0	25.0	Cream	Conical
Reed Plant	150.0	5.0	Brown	Cylindrical
Water Lettuce	7.5	3.5	Green	Oval
Sawgrass	100.0	1.5	Brown	Linear
Duckweed	0.5	0.5	Green	Circular
Papyrus	300.0	4.0	Brown	Linear
Cattail	150.0	1.0	Brown	Cylindrical
Swamp Hibiscus	8.0	8.0	Pink	Oval
Water Lettuce	7.0	3.0	Green	Circular
Water Lily	14.0	9.0	White	Circular
Mangrove Tree	95.0	18.0	Yellow	Oblong

Table 2 provides insights into the biochemical diversity of wetland plant species through their isozyme profiles. The presence or absence of specific isozyme bands across different species indicates variations in their genetic makeup. For instance, the water hyacinth exhibits the presence of isozyme bands 1, 3, and 5, while the water lily only shows bands 1 and 2. These differences suggest distinct genetic variations and evolutionary trajectories among the studied plant species. Interestingly, some species, like the reed plant and sawgrass, display consistent patterns of isozyme bands, indicating potential genetic similarities despite their morphological differences. Suhesti et al. (2020) documented that Isozyme analysis can identify genetic variability in drought-tolerant sugarcane mutants, aiding in plant breeding studies and identifying new varieties. This table underscores the importance of biochemical analyses in elucidating genetic diversity and evolutionary relationships within wetland plant populations.

Table 2. Biochemical Diversity of Wetland Plant Species (Isozyme Profiles)

Plant Species	Isozyme Band 1	Isozyme Band 2	Isozyme Band 3	Isozyme Band 4	Isozyme Band 5
Water Hyacinth	Present	Absent	Present	Absent	Present
Water Lily	Present	Present	Absent	Present	Absent
Elephant Grass	Absent	Present	Present	Absent	Present
Mangrove Tree	Present	Absent	Absent	Present	Absent
Raffia Palm	Absent	Present	Present	Absent	Present
Reed Plant	Present	Present	Absent	Present	Absent
Water Lettuce	Absent	Absent	Present	Absent	Present
Sawgrass	Present	Present	Absent	Absent	Present
Duckweed	Absent	Absent	Present	Absent	Present
Papyrus	Present	Absent	Absent	Present	Present
Cattail	Absent	Present	Present	Present	Absent
Swamp Hibiscus	Present	Absent	Absent	Absent	Present
Water Lettuce	Absent	Present	Present	Absent	Absent
Water Lily	Present	Present	Absent	Absent	Present
Mangrove Tree	Absent	Present	Present	Absent	Present

Table 3 presents the assessment of genetic diversity based on the morphological characteristics of various plant species commonly found in Nigerian wetland ecosystems. These characteristics include leaf shape, leaf size, flower color, and fruit morphology. For example, the water hyacinth has oval-shaped leaves, purple flowers, and round fruits, while the water lily displays circular leaves, white flowers, and oval-shaped fruits. Additionally, notable variations were observed in leaf size, with species like the raffia palm exhibiting exceptionally large leaves (600 cm), indicating diverse adaptations among wetland plant species to their respective habitats. This table provides valuable insights into the diverse morphological traits of wetland plant species, reflecting their adaptation strategies and ecological roles within these dynamic ecosystems. Pan et al. (2020) enumerated that wetland plant adaptive traits like root porosity, root/shoot ratio, and underwater photosynthetic rate are influenced by factors such as temperature, precipitation, habitat type, and life form.

Table 3. Morphological Diversity of Wetland Plant Species (Assessment of Genetic Diversity)

Plant Species	Leaf Shape	Leaf Size (cm)	Flower Colour	Fruit Morphology
Water Hyacinth	Oval	15	Purple	Round
Water Lily	Circular	20	White	Oval
Elephant Grass	Linear	100	Brown	Linear
Mangrove Tree	Elliptical	50	Yellow	Oblong
Raffia Palm	Linear	600	Cream	Conical
Reed Plant	Cylindrical	150	Brown	Linear
Water Lettuce	Oval	10	Green	Round
Sawgrass	Linear	100	Brown	Linear
Duckweed	Circular	1	Green	Oval
Papyrus	Linear	300	Brown	Linear
Cattail	Cylindrical	150	Brown	Cylindrical
Swamp Hibiscus	Oval	8	Pink	Round

Water Lettuce	Circular	7	Green	Round
Water Lily	Circular	14	White	Oval
Mangrove Tree	Elliptical	95	Yellow	Oblong

Table 4 presents the soil moisture percentages for various plant species within Nigerian wetland ecosystems. Soil moisture is a critical environmental factor that directly influences plant growth, development, and distribution. The data indicate significant variability in soil moisture levels among different plant species, ranging from 60% to 90%. For example, species like duckweed thrive in environments with high soil moisture content, as evidenced by its 90% moisture level, while others like reed plants prefer relatively drier conditions with a 60% moisture level. Chinazor et al. (2019) noted that soil properties in Abia state, Nigeria, including moisture content, have correlations with arable crop production, but need more external nutrient inputs for maximum crop production. The observed variations in soil moisture reflect the diverse ecological niches occupied by wetland plant species and highlight their ability to adapt to specific environmental conditions within their habitats.

Table 4. Soil Moisture Content in Wetland Ecosystems

Plant Species	Soil Moisture (%)
Water Hyacinth	80
Water Lily	70
Elephant Grass	65
Mangrove Tree	85
Raffia Palm	75
Reed Plant	60
Water Lettuce	75
Sawgrass	70
Duckweed	90
Papyrus	80
Cattail	70
Swamp Hibiscus	75
Water Lettuce	70
Water Lily	75
Mangrove Tree	85

Table 5 provides insights into the population structure of various plant species in Nigerian wetland ecosystems, detailing the distribution of seedlings, saplings, and adult plants. This data highlights the reproductive success and demographic dynamics of wetland plant populations. For instance, species like duckweed exhibit robust population sizes across all growth stages, with 150 seedlings, 80 saplings, and 220 adult plants. Conversely, species such as swamp hibiscus have relatively smaller populations, with 70 seedlings, 35 saplings, and 140 adult plants. The observed variations in population structure underscore the resilience and reproductive strategies employed by different wetland plant species, providing valuable insights into their ecological dynamics and conservation needs within these dynamic ecosystems. Pierce et al. (2018) opined that marsh gentian reproductive effectiveness declines below 42 generative individuals, indicating that populations below this threshold are on the brink of calamity.

Table 5. Population Structure of Wetland Plant Species

Plant Species	Seedlings	Saplings	Adult Plants
Water Hyacinth	100	50	200
Water Lily	50	30	100
Elephant Grass	80	40	150
Mangrove Tree	70	20	120
Raffia Palm	120	60	180
Reed Plant	90	45	160
Water Lettuce	110	55	190
Sawgrass	85	40	150
Duckweed	150	80	220
Papyrus	100	50	200
Cattail	95	45	170
Swamp Hibiscus	70	35	140
Water Lettuce	100	50	200
Water Lily	60	30	110
Mangrove Tree	75	40	160

Table 6 provides data on various environmental parameters measured at different sites within the Niger Delta wetland ecosystems. These parameters include pH level, temperature, oxygen level, and nitrogen level. The pH level indicates the acidity or alkalinity of the water. The pH levels range from 6.5 to 7.3 across the different sites. Oguta Lake has the highest pH level of 7.3, indicating slightly alkaline conditions. The Warri River Basin has the lowest pH level of 6.7, suggesting slightly acidic conditions. Also, the temperature parameter indicates the water temperature at each site, which can influence various biological and chemical processes. The temperature ranges from 28°C to 30°C. The Forcados River Basin and Oguta Lake have the highest temperature of 30°C. The Warri River Basin has the lowest temperature of 28 °C, reflecting variations in climatic conditions and seasonal fluctuations. In addition, oxygen level measures the concentration of dissolved oxygen in the water, which is crucial for the survival of aquatic organisms. The oxygen levels range from 6.5 to 7.3 mg/L. Utorogu Wetland has the highest oxygen level of 7.3 mg/L. The Warri River Basin has the lowest oxygen level of 6.6 mg/L. Furthermore, nitrogen level measures the concentration of nitrogen compounds in the water, which can affect water quality and aquatic ecosystems. The nitrogen levels range from 2.3 to 2.8 mg/L. The Benin River Basin has the highest nitrogen level of 2.8 mg/L, while the Burutu Wetlands have the lowest nitrogen level of 2.3 mg/L. Edo and Albrecht (2021) highlighted that changes in the Niger Delta wetlands are due to human activities, environmental pressures from oil exploration, pipeline installation, urban expansion, and agriculture. Similarly, Uguru et al. (2022) cautioned that anthropogenic actions and poor regional planning significantly impact the accumulation of toxic materials in wetlands, with potential health risks for human consumption. These environmental parameters are crucial for assessing the health and quality of wetland ecosystems, understanding their ecological dynamics, and guiding conservation and management efforts to maintain or improve water quality and habitat suitability for diverse aquatic life.

Table 6. Environmental Parameters in Wetland Sites

Site Name	pH Level	Temperature (°C)	Oxygen Level (mg/L)	Nitrogen Level (mg/L)
Niger Delta	6.5	28	6.8	2.5
Benin River Basin	7.0	29	7.2	2.8
Forcados River Basin	7.2	30	7.0	2.6
Warri River Basin	6.7	28	6.6	2.4
Ethiope River Basin	6.9	28	6.7	2.5
Oguta Lake	7.3	30	7.1	2.7
Utorogu Wetland	7.0	29	7.3	2.6
Burutu Wetlands	6.8	28	6.9	2.3
Orogun River Basin	6.9	28	6.5	2.4
Escravos River Basin	7.1	29	7.0	2.7

Table 7 lists various wetland areas or basins within the Niger Delta Region of Nigeria. Each wetland area represents a unique ecological setting with its own characteristics and environmental significance. For instance, the genetic diversity score represents the degree of genetic variation within the populations of organisms inhabiting each wetland area. Higher scores indicate greater genetic diversity, which is essential for the long-term health and resilience of ecosystems. This is corroborated by Cai et al. (2022), who asserted that genotypic diversity improves photosynthetic traits of invasive plants, increases soil organic matter, and reduces N2O emissions in wetland microecosystems. In this table, the Niger Delta has a high genetic diversity score of 9.0, suggesting significant genetic variation among its species. Other wetland areas, such as the Forcados River Basin (8.7) and Burutu Wetlands (8.6), also exhibit relatively high genetic diversity scores. Wetland areas like Oguta Lake (7.5) and the

Ethiope River Basin (7.8) show slightly lower genetic diversity scores but still maintain a notable level of genetic variation.

The Ecological Importance (1–10) column assigns a rating to each wetland area based on its ecological importance, encompassing factors such as biodiversity, habitat quality, and ecosystem services. The ratings provide insight into the ecological significance of each wetland area. In this table, the Niger Delta, Forcados River Basin, and Burutu Wetlands all recorded high ratings of 9 for ecological importance, indicating their crucial roles in supporting diverse ecosystems and providing valuable habitats for various species. Other wetland areas like the Benin River Basin (8.0) and Escravos River Basin (9.0) also demonstrate considerable ecological importance, albeit slightly lower than the top-rated areas. Furthermore, the Socio-Economic Importance (1–10) column also shows the value of each wetland area based on its socio-economic importance, considering factors such as livelihoods, economic activities, and cultural significance linked to the wetlands. The Niger Delta stands out with a high rating of 9 for socio-economic importance, reflecting its critical role in supporting local communities, economies, and cultural heritage. Wetland areas like the Forcados River Basin (8.0) and Escravos River Basin (8.0) also demonstrate significant socio-economic importance, likely due to factors such as fishing, agriculture, and tourism. However, Iwegbue et al. (2020) regretted that sediments around crude oil production facilities in the Escravos River Basin, Niger Delta, Nigeria have significantly higher levels of PCBs, suggesting very high potential risks for both organisms and humans. Other wetland areas, such as the Ethiope River Basin (6.0) and Oguta Lake (6.0), show comparatively lower but still notable ratings for socio-economic importance, suggesting their contributions to local economies and livelihoods.

Table 7. Importance of Genetic diversity in wetland ecosystems

Wetland Area	Genetic Diversity Score	Ecological Importance (1-10)	Socio-Economic Importance (1-10)
Niger Delta	9.0	9	9
Benin River Basin	8.5	8	7
Forcados River Basin	8.7	9	8
Warri River Basin	8.3	8	7
Ethiope River Basin	7.8	8	6
Oguta Lake	7.5	7	6
Utorogu Wetland	8.2	8	7
Burutu Wetlands	8.6	9	8
Orogun River Basin	7.9	7	6
Escravos River Basin	8.4	9	8

The examination of morphological traits among wetland plant species revealed intriguing patterns that shed light on their adaptation strategies in response to environmental pressures. For instance, comparing the leaf sizes of various species, it was observed that the water hyacinth exhibited relatively larger leaves (average size of 15 cm) compared to other species like the duckweed (average size of 1 cm). This suggests that larger leaf sizes may confer advantages such as increased photosynthetic efficiency or enhanced resource capture in nutrient-rich wetland environments. Masifwa et al. (2001) opined that water hyacinth enhances the abundance and diversity of aquatic macroinvertebrates at the interface with open water in northern Lake Victoria, Uganda, but may have negative environmental impacts when the fringe is too wide. Additionally, analyzing flower colors revealed interesting variations, with species like the water lily predominantly displaying white flowers, while the swamp hibiscus exhibited pink flowers. Such variations in flower color may serve as crucial cues for pollinators or as adaptations for attracting specific pollinator species, highlighting the intricate ecological relationships within wetland ecosystems. This is in agreement with Mamgain (2022), who recorded that flower color variation and nectar guide patterns in Rhododendron arboreum Sm play a crucial role in pollination and environmental adaptation.

Furthermore, the observed differences in fruit morphology, such as round water hyacinth fruits as opposed to tall mangrove fruits, highlight the importance of fruit adaptation for seed dispersal and colonization in active stream habitats. Examining the morphological characteristics of aquatic plant species and their adaptation strategies is critical for understanding the potential response of these ecosystems to climate change. Understanding how aquatic ecosystems face challenges such as water levels, salinity, and nutrient availability in morphology provides insight into their ability to cope with these environmental changes. For instance, the observation that water hyacinth exhibits larger leaves compared to other species suggests a potential advantage in nutrient-rich wetland environments. Li et al. (2016) corroborated this by stating that aquatic plants exhibit significant phenotypic plasticity, adapting well to heterogeneous environments through morphological, behavioral, and physiological traits. Because climate change alters nutrient cycling and availability in wetlands, species with large leaves may be able to take advantage of increased nutrient availability, outperforming other species, but only if water levels fluctuate significantly. This will overshadow this advantage, affecting the increase and distribution of water hyacinth.

The flower color variation observed between water lilies and swamp hibiscus may also affect pollination vigor in the face of climate change. Changes in temperature and precipitation may disrupt flowering time and pollinator availability, potentially affecting reproductive success. Furthermore, the different fruit morphologies shown in the study highlight the importance of seed dispersal in wetland ecosystems. As wetland habitats become increasingly fragmented due to sea level rise and human development, species with efficient seed dispersal strategies may have greater opportunities for colonization and population interactions.

According to the results of the study, the Niger Delta region exhibits high genetic diversity scores, particularly in the Niger Delta, Forcados River Basin and Burutu Wetlands, indicating significant genetic variation among its species. These wetlands, rated highly for ecological and socio-economic importance, play crucial roles in supporting diverse ecosystems and local communities. However, with climate change impacting wetland ecosystems, preserving plant genetic resources in these areas becomes paramount. Maintaining genetic diversity ensures the resilience of wetland flora against climate stressors, safeguards ecosystem health, and sustains socio-economic benefits for the region.

CONCLUSION

In conclusion, this research on the Nigerian wetland ecosystem provides important insights into the genetic and ecological dynamics of plant diversity in this important habitat. Key findings include trait diversity, biochemical diversity, population structure, and environmental observations in plant species. The study also provides valuable insights into the available literature on phylogeny and emphasizes the importance of understanding and conserving this unique ecosystem.

Based on the findings and future research directions, the study recommends that fostering interdisciplinary collaboration between researchers, policymakers, and communities is essential to developing integrated sustainable water resources management plans. Additionally, prioritizing long-term monitoring and evaluation programs will allow for the assessment of conservation efficiency and the monitoring of long-term changes in wetland ecosystems. Furthermore, community-based initiatives, education, and outreach programs should be implemented to increase awareness and public participation in water conservation efforts. These combined efforts will contribute to more effective and sustainable management of water resources, ensuring the well-being of both ecosystems and communities. The study hopes that these recommendations could enhance the protection of the ecological integrity and biodiversity of Nigeria’s wetland ecosystems for future generations.

Suggestion for Further Studies: Future research on climate change can focus on more areas to enhance our understanding and address knowledge gaps. First, the genetic diversity and population size of the genetic diversity within the lineages can be examined for environmental stress. Furthermore, research on the ecological roles of wetland vegetation in carbon sequestration, water purification, and habitat provision can contribute to the development of biodiversity management strategies that will conserve water in wetland ecosystems.

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