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ROLE OF NATIVE PLANT SPECIES IN URBAN ECOLOGICAL RESTORATION IN KERALA

Akshaya.P.I, Research Scholar, Department of Botany, Dr. APJ Abdul Kalam University, Indore.
Guide Name: **Dr. Swati Yadav**, Associate Professor, Dr. APJ Abdul Kalam University, Indore.

ABSTRACT

The paper proposes that urbanisation remains a major threat to biodiversity specifically in regions that are experiencing rapid expansion such as Kerala in India. This research aims to determine effectiveness of employing native plant species in ecological urban environment specifically on the aspect of species richness and composition, soil characteristics and carbon accumulation. Cross-sectional assessments on a total of 12 restoration sites in Kochi, Thiruvananthapuram and Kozhikode were done before and after the planting of native species using structured methods including assessment of species richness, soil structure and carbon sequestration . The outcomes suggested a significant increase in species richness that the averaged rising of 130% between all the sites, providing evidence for the benefits of planting natives in improving the site conditions for native fauna. In addition, there appeared more favourable changes in soil quality, on average, increasing the organic matter by 130%, and decreasing the pH level, making the soils more alkaline and suitable for plant growth.

Further, sequestration escalation also rose to a remarkable 220% thus pointing to the capability of native trees to combat climate change through carbon sequestration. The understanding drawn from this study is the significance of native plant species in such ecosystem regeneration processes and the premise that supports their use in future urban design and ecology enhancement. Nevertheless, threats like the native or non-indigenous species and anthropogenic disturbances need to be controlled to have efficient restoration programs in the future. Knowledge of the successes of prior projects, more citizen involvement in the restoration work and greater public awareness of the issues will help to create sustainable and resilient cities.

Keywords:Urbanisation, Native Plant Species, Ecological Restoration, Biodiversity, Soil Quality, Carbon Sequestration, Kerala, Urban Ecosystems.

1. Introduction

Urbanization is one of the most fundamental biophysical processes that have occurred around the world and has had a profound impact on the geography of ecosystems. During the past century, cities have physically spread out as a result of growth in population, industrialization, and economic growth. This rapid urban expansion has caused considerable deterioration of habitats, decline in species' populations, environmental contamination and the isolation of ecosystems. Large populations live in urban areas which have become home to more than fifty percent of the world'spopulation today and a lot of men and women activities are performed within these regions with little or no regard to the consequences they have on the environment. A larger number people living in a specific area of land increases pressure on the natural resources, and brings out the environmental problems of urban nature such as air and water pollution, heat island effect and biogeographical depletion. As a result, concepts relating to cities as agents of change in environment and, at the same time, centers for restoration of the natural environment have drawn the interest of researchers, policy makers and urban planners.

Redemption of such ecosystem services has therefore come out as one of the critical approaches to managing such problems in urban settings. Restoration ecology is a scientific field that addresses the management of ecosystems that have been : degrading, damaged or disturbed in an effort to restore these ecosystems to a state of functionality that will support species and bring forth ecosystem services. Ecological restoration within an urban framework is the salving of parks, shoreline, green belts and other dismembered or spoiled natural habitats within cities. Urban ecological restoration adds value to mitigation of adverse impacts of urban development mainly on the natural environment while at the same time offering benefits to the citizens of the urban centre in the form of improved air and water quality, cooler temperatures, recreational areas, and closer appeal to nature.

Paying attention to ecosystem services has also contributed to the global process of urban ecological restoration. Ecosystem services are the benefits that people obtain from ecosystems, this can may include purification of water, air, flood management, climatic regulation, and production of food, medicine etc. This point comes out very well when considering the performance of these urban ecosystems as we see cities expanding continually in the future; their offer of these services is important in sustaining the health of the urban citizens. Studies have established that features of urban green elements like parks and urban forests can considerably improve on temperature control, stormwater control, and air quality management. Nonetheless, availability of such services depends on the native species and the general diversity of species in such ecosystems. This has helped in there being appreciation of native species used in the restoration of urban environments, these are well adapted to the environment as compared to the non-native species; they also sustain higher numbers of bio-diversity.

Subsequently, native species have an important function in defining the ecological role and promoting the biotic components in urban ecosystems. While native species are defined as non-indigenous or invasive species, native plants, and animals can participate in the ecosystems and climate of the locality in which they have evolved. Climatic conditions like heat, pollution, and soil disturbances are frequent in the urban environment, and planting native species may be more hard-wearing and little demand high-energy and time-consuming compared to non-native species. Further, native plants are crucial for maintenance of ecosystem and pollinators, birds and small mammals that feed on these plants. Restoration works that seek to reinstate native species can thus become highly effective in improving the quality of urban biodiversity, stabilizing ecosystems in degraded urban habitats and general rehabilitation of urban ecosystems.

City ecological restoration has emerged as an international phenomenon in the last few decades as many cities across the world started coming up with big restoration projects to counter the effects of sprl owned urbanization. From the High Line park in New York City to rewilding projects in London to replanting native species on Sydney coastline, restoration ecology is now visualized into the planning and designing of cities across the world. They are intended to act as measures that would not only reduce effects of the growth of urban centers but also provide the conditions under which man and nature can harmoniously live. Ecological restoration of our urban environments is viewed as a method of developing climate resilience and general wellbeing, and in addition beautification and recreation improvements that will make our urban centers greater places to live in the long run.

But urban ecological restoration still constitutes a problem. There are multiple challenges that contribute to effective restoration in urban environment such as separate connected lands cape mosaics, high pollution rates, and the existence of invasive species. As well, reference ecosystems in urban areas are often non-existent or not suitable to be used in defining restoration goals. There are then other factors which seem to influence the success of urban restoration projects such as public participation, interprofessional cooperation and the creation of new principles of restoration that reflect the specific circumstances of urbanized landscapes.

Moreover, the management of urban ecology restoration is another consideration which needs collective efforts of the local authorities, environmental agency, scholars and the society. Urban restoration can be confusing deal with competing land, it can try to fit growth with preservation and it can be dealing with socio-political realities of the city. This means that sound urban restoration policies must consider the demands of various stakholders, including residents of the urban setting, commercial undertakings, and related local governments even as environmental goals are set and implemented.

In summary, urban ecological restoration is a critical response to the environmental challenges posed by urbanization. It represents a multifaceted approach that seeks to restore degraded ecosystems, enhance biodiversity, and provide essential ecosystem services in cities. As cities continue to grow and the impacts of climate change become more pronounced, urban ecological restoration will play an increasingly important role in creating sustainable and resilient urban environments. Through the integration of native species, innovative restoration strategies, and collaborative governance, urban ecological restoration offers a path forward for cities to reconcile development with ecological integrity, ultimately contributing to the well-being of both people and nature.

1.1.Objectives of the Study

This study aims to explore the role of native plant species in urban ecological restoration projects in Kerala. The objectives are:

- To quantitatively evaluate the impact of native plant species on biodiversity, soil quality, and carbon sequestration in urban areas.
- To identify successful case studies of urban restoration projects in Kerala that utilised native plant species.
- To discuss the challenges and opportunities for promoting native plant species in future urban ecological restoration efforts.

2. Literature Review

Urban ecological restoration has been identified as one of the strategic methods of managing adverse environmental effects of urbanization. The baseline study indicates that as city size increases, the requirements of ecosystem services and the protection of biological diversity are more urgent in large cities with a high population density. This paper reviews the global trends, issues, approaches, and impacts of urban ecological restoration based on diverse international literature and varied restoration methods.

Urban ecological restoration has recently become popular as a way of addressing the issue of redesigning cities to support diverse species. In another global assessment of the effects of urbanization on plant and bird richness and composition, Aronson et al. (2014) showed that cities continue to support a significant portion of native species. According to the study that looked at 110 cities across the world, although urbanization has contributed to the reduction of species densities most cities still have native species population that are important in the conservation of the region’s bio diversity. The research also finds that the native species were more abundant where there was more existing vegetation – a finding that is useful for urban planning. Here, this research has pointed out a clear hope for future urban restoration to try to add value to native species in programs of complete diversity renewal as well.

Ecological steps have been taken in many cities because urbanization has devastating impacts on ecological systems. Handel et al. (2013) pointed out that the number of urban sites that could be restored is limited by their size, isolation and protracted encroachment by manmade infrastructures. These constraint factors relate to the quality of natural communities that can be restored. Furthermore, novel abiotic stressors in urban ecosystems, including heat island effect, altered water regime, and soil disturbance provide extra complexity to native species restoration. Nevertheless, despite these challenges in a variety of different cities, urban restoration projects have honors, and established the specific protocols for the ecological restoration, which proves that such approaches can enhance the quality of community’s living not only in terms of the healthy improvement of the biodiversity but also in terms of health care. The works of Handel call for integration of interdisciplinary approaches by the planners, engineers and ecologist in order to get positive restoration results.

As this paper has sought to explicate, there are some inherent difficulties and contentiousness inherent in urban ecological restoration and Nephas' arguments that acknowledge the possibility of improving urban biodiversity supplies and ecosystem services. Using a statistical approach, Bullock et al. (2011) investigated the interactive effects of ecosystems services and diversity restoration projects. They found out that even as the restoration increases both, problems of conflict tend to manifest where specific ecosystem services are being targeted in a specific project. For example, stormwater management or air quality enhancement can be achieved at the expense of large scale habitat conservation. Similarly, many ecosystems and the associated biota continue to develop slowly or remain impaired where urban development is extremely intense. The authors recommended the use of PES schemes for addressing the problem and noted, however, that such programs must be properly structured with a view to improving the quality of ecosystem services, particularly biodiversity.

Besides, there is another considerable problem of the urban restoration connected with a search of the suitable reference ecosystem for usage in studying the structure and functioning of peculiar ecosystems-service constellations in urban sociogenesis. According to Klaus and Kiehl (2021), the numerous urban ecosystems have assumed new or combined features because of increasing human impact; thus, they have suggested a conceptual framework that may be useful in understanding these ecosystems' complexity. They recommend the use of current, well-functioning metropolitan environments as templates since many of the ecosystems of North America currently are greatly altered from their original states. Based on this approach, urban regions are considered novel ecosystems as well as supports restoration endeavours that focus on ecosystem services and biodiversity that are notable in the area.

The second concern of urban ecological restoration is governance and policy issues. Wilkinson et al. (2013) highlighted a big research agenda for international initiatives and local governments: to advance the ways in which city governments can effectively govern demand for, and supply of, ecosystem services. However, they also pointed to innovative governance solutions in various cities, emphasizing the need for more inclusive, interdisciplinary approaches that incorporate local knowledge and scientific expertise. Their research highlighted that while many cities face similar governance challenges, solutions must be tailored to local contexts to be effective.

Restoration projects that prioritize native species have shown promising results in urban settings. Native species not only support local biodiversity but also contribute to essential ecosystem services, such as air purification, water filtration, and the reduction of urban heat islands. Ziter (2016) conducted a quantitative review of urban ecosystem services (ES), finding that most studies on urban ES focus on weather and climate-related regulating services, with little attention paid to the cultural or supporting services that native biodiversity can offer. Ziter's work suggests that future studies should expand to consider a wider range of ES and place greater emphasis on the role of native species in providing these services.

Johnson and Handel (2016) examined long-term post-restoration tree planting dynamics in New York City's urban forests. In Evaluations after 15–20 years, all the restored forests were found to have reduced abundance of invasive species, a higher structural heterogeneity and enhanced native tree recruitment compared to that of the non-restored areas. The research shows that there is tangible long-term benefit to urban renewal should native species be the focus of the project, this can be easily inferred by other cities grappling with issues to do with invasive species.

It is possible to reach higher levels of native plant establishment in vacant urban land with a less intense level of restoration. Anderson and Minor (2020) established four approaches for enhancing plant richness from professional gardening to low-input broadcasting sowing. For instance, broadcast seeding, which is inexpensive, was usually as effective or more so than other higher impact strategies according to their study. Based on this research, they recommend that ULBIN can use broadcast seeding to restore the diversity of natives in urban areas especially vacant lands cheaply and at scale.

Biodiversity conservation is gradually moving to the core of ecological restoration as a fundamental factor in ecosystem functioning. Montoya et al. (2012) bolstered the importance of returning the lost ways of the ecosystem to ensure that it produce services for example pollination, suppression of pests and seed dispersive. Yet, as was noted, contemporary approaches to restoration fail to recognize the multiple biotic interactions that support these services. Another important area Montoya et al pointed out that researchers should focus on a more synthesising view of restoration that incorporates both the BEF and food-web and metacommunity theories. It is important to underline that interdisciplinary character of the works is necessary for enhancement of the stability and sustainability of restored ecosystems in context of urban ecosystems.

Aerts and Honnay (2011) extended this perspective to forest ecosystems, arguing that restoring biodiversity is essential for maintaining ecosystem functioning, particularly in the face of climate change and other global stressors. Their research suggests that species-poor plantations may be optimal for biomass production but fail to support the broader range of ecosystem services needed for long-term ecosystem stability. Aerts and Honnay emphasized the importance of functional diversity, which is more critical than taxonomic diversity for ensuring the resilience of restored ecosystems.

Hall et al. (2020) highlighted the importance of incorporating Indigenous knowledge into urban ecological restoration projects. Their research in Aotearoa New Zealand showcased two successful case studies where Indigenous communities were involved from the project's inception, leading to restoration outcomes that were both ecologically and culturally significant. The authors argued that recognizing power inequalities and historical injustices is essential for fostering partnerships between Indigenous communities and restoration practitioners. Incorporating Indigenous perspectives can lead to more inclusive, culturally relevant, and sustainable restoration outcomes.

Urban ecological restoration plays a vital role in mitigating the environmental impacts of urbanization by enhancing biodiversity and ecosystem services. While global trends demonstrate the potential for successful restoration, numerous challenges must be addressed, including trade-offs between ecosystem services, governance issues, and the lack of suitable reference ecosystems. The prioritization of native species has proven to be an effective strategy for long-term restoration success, as demonstrated in multiple case studies. Emerging perspectives emphasize the need for interdisciplinary approaches that incorporate biodiversity-ecosystem functioning theories and Indigenous knowledge. By addressing these challenges and integrating diverse perspectives, urban ecological restoration can contribute significantly to creating more resilient, biodiverse, and sustainable cities.

3. Methodology

This study aimed to quantitatively assess the role of native plant species in urban ecological restoration in Kerala. The methodology was designed to evaluate key ecological parameters, including species diversity, soil quality, and carbon sequestration, before and after the reintroduction of native plants. Data was collected through field surveys, laboratory analysis, and statistical evaluation.

3.1 Study Area

The study was conducted across three major urban centres in Kerala: Kochi, Thiruvananthapuram, and Kozhikode. These cities were selected because they represent some of Kerala's most urbanised areas, each experiencing significant ecological degradation due to rapid urban expansion. The research focused on 12 urban restoration sites within these cities, covering a range of green spaces such as public parks, riverbanks, and community gardens. These sites were undergoing active restoration efforts, including the planting of native species aimed at improving ecosystem resilience and biodiversity.

The diversity in geographic conditions of these cities—coastal regions, riverbanks, and inland urban areas—provided a comprehensive understanding of how native plant species adapt to different urban ecological challenges in Kerala.

3.2 Sample Size

The sample size for the study was 12 restoration sites, distributed as follows:

- **Kochi**: 3 sites
- **Thiruvananthapuram**: 3 sites
- **Kozhikode**: 3 sites

At each site, data collection was conducted across multiple quadrats (1 m² sampling units), with 10 quadrats per site, yielding a total of 150 quadrats for analysis. The quadrats were randomly placed at each site to ensure a representative sampling of plant species diversity, soil conditions, and other ecological parameters. Data was collected at two time points: before the introduction of native plant species (pre-restoration) and one year after the restoration efforts began (post-restoration).

3.3 Selection of Native Plant Species

The selection of native plant species for this study was based on consultations with botanists, ecologists, and urban planners. The criteria for selecting native species included:

- **Ecological Function**: Plants that contribute to habitat creation, soil stabilisation, and water retention.
- **Adaptation to Local Conditions**: Species well-suited to Kerala's tropical climate and heavy monsoon seasons.
- **Biodiversity Support**: Plants that provide resources such as nectar, seeds, or shelter for local wildlife, including pollinators and small mammals.

Species such as *Syzygiumcumini* (Jamun), *Cassia fistula* (Golden Shower Tree), *Pongamiapinnata* (Indian Beech), and *Tectonagrandis* (Teak) were widely used across the restoration sites. These species were chosen for their known benefits to the local ecosystem and their ability to support urban biodiversity.

3.4 Data Collection Process

Data collection was conducted through extensive field surveys and laboratory analysis to assess the ecological parameters related to biodiversity, soil quality, and carbon sequestration. The data collection took place over a period of 12 months, capturing both pre- and post-restoration conditions.

3.4.1 Biodiversity Assessment

To assess biodiversity, the number of plant, bird, and insect species present in each quadrat was recorded. The quadrat method involved laying down 1 m² plots at each site and cataloguing all species within the plot. The species were identified with the help of field guides and expert consultations. This allowed the researchers to calculate species richness (the number of different species) and species evenness (the relative abundance of different species) before and after the introduction of native species.

- **Pre-restoration Survey**: Conducted before native species were planted, providing a baseline measure of species diversity.
- **Post-restoration Survey**: Conducted 12 months after the restoration, allowing for a comparison of biodiversity levels before and after the intervention.

3.4.2 Soil Quality Analysis

Soil samples were collected from each quadrat at two depths: 0-15 cm and 15-30 cm. These samples were taken both pre- and post-restoration to assess changes in soil quality over time. Key soil parameters measured included:

- **Organic Matter Content**: Soil organic matter is a crucial indicator of soil fertility and health. Higher levels of organic matter suggest better nutrient availability for plants.
- **Soil pH**: Soil pH is a measure of acidity or alkalinity, which can affect plant growth. Optimal pH levels for most plants range from 6 to 7.

The soil samples were analysed in a laboratory using standard soil testing techniques. The increase in organic matter and pH changes were used as indicators of improved soil quality resulting from the restoration efforts.

3.4.3 Carbon Sequestration Measurement

Carbon sequestration potential was estimated by measuring the biomass of trees and shrubs in each quadrat. Carbon sequestration refers to the process by which trees absorb and store carbon dioxide from the atmosphere, helping mitigate climate change. Biomass measurements were taken by recording the diameter at breast height (DBH) of trees in each quadrat. Allometric equations, which relate tree size to biomass, were used to estimate the amount of carbon stored in each tree.

The difference in carbon sequestration before and after the restoration was calculated by comparing the biomass measurements taken at the beginning of the study and one year later. This allowed the researchers to quantify the increase in carbon storage associated with the growth of native species.

3.5 Statistical Analysis

The data collected from the field surveys and laboratory tests was analysed using statistical techniques to evaluate the impact of native plant species on urban ecosystems.

3.6 Limitations and Challenges

Kerala's tropical monsoon climate caused seasonal fluctuations in biodiversity and soil conditions, requiring extended data collection to capture changes. Invasive species, such as Lantana camara, continued to dominate, competing with native plants for resources. Additional measures were taken to control their spread in some sites. Human interference, such as littering, construction, and soil compaction, affected the growth of native plants in urban restoration sites. These factors were accounted for in the analysis.

4. Results and Discussion

The results of this study are based on the quantitative analysis of data collected from 12 urban restoration sites across Kochi, Thiruvananthapuram, and Kozhikode. The study aimed to evaluate the ecological impact of native plant species on species diversity, soil quality, and carbon sequestration. Data was collected before and after the introduction of native species, and the results were statistically analysed to assess the significance of the changes observed.

4.1 Impact on Biodiversity

Species Diversity (Pre- and Post-Restoration)

The biodiversity assessment involved measuring the number of plant, bird, and insect species within 150 quadrats (1 m² plots). The data revealed a significant increase in species diversity across all restoration sites after the reintroduction of native species.

City	Restoration Site	Species Diversity (Before)	Species Diversity (After)	% Increase
Kochi	Site 1	14	30	114%
	Site 2	12	28	133%
	Site 3	16	35	119%
Thiruvananthapuram	Site 4	17	38	123%
	Site 5	19	42	121%
	Site 6	13	31	138%
Kozhikode	Site 7	12	29	142%
	Site 8	15	34	127%
	Site 9	10	26	160%

Interpretation

The results indicate a marked increase in species diversity across all sites. The percentage increase in biodiversity ranged from 114% to 160%, with the most significant increase observed in Kozhikode’s Site 9, where species diversity grew by 160%. The reintroduction of native species created habitats that attracted a variety of fauna, including birds and pollinators, contributing to a richer ecosystem. The increase in plant species diversity also indicates that native plants successfully colonised the restored sites, providing the ecological functions needed to support local wildlife.

The paired t-test analysis comparing pre- and post-restoration biodiversity values showed that the differences were statistically significant ($p < 0.01$), confirming that the introduction of native species had a substantial positive impact on species diversity.

4.2 Soil Quality Improvement

Soil Organic Matter and pH (Pre- and Post-Restoration)

Soil samples were collected from each site before and after the introduction of native species. Two key indicators of soil health—organic matter content and soil pH—were measured. The results are summarised below:

City	Restoration Site	Organic Matter (Before, %)	Organic Matter (After, %)	% Increase	Soil pH (Before)	Soil pH (After)
Kochi	Site 1	1.2	2.6	117%	6.4	6.9
	Site 2	1.3	2.9	123%	6.2	6.7
	Site 3	1.0	2.5	150%	6.5	7.0
Thiruvananthapuram	Site 4	1.1	2.7	145%	6.3	6.8
	Site 5	0.9	2.2	144%	6.1	6.6
	Site 6	1.4	3.0	114%	6.0	6.7
Kozhikode	Site 7	1.1	2.4	118%	6.2	6.8
	Site 8	1.2	2.5	108%	6.3	6.9
	Site 9	0.8	2.0	150%	6.0	6.5

Interpretation

Soil quality improved significantly at all restoration sites, as indicated by the increase in organic matter content and the neutralisation of soil pH. Organic matter content rose by 108% to 150% across the sites, with Site 3 in Kochi and Site 9 in Kozhikode exhibiting the highest percentage increases (150%). The increase in organic matter can be attributed to the leaf litter, root biomass, and organic deposits from the native plant species.

Soil pH moved closer to neutral in all sites, with the post-restoration values ranging from 6.5 to 7.0, indicating a more balanced environment for plant growth. Soils that are too acidic or too alkaline can hinder plant nutrient uptake, so this neutralisation is an important sign of improved soil health.

The paired t-test results confirmed that the increase in organic matter and the shift in pH were statistically significant ($p < 0.05$). These improvements in soil health suggest that native plant species contribute positively to soil quality, thereby supporting the growth of other plant species and enhancing the overall ecosystem.

4.3 Carbon Sequestration Rates

Carbon Sequestration (Pre- and Post-Restoration)

Carbon sequestration rates were measured by estimating the biomass of native trees and shrubs in each quadrat, using allometric equations to convert tree size to carbon storage. The results are summarised in the table below:

City	Restoration Site	Carbon Sequestration Rate (Before, tonnes/ha/year)	Carbon Sequestration Rate (After, tonnes/ha/year)	% Increase
Kochi	Site 1	0.9	2.7	200%
	Site 2	0.8	2.5	213%
	Site 3	1.0	3.1	210%
Thiruvananthapuram	Site 4	0.7	2.4	243%
	Site 5	0.6	2.1	250%
	Site 6	0.9	2.9	222%
Kozhikode	Site 7	0.8	2.6	225%
	Site 8	0.9	2.7	200%
	Site 9	0.7	2.3	229%

Interpretation

The data indicates a dramatic increase in carbon sequestration rates across all restoration sites, with percentage increases ranging from 200% to 250%. The highest carbon sequestration rate was observed in Thiruvananthapuram’s Site 5, where carbon storage increased by 250% compared to pre-restoration levels. The native plant species introduced in the restoration efforts—many of which are trees—play a crucial role in absorbing carbon dioxide from the atmosphere, making them effective tools for climate change mitigation.

The increase in carbon sequestration is consistent with the growth of native trees, which have larger biomass and deeper root systems than many exotic species. As these native species mature, their capacity to sequester carbon will likely increase further.

A paired t-test confirmed that the changes in carbon sequestration rates were statistically significant ($p < 0.01$), highlighting the role of native plant species in enhancing the carbon storage capacity of urban ecosystems.

4.4 Summary of Results

The findings of this study indicate that the reintroduction of native plant species in urban restoration projects has significantly improved biodiversity, soil quality, and carbon sequestration in Kerala’s urban areas. The data supports the hypothesis that native species are more effective than exotic species in restoring ecological balance and enhancing ecosystem services. The quantitative results demonstrate the positive ecological impact of using native species in urban restoration and provide a strong case for their inclusion in future urban planning and environmental policy decisions.

- **Biodiversity**: Increased by an average of 130%, with significant improvements in plant, bird, and insect species diversity.
- **Soil Quality**: Organic matter content increased by an average of 130%, and soil pH levels moved closer to neutral, indicating healthier soils.
- **Carbon Sequestration**: Carbon storage increased by an average of 220%, demonstrating the critical role of native trees in mitigating climate change.

5. Discussion

The findings from this study offer valuable insights into the role of native plant species in urban ecological restoration, particularly in Kerala, where urbanization has posed significant challenges to biodiversity, soil health, and carbon storage. In this section, the results are discussed in the broader context of urban restoration, drawing on relevant literature to highlight the implications of these findings for future ecological planning.

5.1 Enhancing Urban Biodiversity through Native Species

Among the many discoveries made when conducting this research was that of the dramatic rise in species richness after the introduction of native plant species. Vegetation extent expanded by an average of 37 percent of the initial value at all the sites considered sites, though in some sites like the Kozhikode Site 9 it enhance by 160 percent. This dramatic increase in the evaluated biodiversity indicates that native species are rational in colonizing the environment that would support a diverse number of plants, birds, and insects.

Science has revealed that the native plants due to being native to the particular environment are better suited in supplying the demand requirements of leading the seed, nectar and habitation to the wildlife as compared to the exotic plants. According to Berthon et al. (2021) native plants are vital in sustaining native insects, which on their own sustain higher trophic levels such as birds and small mammals. This principle was evident in the restoration sites of Kerala, where the original species brought in due to restoration programme attracted pollinators and seed dispersers, supposedly achieving an equilibrium.

Moreover, mutualisms between plants and animals are a necessity for conservation of plant and animal species in urban habitats. For instance, while establishing green highways, ornamental planting like Cassia fistula (Golden Shower tree) and Pongamiapinnata (Indian Beech) are useful food plants for pollinators like bees and butterflies that are indispensably useful for many planted and natural vegetation species. These interactions are important for ecosystem processes, particularly in fragmented urban environments where habitats are often severally broken (George & Christopher, 2019).

5.2 Improvement in Soil Quality

Another consideration was that the study conducted also resulted to a significant increase in the level of soil health relative to the presence of organic matter as well as the pH values. The general content of organic matter per site enhanced by 130% additionally, the pH levels of the soils improved to slightly alkaline. This enhancement in the soil status is a crucial measure to show that restoration is on track inasmuch as soil health is key to sustainable and healthy ecosystem.

The raw data suggests that with increased organic matter could be explained by the accumulation of the leaf litter and root biomass from the native plants. Most of these are the native trees and shrubs that form stable soil structure mainly through the deep root associations and organic matter build up from the decomposition of the litter materials. /later on, it enhances the load bearing capacity of soil, water holding capacity and availability of nutrients in the soil which provides a better growth status to plants and microbial biomass (Pant & Pant, 2017).

Hence, these results corroborate with other studies like Harishma et al. (2020) that research stated that the native species in ecosystems of Kerala mangrove significantly improved the biochemical quality of the soil including organic content of the soil. This highlights a need to embrace native species in the improvement of soils, a challenge which is more complex given the fact that compacted and polluted soils are common in the urban areas.

5.3 Carbon Sequestration and Climate Change Mitigation

They also showed just how much A4FS restoration can boost the carbon stocks of native plant species, which was a staggering average of 220 percent across the restoration sites. Carbon storage is a fundamental ecosystem service in the context of climate change because it entails the uptake of carbon dioxide from the atmosphere and its incorporation into live and dead plant material and soil organic matter pool. The study also found that there were progressive improvements in the carbon accumulation potential of the urban green structures after introduction of native trees like Tectonagrandis (Teak) Mangiferaindica (Mango), etc.

This is in tandem with the studies by Cunningham et al. (2015) which show that native mixed-species plantings can store carbon effectively. In their case study in Australia they showed that projects for native reforestation store carbon at similar rates to natural forest, thus underlining the importance of native species for climate change. Likewise, Harishma et al. (2020) identified that the native mangrove varieties of Kerala were capable of sequestering a lagerment of carbon which emphasized the importance of native flora in carbon sequestration in the tropical ecosystems.

Especially when seen in the context of Kerala, where intense urbanization is causing a rise in degrees of carbon being released into the atmosphere, the abilities of native plants to solve climate change are invaluable. Some of the detrimental effects of urban development can be mitigated through improving the amount of carbon which native species are capable of retaining. But, even if the current and future programmes of carbon sequestration are to be made effective and sustainable, it would depend on nurturing these urban forests.

5.4 Addressing Challenges in Urban Ecological Restoration

However, this exploration has shown that some obstacles still exist in relation to the urban ecological restoration projects. The following are the limitations encountered in this study: As mentioned one of the main challenges we came across is the issue with invasive species. In some cases, while equal status native plants like those consisted of Lantana camara dominated the region and cut a lot of success to efforts at restoration. This problem makes it clear that active management of the restoration sites is needed along with subsequent tracking to prevent native species from being outcompeted by the invasive ones (Khan et al., 2019).

Further, extraneous human activities including constructions, and possibly pedestrian traffic that compacts the ground was also noted in some of these sites. These disturbances are particularly detrimental to the gymnosperms and angiosperms in the area, and will make the overall attempts at restoration a challenging long-term proposition. The general public and community members are important in combating such challenges as they become directly involved in the preservation of urban green space because they are the occupant of the areas (George & Christopher, 2019).

Conclusion

This study also re-emphasises the importance of native species in increasing the level of species per unit area and the proportion of native species; as well as improving the quality of the soil and thus facilitating increased carbon sequestration in the urban restoration projects of Kerala. The research results offer robust support for the premise that native species are critical for the development of diverse and sustainable urban environment. Nonetheless, if the aims of urban ecological restoration are to be achieved on a larger scale, more attention has to be paid to preventing the spread of invasive species, protecting the sites from human impact and increasing the public awareness of the issue.

Better attention needs to be paid on the applicant of native species in future green infrastructure and urban planning initiatives in the state The idea of urban ecological restoration should be taken into cognizance while making policies on climate change mitigation in future in Kerala. These projects will remain successful if the future research will be conducted, popularised, and the policies will be made to extend the demanded green territory in populated areas.

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