

NATURE-BASED SOLUTIONS FOR BIODIVERSITY RESTORATION AND CARBON SEQUESTRATION

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ABSTRACT

This research evaluates restoration strategies that enhance biodiversity and carbon storage in degraded landscapes. The study investigates the effectiveness of various nature-based interventions, including reforestation, wetland restoration, and habitat connectivity enhancement, in promoting species richness and ecosystem function. Using field surveys, GIS spatial analysis, and carbon stock assessments, the research quantifies improvements in vegetation cover, habitat quality, and carbon sequestration potential. Findings indicate that integrated restoration approaches can increase species richness by over 35% and enhance carbon storage significantly, demonstrating the dual benefits of ecological restoration for biodiversity conservation and climate change mitigation. The study provides insights into scalable and sustainable restoration practices applicable to a variety of degraded ecosystems.

Keywords: Biodiversity; Restoration; Carbon sequestration; Ecosystems

Received: 20 November 2024; **Accepted:** 23 October 2025; **Published online:** 08 December 2025.

INTRODUCTION

Global ecosystems are experiencing unprecedented levels of degradation due to anthropogenic pressures, including deforestation, land-use change, pollution, and climate change. These disturbances have resulted in significant biodiversity loss, habitat fragmentation, and the disruption of essential ecosystem services such as carbon sequestration, water regulation, and soil fertility. Maintaining and restoring biodiversity is crucial not only for ecological integrity but also for human well-being, as healthy ecosystems underpin food security, climate regulation, and resilience against environmental change.

Nature-based solutions, which involve sustainable management, conservation, and restoration of ecosystems, have emerged as effective strategies to simultaneously address biodiversity loss and climate change mitigation. By enhancing habitat quality, increasing vegetation cover, and promoting connectivity across landscapes, these interventions can support species recovery while capturing and storing carbon in plant biomass and soils.

Previous studies have highlighted the potential of reforestation, wetland rehabilitation, and agroforestry systems to contribute to both biodiversity conservation and carbon sequestration, yet comprehensive evaluations of integrated restoration approaches across diverse landscapes remain limited. This study aims to assess the effectiveness of nature-based restoration strategies in improving biodiversity and enhancing carbon storage in degraded ecosystems. By combining field surveys, GIS spatial analysis, and carbon stock assessments, the research evaluates both ecological and functional outcomes of restoration interventions. The findings provide insights into scalable practices that can inform conservation policies, ecosystem management strategies, and climate mitigation initiatives, emphasizing the role of ecological restoration in promoting sustainable development and resilient landscapes.

MATERIALS AND METHODS

The study was conducted across multiple degraded landscapes representing diverse habitats including deforested areas, wetlands, and fragmented

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agricultural fields. Restoration interventions were tailored to site-specific ecological conditions and included reforestation with native species, wetland hydrological rehabilitation, and creation of habitat corridors to improve connectivity. Field surveys assessed baseline vegetation cover, species richness, and structural attributes using standardized plot sampling techniques. Carbon stocks were estimated through aboveground biomass measurements using allometric equations and soil sampling for belowground carbon content. Geographic Information Systems (GIS) were employed to analyze land cover changes, habitat fragmentation, and landscape connectivity. Post-restoration assessments compared pre- and post-intervention biodiversity, ecosystem structure, and carbon sequestration potential. Data were statistically analyzed to evaluate the effectiveness of each restoration strategy, with sensitivity analyses identifying key factors influencing restoration success.

RESULTS

Restoration interventions led to substantial improvements in both biodiversity and carbon storage across the study sites. Species richness increased by

effects were limited when implemented in isolation. By contrast, integrated approaches that combined multiple adaptation measures yielded substantially greater reductions in projected losses, highlighting the synergistic benefits of coordinated interventions. This finding aligns with previous research indicating that complex, multi-faceted adaptation strategies are generally more effective than single solutions in building agricultural resilience under climate uncertainty.

The observed variability in yields further emphasizes the importance of considering not only average productivity but also stability and risk. Increased interannual variability under high-emission scenarios without adaptation reflects the sensitivity of crop systems to extreme events, which can exacerbate vulnerability and undermine the reliability of food supplies. Adaptation strategies not only improved mean yields but also reduced variability, suggesting that resilience encompasses both productivity and predictability. This has important implications for smallholder farmers, for whom stability may be as The

approximately 35% compared to baseline conditions, with notable gains in native plant abundance and diversity. Reforested areas exhibited enhanced structural complexity, while wetland restoration improved hydrological connectivity and supported a wider range of aquatic and semi-aquatic species. Carbon stock assessments indicated significant increases in both aboveground biomass and soil carbon content, reflecting the positive impact of vegetation recovery and improved soil conditions. GIS analyses revealed that habitat connectivity improved through the establishment of corridors, reducing fragmentation and creating more continuous ecological networks. Comparative analyses of different restoration strategies demonstrated that integrated approaches combining multiple interventions were more effective in enhancing biodiversity and carbon sequestration than single interventions alone. Overall, the results highlight that nature-based restoration strategies can provide measurable ecological and functional benefits, supporting both conservation and climate mitigation objectives.

DISCUSSION

Results of this study demonstrate that nature-based restoration strategies can significantly enhance biodiversity and carbon sequestration in degraded landscapes. The observed increases in species richness and structural complexity indicate that reforestation, wetland rehabilitation, and habitat connectivity interventions effectively restore ecological integrity. These findings align with previous research suggesting that integrated restoration approaches provide synergistic benefits, simultaneously improving habitat quality and ecosystem function.

The increase in carbon stocks observed across restored sites highlights the dual role of ecological restoration in climate mitigation. Aboveground biomass accumulation and improved soil carbon content demonstrate that restored ecosystems can act as effective carbon sinks, contributing to global efforts to reduce atmospheric greenhouse gas concentrations. These outcomes emphasize the potential of restoration initiatives to deliver both biodiversity and climate benefits, reinforcing the value of nature-based solutions in sustainable landscape management.

Moreover, the enhanced habitat connectivity observed through GIS analyses indicates that restoration can mitigate the negative effects of fragmentation, facilitating species movement and genetic exchange. This is particularly important for maintaining resilient ecosystems under changing climatic conditions, as connectivity supports population stability and adaptive capacity.

The comparative analysis of single versus integrated interventions underscores the importance of employing multiple complementary restoration strategies. While individual measures provided measurable improvements, the greatest ecological and functional gains were achieved when reforestation, wetland rehabilitation, and corridor establishment were implemented together. This suggests that planning restoration at a landscape scale, considering multiple ecological processes and stressors, is essential for maximizing outcomes.

These findings have important implications for policy and practice. Effective restoration requires not only ecological expertise but also institutional support, stakeholder engagement, and long-term monitoring to ensure sustainability. Incorporating restoration into land-use planning, incentivizing nature-based interventions, and fostering community participation can enhance adoption and long-term success. Additionally, the study highlights the need to tailor restoration strategies to local environmental and socio-economic conditions to achieve optimal outcomes.

Overall, the results support the view that nature-based solutions provide a cost-effective, scalable approach to address biodiversity loss and climate change simultaneously. By restoring degraded landscapes, enhancing carbon storage, and improving ecosystem connectivity, such interventions contribute to resilient, multifunctional ecosystems that support both environmental sustainability and human well-being.

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