NOTATION TRENDPLUS PUBLISHING
WHERE IDEAS MEET IMPACT

Volume-1, Issue 1, August 2026, Page No- 168-185

Journal of Sustainable Futures and Interdisciplinary Solutions (JSFIS)

Evaluating Integrated Biodiversity Conservation and Ecosystem Restoration: Empirical Pathways to Environmental Sustainability

Shivani Kaim

Program Manager SONF

Article Received: 27-03-2026

Revised Version: 25-06-2026

Accepted: 05-07-2026

*Corresponding Author

Shivani Kaim

E-Mail Id: shivanikaim007@gmail.com

Abstract: Selected 5 representative ecosystem types (tropical forest, wetland, grassland, riverine and coastal mangrove) of the study area where quantitative and field-based ecologial study on the effectiveness of integrated biodiversity conservation and ecosystem restoration programs were conducted. The main hypothesis stated that there would be measurable restoration success in restored projects regarding ecological integrity, ecosystem carbon sequestration, habitat restoration and socioeconomic indicators. A total community of 50 restoration sites and 25 reference sites (undisturbed) were included in the study and analysed during the vegetation survey, wildlife monitoring, soil and water quality analysis and interviews with the communities. The result indicated the ecological recovery from SBFM and mangrove rehabilitation was the highest (96 and 93, respectively). Remarkably, species richness increased by 46.5% (from 71 to 104), the Shannon diversity index rose by 47.5% (2.36 to 3.48), and vegetation cover improved by 61.2% (49% to 79%). The benefits to environment were significant with carbon sequestration increasing from 3.1 to 6.7 t C ha^{-1} yr^{-1} (a 116.1% gain) and the habitat quality index going from 58 to 88 (51.7% increase). In addition, there were significant socioeconomic effects: Household income increased by 44.9%, the number of ecotourism visitors increased 58.9%, and the involvement of the community increased 76.1%. The Pearson correlation revealed good positive correlations among the ecological variables and the most correlation in terms of supporting the ecosystem was observed for species richness, ecosystem sustainability index, r = 0.95.

Keywords: Biodiversity Conservation, Ecosystem Restoration, Environmental Sustainability, Ecological Resilience, Conservation Strategies.

Introduction

Staking a balance between economic development, ecological sustainability and social welfare is one of the most challenging twenty-first century global issues for sustainability (Kumari et al., 2025). This has put planetary health, climate accountability and human livelihoods at risk due to the ever-fincreasing biodiversity loss and ecosystem degradation rates (Babu & VijayKumar, 2024). Although species protection measures have been taken, the count and functionality of species in the world decline alarmingly due to changes in land-use, habitat fragmentation, invasive species and climate change (Kok et al. 2018). It has provoked the need for global standards on ecosystems restoration and for the conservation of biodiversity, but so far, a limited evidence base to inform effective interventions exist (Nasruddin et al., 2025). This policy-science divide underscores the importance of the need to perform chal-[28] lenge multi-ecosystem assessments to evaluate ecological and socioeconomic impacts for restoration project =ting in a variety of habitats.

This research was undertaken to test the hypothesis that multiple significant values of ecological integrity, carbon sequestration, habitat quality and socioeconomic value, across a spectrum of ecosystem types, will be measured; however, these values, when restoration interventions are undertaken on a systemic and integrated basis, would be synergistic and measurable. This has emerged from an expectation based on theoretical models that said biodiversity is a key element of ecosystem function, and in degraded conditions, restoration of it results in a "Domino effect" of a system strengthening its ability to be resilient (Orenstein et al., 2025). The overall goal of this study was thus, to compare the effectiveness of a set of ten restoration practices across five typical ecosystems (tropical forest, wetland, grassland, riverine and coastal mangroves) through a quantitative field-based ecological research design that includes assessment of biodiversity, analysis of remote sensing data, analysis of Geographic Information System results and statistical modeling.

This research, foremost among its findings, offers hard data on a major scale that indicates that the combined (syncronous) forest restoration approaches, particularly community-based forest management and mangrove restoration produce the greatest biodiversity, carbon sequestration, habitat and socio-economic benefits. The results of this study clearly and measurably show the trajectory towards environmental sustainability: species richness, Shannon diversity index and carbon sequestration, while documenting household income increasing by 44.9%, thus opening opportunities for evidence-based results to be documented and used in policy and practice to achieve environmental sustainability. Overall, there is a reinforcing correlation between the ecological variables, where species richness correlates with the ecosystem sustainability index at a level of $r = 0.95$, demonstrating the synergistic nature of the results of the restoration and pointing out the need for integrated approaches (Yildirim et al., 2026).

Moreover, when employing economic or social indicators in the ecological framework, it is also a methodological advancement as it points to the need to recognize the interdependence of two healths, human and ecosystem. Previous assessments of restoration have often been limited in scope to biophysical results, and have failed to take into account social issues that are essential to the longterm success and sustainability of conservation programmes (Olaitan et al., 2026). In this regard, the present study showed that through the execution of restoration, the participation of the communities has also been going up in 76.1%, Community participation is very important to achieve long run environmental benefits in restoration projects as restoration is a local ownership project. In the Anthropocene, wherein a whole-ocean vision is also a priority (Orenstein et al., 2025), an integrated view fits in well with new ecosystem-management models.

A review of relevant literature on ecosystem restoration, conservation of biodiversity and environment sustainability framework is presented in Section 2 with the aim of highlighting some gap points which will be filled by the present research. The study design and criteria to select sites, the restoration initiatives implemented, the data collection methods and statistical analysis performed are described in this section. The results of the empirical research are presented in Section 4, where they are compared between the different types of intervention and ecosystem type, both on an ecological level and an environmental and socioeconomic level. In Section 5, the implications of these findings for the application and policy of restoration and the challenges indicated by results of the research are explored, as well as future directions in integrated conservation strategies suggested. The key contributions and recommendations for implementing to evidence-based restoration management are summarized in Section 6.

Literature Review

The recognition of catastrophic environmental loss as inherent dangers for both human society and natural systems has led to the rise in importance of ecosystem restoration and biodiversity conservation over the past few decades and draw the scientific interest. Species richness, functional diversity and genetic diversity are interlinked in the fundamentals underlying the stability, productivity and resilience of the environment, as a result of which the focus on 'biodiversity-ecosystem function' (BEF) has resulted in an increasing body of evidence (Orenstein et al., 2025). This BEF paradigm has been applied to guide conservation and restoration practice in many cases, and some are developed to management guidelines for a range of ecosystem types and socio-ecological context, but not to the proper degree of development.

In total, five studies specifically focused on the effectiveness of interventions for restoration have been done. In tropical forests, for instance, assisted natural regeneration and native tree plantations are under wide discussion and are proven to be viable solutions to accelerate forest recovery, but in turn meta-analyses indicate that using assisted natural regeneration could provide better biodiversity results with lower implementation costs (Axelsson et al., 2024). Similarly, mangrove rehabilitation is an area of significant interest, as the benefits for coastal protection and mangrove carbon sequestration are high, and community-based methods of mangrove rehabilitation have a higher species survival rate in the long term compared to technical rehabilitation (Ardiyansah et al., 2026). But the number of studies evaluing these interventions is relatively small and many focus on a single ecosystem type or intervention category, and there are relatively few studies that make comparisons across ecosystems.

There has been a growing trend of considering the socioeconomic components of restoration evaluations in recent years. Traditional Ecological Knowledge (TEK) is seen as a useful complement to scientific restoration practices to offer local knowledge and long-term stewardship perspectives to help project durability (Olaitan et al., 2026). Research on community-based natural resource management (CBNRM) has proven that the involvement of stakeholders and institutions in natural resource management is crucial and can enhance environmental results as well as the adoption of the activities by the communities (Ardiyansah et al., 2026). Though, there are not many quantitative assessments available to date that provide integrated (ecological, environmental and socioeconomic) indicators, giving a lack of evidence for integrated policy design.

On methodological terms, using remote sensing and spatial analysis was a great help in monitoring both the effectiveness and the results at a level larger than local. These methods can be applied to large tracts of space whilst covering a low-cost area, for instance, through satellite imagery, drone surveys, Geographic Information System (GIS) mapping, which can be used today for habitat mapping, vegetation cover estimation, and landscape connectivity analysis (Nasruddin et al., 2025). Furthermore, new Modelling methods such as environmental niche models and multi-criteria decision analysis have been applied to prioritise restoration sites and to model how interventions will work in the future climate (Prakash et al., 2025). Although these technologies exist, most modeling work continues to be focused at the level of individual taxa or, at the most specific level on ecosystem services, and few attempts have been made to combine biodiversity metrics, carbon accounting and habitat quality and socioeconomic variables into an integrated analytical framework.

There has been some thought within the restoration literature into what the definition of sustainable environmental outcomes would look like.The definition of sustainable environmental outcomes has been discussed in the restoration literature. A growing number of researchers propose that a narrow understanding of sustainability - based on long-term ecosystem states should be replaced by an approach to resilience that embraces dynamism and uncertainty (Kumari et al., 2025). On the other hand, it is important to embed the “value of non-human life” / “ethical consideration” principle in sustainability frameworks, given the risk of anthropocentric “short-sighted” considerations to create a negative impact on long-term conservation plans and goals (Egule & Angaware, 2025). Whole System Diversity (WSD) is a potential effective way of managing ecosystems holistically by incorporating geodiversity, biodiversity and social diversity; however, WSD has been implemented only in parts and sporadically applied at the geographical and ecological level (Orenstein et al., 2025).

The above literature review shows that there are some gaps that will be filled in the data for the present study. First, there are no multi-ecosystem and multi-intervention evaluations available which systematically compare outcomes of mangrove restoration in both the tropical forests and wetlands and across the grasslands, riverine and coastal mangroves, with a consistent methodological approach. Secondly, there is a limited use of ecological (species richness, Shannon diversity), environmental (carbon sequestration, soil organic carbon, water quality) and socioeconomic (household income, ecotourism, employment, community participation) indicators to the satisfaction of a single study design. Third, while the carbon sequestration analyses have included a number of these dimensions, an explicit multivariate statistical investigation of the interactions between these different dimensions of restoration effectiveness has lacked consideration, other than carbon sequestration, and thus, hindered understanding of how these dimensions interact to achieve ecosystems sustainability. This study provides empirical evidence across five ecosystem types and 10 restoration actions representing strategies derived from nine different measure groups in the ecological, environmental and socioeconomic aspects, helping to move from theory towards action and to formulate policies that are based on ecological science.

Methods

Study Design and Site Selection

A weather-based comparative quantitative and field-based ecological design was used in this research, which included biodiversity assessment, ecosystem restoration monitoring, remote sensing, Geographic Information System (GIS) analysis, habitat quality evaluation and the use of statistical models to quantify the effectiveness of the biodiversity conservation and ecosystem restoration. The study, in five representative ecosystem types—tropical forest, wetland, grassland, riverine, and coastal mangrove ecosystems, covered a wide range of ecosystem conditions and restoration contexts. Stratified random sampling was used to ensure geographic and ecosystem representativeness, to identify a total of 50 restoration sites and 25 reference sites. Criteria for choosing restoration sites were a documented history of degradation and the presence of active restoration projects, while reference sites were selected because relatively little anthropogenic activity has occurred at them and they have good ecological integrity, as confirmed based on preliminary vegetation surveys and from consultations with protected area managers (Yildirim et al., 2026).

At the study sites all the different ecosystem restoration measures (ORN, AIR, Wetland restoration, Riparian buffer restoration, Mangrove rehabilitation, Eradication of exotic species, Wildlife habitat restoration, CBFM, Soil & water conservation and ecological corridors) were carefully compared. All interventions followed the existing project restoration protocols which were modified in each locality based on the existing on-site conditions but should be comparable across localities (Olaitan et al., 2026). Individual interventions to specific sites was decided based on ecosystem basics, key ecosystem degradation drivers identified during the initial assessment phase.

Data Collection Methods

Primary data gathered was from vegetation surveys and wildlife surveys, quadrat sampling, transect sampling, soil and water quality testing, drone habitat mapping and community interviews. Quadrats have been installed systematically and under different grid size (20 m² and 5 m² for species associated to tree and herbaceous/shrub layer respectively), while species identification has been based on the standard taxonomic references used (Axelsson et al., 2024). Direct observation and indirect sign surveys were done on the defined wildlife transects and employed a 500 m x 3 transects per site of wildlife monitoring. Five random soil samples were taken in each quadrat from the top 30 cm of soil and composited for lab analysis of SOC via Walkley-Black dichromate oxidation method. To assess the water quality according to Ardiyansah et al (2026), the following items were analyzed: water quality was determined by using in-situ pH, DO, turbidity, conductivity measurement using calibrated portable water quality meters and laboratory analysis for nutrient concentration and biochemical oxygen demand (BOD).

Secondary data were compiled from satellite data from pre-restoration baseline period (Landsat 8 OLI and MSI sen2), the Forest department records, and databases on biodiversity (Global Biodiversity Information Facility), protected area management data, climate data from local meteorological stations and peer reviewed scientific publications. The habitat mapping was carried out using an altitude of typically 120m for a DJI Phantom 4 Multispectral drone with a 5-band multispectral sensor (blue, green, red, red-edge, near infra-red) providing a ground sampling distance of about 5.5cm per pixel. The images collected by the drone were used with the structure from motion (SfM) method in Agisoft Metashape software to generate 2D representations of the site. 2D classification into habitat categories was done using supervised maximum likelihood classification in ArcGIS Pro version 2.9.

Various parameters measured in the present study is summarized in Table- 1 which shows each parameter and its unit of measurement.

Table 1. Parameters measured and their corresponding units.

Parameter	Unit
Species richness	Number of species
Shannon diversity index (H')	Index
Vegetation cover	Percentage
Soil organic carbon	Percentage
Carbon sequestration	$t\,C\,ha^{-1}\,yr^{-1}$
Habitat quality index	Score (0—100)
Water quality index	Score
Ecosystem sustainability index	Score (0—100)

The total number of species and the proportional abundance of the th species were used in the Shannon diversity index computed as follows: The habitat quality index is an assessment of habitat quality using multiple criteria with a value between 0 to 100 to account for habitat quality based on the quality of the habitat vegetation, presence of keystone species, fragmentation factors, and soil health factors. In the same way, a weighted composite of species richness, habitat quality, carbon sequestration potential, water quality and soil organic carbon were calculated for ecosystem sustainability index, with the weight of each component reflecting the contribution to ecosystem function based on principal component analysis results (Orenstein et al., 2025).

Experimental Procedure and Statistical Analysis

The research was done in 8 successive stages. To characterize pre-restoration conditions, all 75 sites were initially visited to evaluate the baseline ecosystem characteristics and parameters. Secondly, a detailed biodiversity inventory and habitat mapping project using field sampling methods outlined above and the remotely sensed data took place. Third, suitable training interventions were chosen considering the outcomes of the baseline assessment, drivers of the degradation and the ecological feasibility. Fourthly, ecosystem restoration activities were undertaken in compliance with standard protocols for each type of intervention and the time for carrying out the action was variable (between 6–to 18 months depending on the type of intervention). Fifth, all the ecologic parameters described in the Table 1 described were then sampled at six-month intervals and for three years there was uniformity in methods during sampling. Sixth, an integrated environmental assessment and socioeconomic impacts were conducted on community conducted structured interviews with communities using a questionnaire on household income, tour visitation/usage rate, employment and community participation rate. Measurements of all the parameter categories were taken and compared statistically to test the hypothesis in seventh, that measurable improvement will be stimulated in all the parameter categories due to interventions for restoration. Eighth came the prediction on ecosystem restoration outcomes for various types of ecosystem restoration investments based on the validated statistical relationships (Prakash et al., 2025) for future ecosystem restoration scenario modelling.

All the statistical analysis has been performed using R software version 4.2.1 (R Core Team, 2022). Summaries in the form of descriptive (mean, standard deviation and range) statistics were used for each parameter to represent central tendency and variability among the different Ecosystem Categories and different Intervention Types. One-way analysis of variance (ANOVA) was used to determine if there were significant differences in the parameter values between types of interventions, and Tukey's honestly significant difference (HSD) test used to make pairwise comparisons when the F-test was significant at . Pearson correlation coefficients (weak , moderate and strong) were used to obtain measures of how well ecological, environmental and socioeconomic data were related to one another. Number dimensions were reduced by principal component analysis (PCA) of correlation matrix of the standardized values using Kaiser criterion (eigenvalue > 1) for the dominant axes of variance in outcomes of restoration. Groups of restoration interventions were consolidated by clustering using the technique of Ward's minimum variance criterion with Euclidean distance to see the natural typologies of the most effective interventions. Finally, multiple linear regression models were built to model a sustainable ecosystem index as function of species richness, habitat quality and carbon sequestration and water quality and the variance inflation index was calculated to look for high correlation among the potential models, capturing the ecosystem sustainability index as a function of the other variables. All tests were considered to be statistical if P<, and -values for all are two-tailed (Orenstein et al., 2025).

Results

Results indicated that the effectiveness of the 10 restoration treatments was quite variable, and ecological recovery and biodiversity benefits, as well as positive socio-economic outcomes, were quite different across the five ecosystem types. In the following subsections, each intervention is compared in terms of change in biodiversity, the benefits to the environment or socioeconomic benefit, and loss of biodiversity avoided, and in statistical terms with each other, between the different biodiversity restoration outcomes.

Comparative Performance of Ecosystem Restoration Practices

The highest level reduction in ecological deterioration and enhancement of biodiversity and mangrove ecosystems was observed during "Community based forest management (CBFM) and Mangrove rehabilitation". Community based forest management had the most species rich (112 spp.), most vegetation cover (88%) and highest carbon sequestration rate (7.6 t C ha-1 yr-1) with the highest ecosystem sustainability index of 96. The mangroves were next in order with 105 species, 84% vegetation cover, 7.2 t C ha^{-1} yr^{-1} carbon sequestration and 93 sustainability index.

Table 2. Comparative performance of ecosystem restoration practices across key ecological indicators.

Restoration Practice	Species Richness	Vegetation Cover (%)	Carbon Sequestration (t C ha^{-1} yr^{-1})	Sustainability Index
Native Tree Plantation	92	76	5.8	86
Assisted Natural Regeneration	98	81	6.4	89
Wetland Restoration	87	72	5.1	84
Mangrove Rehabilitation	105	84	7.2	93
Community-based Forest Management	112	88	7.6	96

The assisted natural regeneration and native tree plantation also had good results, with sustainability indices of 89 and 86 respectively. The planted areas for native species (76%) and vegetative cover (76%) were lowest in the tree plantation while the highest species richeness was found in assisted natural regeneration (98%) and highest vegetative cover (81%). The positive effect of wetland restoration was reflected in the lowest results with regard to species richness (87), vegetation cover (72) and carbon sequestration (5.1 t C ha-1 yr-1), as well as a sustainability index of 84. The outcomes of these findings point towards good ecological results when interventions are community involved and/or the process of natural regeneration is used, as opposed to purely technical, or monoculture interventions.

The sustainability index scores were very distinct and differentiated restoration practices in a hierarchy. The uppermost level was community based forest management and mangrove rehabilitation which scored above 90. The middle tier's scores were between 86-89 for assisted natural regeneration and native tree plantation. The bottom level was used for restoring wetlands, and was valued as 84. Based on this scale, the interventions able to maximize holism in sustainability are those which integrate both social and ecological aspects such as interventions that include ecological restoration and enhancement of local livelihoods, such as the community-based forest management. The restoring performance of mangrove rehabilitation can be explained because mangroves are fast growing species, have high carbon sequestration ability, and the introduction of mangrove protection governance systems with a reduction in further disturbances (Nasruddin et al., 2025).

Biodiversity Improvement Following Restoration

Restoration measures were applied at each of the sites and statistically significant and meaningful differences in biodiversity indicators were expressed. Table 3 shows that the species richness at the 50 restoration sites was 104 species after the restoration compared to 71 species prior to the restoration, which is a 46.5% improvement. The restored communities had also been confirmed by increase in the diversity index, Shannon, from 2.36 to 3.48 (increase 47.5%) which was associated with an increase in the number of species in addition to the more even distribution of species abundance. It led to a 30% rise in the proportion of vegetation cover (49% to 79%), or a 61.2% increase in structural complexity and canopy cover. The habitat quality index (combining the aspects of vegetation structure, canopy cover, keystone species, fragmentation level and soil health) improved from 58 to 88 – a 51.7% increase.

Table 3. Mean ecological indicators before and after restoration across all treatment sites ($n = 50$).

Indicator	Before Restoration	After Restoration	Improvement (%)
Species Richness	71	104	46.5
Shannon Diversity Index	2.36	3.48	47.5
Vegetation Cover (%)	49	79	61.2
Habitat Quality Index	58	88	51.7

This has been done by way of one-way analysis of variance to check for significant difference between pre-restoration and post-restoration values for each of the four indicators listed above—species richness, Shannon diversity index, vegetation cover and the habitat quality index. The results corroborate the hypothesis with great confidence that effective restoration projects can substantially improve biodiversity and enhance ecological integrity over a variety of ecosystems.

There were differences in the amount of biodiversity improvement, depending on the type of intervention, with the community-based forest management having the highest improvement in terms of species richness (an increase of 47.4%) and Shannon diversity (an increase of 42.5%). Mangrove rehabilitation showed significant improvement in species richness from 74 to 105 (41.9%) and Shannon diversity from 2.48 to 3.55 (43.1%) which was very highly significant. In the areas that realized relatively less restoration success in wetlands, species richness increased from 65 to 87 (33.8%) while vegetation cover increased from 44% to 72% (63.6%). The differences could be attributed to different level of general background degradation level, ecosystem resilience, effectiveness of specific intervention, and/or habitat type (Axelsson et al. 2024).

The reduction in biodiversity indices are in line with theory from the biodiversity-ecosystem function framework, whereby more even species diversity and increased species richness should translate to higher productivity, across various levels of stability and resistance/resilience of ecosystems (Orenstein et al., 2025). This added 47.5% to the Shannon diversity index is particularly useful because this combines both species richness and evenness, indicating that the restoration not only didn't decline the existing species but that it brought new ones in, and that it didn't increase the dominance of a few superior competitors, but actually reduced their impact, making the community more even and stable. Furthermore, total vegetation cover has increased by 61.2%, which provides a better habitat structure and provides direct positive. Effect on wildlife through more food, nesting material and protection from predators is a significant improvement (Babu & VijayKumar, 2024).

This vegetation recovery – habitat quality improvement synergy meant that an increase in the vegetation cover not only led to the betterment of microclimates, but also reduced soil erosion and improved nutrient cycles, driving further advances in species colonization and development of habitats. There was a great synergy in creating riparian buffer restoration and ecological corridors, which have been demonstrated to facilitate the movement of species and encourage gene flow and have produced local and landscape level biodiversity recovery (Prakash et al. 2025). Extensive data for the biodiversity improvement of the intervention interventions show that these interventions are recovering well and have become similar, or better, over the 3-year evaluation period to the 25 reference sites that were not affected.

Environmental Benefits

From an environmental standpoint, the interventions showed improvements in all environmental parameters measured such as carbon storage, soil health, water quality, and ecosystem stability. Sequestration of carbon saw more than double from a mean value of 3.1 t C ha^{-1} yr^{-1} prior to restoration to 6.7 t C ha^{-1} yr^{-1} after restoration, which is a 116.1% increase (Table 4). The remarkable values show this enhancement due to high biomass increase in restored or assisted regeneration sites, high belowground carbon allocation of wetland and mangrove systems wherein high accumulation of organic matter is evident active tree growth (Nasruddin et al., 2025).

Table 4. Environmental performance indicators before and after restoration across all treatment sites (n=50).

Indicator	Before Restoration	After Restoration	Improvement (%)
Carbon Sequestration (t C ha^{-1} yr^{-1})	3.1	6.7	116.1
Soil Organic Carbon (%)	1.24	2.01	62.1
Water Quality Index	67	89	32.8
Ecosystem Stability Score	63	90	42.9

The level of soil organic carbon increased from 1.24 % to 2.01 % (62.1 %) which reflects increased soil fertility, water holding capacity and microbial activity. The increase was significant on restoration areas, especially on the grassland and wetland areas, where root mass and organic detritus build up resulted in significant carbon sequestration in soil pools. Water quality index in these vegetative buffer programs around the riparian and wetland ways have improved from 67 to 89, resulting in 32.8% improvement of Wax being caused by decrease in sediment run-off, nutrient loading and increase in riparian filtration function water quality index (Ardiyansah et al., 2026). The ecosystem stability score was raised from 63 to 90, representing an improvement of 42.9%, indicating high ecological resilience; in a state of ecosystem where environmental factors such as drought, flooding and extremes in temperature are not a threat.

The environmental impacts were also different across the various types of interventions: the Community based forest management and Mangrove rehabilitation received the largest benefits. CBFM showed a 117.1% and 65.2% improvement on carbon sequestration (from 3.5 to 7.6 t C ha-1 yr-1) and SOC (from 1.32 to 2.18%), respectively. Similar outcomes were found for mangrove rehabilitation: carbon sequestration was 3.3 t C ha-1 yr-1 which represented an enhancement of 118.2%, and Soil organic Carbon did better in this case, improving from 1.28 to 2.11%. It is important to highlight the high carbon sequestration rate in mangrove ecosystems which is 3-5 times faster than other forests on land (Nasruddin et al., 2025), as it is one of the key nature-based solutions (NbS) for climate action and particularly for climate mitigation.

This was also the case in the data for the correlation between the various environmental indicators: there was a correlation between those environmental parameters that sites with highest carbon sequestration rate towed those with both high soil organic carbon and water quality improvement. This coupling is because of the direct effect this vegetation cover has on carbon sequestration and its role of providing soil stability, soil erosion control, filtering of pollutants and regulating of microclimatic conditions. Woody vegetation addition to restoration sites for riparian buffers, for example, led to an average of 40% removal of sediment entering the stream, improvements in water clarity via shading, increased dissolved oxygen concentrations via shading that reduces water temperature, and carbon sequestration. The total carbon sequestration reported in all the sites, is equal to 116.1%, which is equivalent to 3.6 t C ha-1 yr-1 in area repaired in this study (500 ha), significant increase in emission avoidance in the local climate mitigation goals (Kumari et al., 2025).

Especially important is the stabilization of the ecosystem between levels of 63 and 90 levels of improvement as there are several aspects of the ecological resilience involved. Restored systems which give a higher stability scores have a higher ability to retain their structure and function under impacts of disturbance, which is very important in a context of accelerating climatic change and increasing frequency of extreme climatic events (Babu & VijayKumar, 2024). This discovery implies that the restoration activities accomplished baseline ecosystems and improved their adaptive capacity to environmental stressors in the future, thereby making a contribution to long-term sustainability. In the broader context, the environmental impacts assessed herein support the potential for restoration of ecosystem and soil quality, water quality, and quantified climate mitigation efforts as well as increasing ecosystem resilience (in an integrated manner) towards environmental sustainability.

Socioeconomic Benefits

These community conservation restoration opportunities were seen to have tremendous socioeconomic effects that led to rise in household income, community participation in ecotourism and employment in the studied communities. Restoration work was followed up by a tabular presentation (Table 5) of benefits, following structured community meetings before and after carrying out restoration.

Table 5. Community-level socioeconomic indicators before and after restoration across all community sites (n=50).

Indicator	Before Restoration	After Restoration	Improvement (%)
Household Income (USD year^{-1})	1,580	2,290	44.9
Ecotourism Visitors (Persons year^{-1})	6,200	9,850	58.9
Employment Opportunities	320	485	51.6
Community Participation (%)	46	81	76.1

A mean house income increase from 1580 USD year^{-1} to 2290 USD year^{-1} after restoration (44.9% increase), thus indicating improved opportunity for livelihoods through restoration related activities. This resulted in an increase in income primarily derived from the employment created in the restoration implementation and maintenance industry, as well as the production of other values derived from non-timber forest products and enhanced testing of forest ecosystem services, such as ecotourism services (Ardiyansah et al., 2026). The community forest stewardship group, which was active in CBFM and mangrove rehabilitation led to establishment of a Programme to enhance income through the creation of jobs and sharing of the benefits from CBFM has experienced the highest level of income improvement.

The egotourism visitation increased from 6200 persons year^{-1} to 9850 persons year^{-1} up to 58.9% indicating the recreational and aesthetical value and benefit of the restored ecosystems. Restoring these streams has yielded charismatic species, nature trails, cleaner streambanks, more beautiful streams and an uptick in the number of visitors, both domestic and international, and economic gains for local economies. The development of the ecotourism aspect was particularly notable in the restoration of riparian function and reforestation which offered opportunities for nature-based tourism based on improved habitat conditions and the opportunity to view the wildlife of this area (Nasruddin et al., 2025). The numbers working on forest direct restoration labour, as well as in forest nurseries management, guiding of ecotourism programs, forest monitoring and patrolling activities increased by 51.6%, 86.9%, 96.2%, and 113.2%, respectively, between 1971 and 1981.

Also the highest Social economic gain's reported in this study is the level of community involvement in conserving biodiversity ranging from 46% to 81%. The overall increment in this important aspect can be attributed to the effectiveness of participatory governance activities, which have been integrated in to the restoration activities at community level, especially through the establishment of resource management committee, availed of benefits and enhancement of the capacity of local actors to actively participate in restoration (Olaitan et al., 2026). This long term conservation benefit project has been successful in establishing the community interest and taking ownership of the project.

The synergical, linkage between the income/employment aspect of the domestic economy and ecological recovery is summarized above. The shrubbery, undergrowth and quality of forest products increased, thereby providing more chances to harvest marketable non-timber forest products (NTFPs) like fibre, fruits and medicines as well as diversifying their income sources, reducing the vulnerability of the forest household to economic shocks. Meanwhile, the amount of visiting tourists continued to grow making provision for infrastructure that is tourism friendly with the added advantage of providing employment to such sectors in the country as the services sector including the employment of women and youths in the informal sector of the economy. This socio-economic feedback, therefore, helped improve the quality of community livelihood, and the community was more willing to follow the rules and regulations to use the resources and engage in beneficial restoration.

However, payment of the socio-economic benefits were not equal across community-typologies. Communities that have already higher social capital and technical resources, and a higher initial level of pre-existing institutions experienced a greater increase in income and employment opportunities to than communities with lower levels of social capital and technical resources, as well as a lower level of pre-existing institutions. Apart from this, since the findings indicate the need for capacity building measures, these should be directed towards all the marginalised groups, and benefit-sharing measures in restaurative approaches should seek to maximise the benefits of the restorative process.There is a need to put in place capacity building measures in this regard and especially involving all the groups of the people and may maximize the benefits of the restorative process by benefit-sharing measures in the process of restoration. Overall, the socioeconomic data provide illustrative examples of how ecosystem restoration can be a powerful tool for development; how ecosystem values can be furthered while providing co-benefits for poverty alleviation, livelihood enhancement and conservation and protection of biodiversity.

Major Challenges

The added values of ecological, environmental and socio-economic values were documented in each of the restoration sites, however there were documented significant barriers that hindered the effectiveness and scalability of each of the conservation/ restoration efforts. The following general challenges were identified by both a community survey of site managers and community members and were identified by restoration professionals as problems and are outlined in Table 6.

Table 6. Major challenges affecting biodiversity conservation and ecosystem restoration across study sites.

Challenge	Mean Score (1–5)	Rank
Habitat Fragmentation	4.62	1
Climate Change	4.46	2
Invasive Species	4.23	3
Insufficient Funding	4.08	4
Weak Community Awareness	3.84	5
Illegal Resource Exploitation	3.73	6

The most important barrier, with a mean score of 4.62, was habitat fragmentation, coming first of all the barriers. The finding aligns with substrates in this and other environmental studies which highlight that landscape connectivity will be an important component to the success of restoration and persistence of biodiversity (Orenstein et al., 2025). Fragmentation can reduce dispersal, gene flow between populations, recolonization of restored habitat by a target species and success of restored habitats in the long-term. Specific results obtained in this present study were that the landscape fragmentation due to the fragmentation of tropical forest and grassland ecosystem by farming practices, construction of infrastructure and urbanization were observed and were manifested in the form of isolated and inhospitable matrix environment (Kumari et al., 2025). Not every one of these interventions is being applied and for those that are there are various landscape areas where the intervention might not be enough to compensate for fragmentation. For interventions assessed in this report, ecological corridors are partially addressing some of these issues, but will this be sufficient in high fragmentation areas?

The second most challenging condition (4.46) was man due to climate change condition. The impact of temperature and precipitation changes caused by physiological stress of the plants, on the restored plants and the indirect effect due to changes in habitat suitability for plant expectations by higher temperature were accounted for, or modeled, (Babu & VijayKumar, 2024). Riparian restoration sites with longer periods of drought also experienced a reduction in seedling survival, an average of 28% reduction, and soil erosion and scouring due to high soil moisture as a result of precipitation led to damage of newly planted vegetation. A challenge for rehabilitated stands to maintain their success in the lower sediment accretion rate stream mangrove ecosystems would be the sea level rise, as will occur sea level rise intensity as a result of storm activity (mangrove ecosystems where sediment accretion rates are slower than sea rise are located at the coast). If the target species/genotypes are adaptive, posting a "firm intention" to deal with the challenges of changing climate and need for climatic adaptability to climate change futures is a compelling issue.

The third most common average score was for Invasive species (4.23 (-2.13 to 7.21)) and suggests a general agreement that the species had a moderate to high influence on restoration success and was widely distributed across the types of ecosystems. For example, Lantana camara is an invasive species that monopolizes all resources, changes fire regimes, and impacts the re-establishment process of natives in the ground and ave.For example, Lantana camara being an invasive species consumes all resources, interacts with fire regime and slows down the re-establishment processes for native species in the ground and ave. Indirect damage on vegetation and predation on the seed and seedlings was caused by invasive animal species such as feral pigs and rats, especially in mangrove and island restoration contexts. Constant effort to keep the invasive species exclusion out of the sites after the initial treatment period limit was required and continue to present significant labour and funding intensive sustainment costs post project beyond the treatment period limit for seines that will impact many sites.

It had the lowest score (4.08), and was always referred to by implementers as one of the obstacles faced during the project and long term monitoring. There are many projects funded by these short-term arms (grants or government donations), and few activities funded for important follow up activities like maintenance, adaptive management and community involvement. Because native plants have significant start-up costs (production, site preparation, labor), and ecosystem and economic values were only realized after a time, financing was a challenge that limited the extent and length of native plant restoration. In approving sophisticated financing mechanisms, such as payment-for-ecosystem-service schemes, carbon credit markets, blended financing mechanisms, sufficient and continued investments in restoration actions are essential for the success of this process (Ardiyansah et al., 2026).

The least satisfied community challenge was awareness (mean = 5th, 3.84) which had greatest impact on the rest of the social challenges. Although community awareness of the ecological and economic value of restoration was absent, low uptake of implementation activities, compliancy with resource use controls, and vandalism/accidental damage to restoration infrastructure more commonly occurred at sites where community was not aware of ecological/economic benefits of restoration (Olaitan et al., 2026). This was particularly true for those areas that hadn't seen any benefits from previous conservation schemes, or where they hadn't adequately informed communities of the new conservation steps that were being taken. Community engagement and benefits sharing may be implemented through the CBFM and Mangrove Rehabilitation programs and could achieve high community participation, while other programs using a more rigid form of implementation of top-down approaches failed to gain community involvement, especially in terms of long-term participation (Ardiyansah et al., 2026).

Although these are conserved, timber poaching and collection of fuel wood/illegal fishing is still common with the lowest mean score (3.73), but these illegal activities are presented as the lowest rank challenge. A lack of institutional governance mechanisms and apparent good institutional enforcement along with some alternative livelihoods was identified as drivers of challenges that impacted on the investment in vegetation restoration (Kumari et al. 2025). These challenges became evident when dealing with the interplay between several: vulnerability for newly restored sites of illegal exploitation coupled with the relatively low perception of community awareness led to low rates of community participation in community patrolling programmes and low rates of reporting of illegal activities. Therefore a coordinated approach with the necessary governance, finance, awareness creation and sensori-motorization, socio-ecological systems considered, is crucial for the adoption of these solutions to overcome these widespread and often intersecting constraints.

Correlation Analysis

A significant number of very strong Pearson correlations where the changes in the core ecological (and environmental) variables measured were not independent and were interrelated were obtained at 50 restoration sites. Additionally, in this study it was observed that ecosystem sustainability index (,) and closely followed by habitat quality (.), had the highest possible correlation with the species richness. The other variables did not have meaningful relationships as exhibited in Table 7. There was also a strong positive correlation between sustainability index (,) and the carbon sequestration. This was supported by the findings which showed that irrespective of the level of intervention, and irrespective of the ecosystem, there was indeed a direct link between the ecosystem sustainability outcomes and the biodiversity and habitat quality.

Table 7. Pearson correlation matrix for key ecological and environmental variables across all restoration sites ($n = 50$).

Variable	Species Richness	Carbon Sequestration	Habitat Quality	Sustainability Index
Species Richness	**1.00**	**0.89**	**0.93**	**0.95**

Variable	Species Richness	Carbon Sequestration	Habitat Quality	Sustainability Index
Carbon Sequestration	**0.89**	**1.00**	**0.86**	**0.91**
Habitat Quality	**0.93**	**0.86**	**1.00**	**0.94**
Sustainability Index	**0.95**	**0.91**	**0.94**	**1.00**

Another interesting feature of note was the almost a similar correlation as between biodiversity and habitat quality ( ) and species richness. This means that there is a critical "mediating" factor in the benefits of biodiversity gains above and beyond ecosystem level benefits, and that is habitat quality. Restoration caused an increase in niche space for different species and the increase in species richness and relative community compositions was observed as vegetation structure and complexity increases (Orenstein et al., 2025). This led to enhanced carbon sequestration through functional diversity of the communities, which in turn helps the better management of nutrients by the different species-specific root architectures, and stabilizes SOC through different functional litter decomposition rates (Babu & VijayKumar, 2024).

The permutations of carbon sequestration showed a correlation with the sustainability index ( ), signalling the critical importance of carbon sequestration as an indicator and driver of a successful restoration. Overall, CBFM and MR had the most sites with maximum sustainability score and had the most carbon sequestration sites. The relation between this could also be attributed to productive vegetation functions such as reducing concentration of green house gases in the atmosphere, increment in soil organic matter and water-holding capacity as well as improved soil structure for wildlife benefit (Nasruddin et al., 2025). This is supported by the high correlation between habitat quality and carbon sequestration (R2 = ; > 0.9) and indicates that habitat of high quality will yield high plant growth and high carbon sequestration.

The result from the principal component analysis (PCA) on the standardized correlation matrix supported the existence of one strong dominant component which is the first principal component with 78.4% of the four variables total variance. The first component captured all 4 of the highest loadings variables with species richness being the most loaded of 0.94, the sustainability index of 0.92, the habitat quality of 0.91 and the carbon sequestration of 0.88. All the 4 considerations follow this pattern and there is a gradient of restoration success if the values of more than 4 variables were considered, there will be a continuum of values for each of the 4 variables as well. The use of integrated measures such as ecosystem sustainability index could be used as a measurement of the bi-dimensional and bi-strength effect of the restoration, as it had a high correlation strength and one dimensionalness here.

The three clusters related to the three levels of effectiveness of the interventions in the effectiveness scale (section 4.1) were confirmed by the cluster analysis with these four variables in terms of Euclidian distances. The 18 community based forest management and mangrove rehabilitation sites were the best performing cluster overall in the uniformly high values that were exhibited across the four variables. Assisted natural regeneration and native species planted in the middle cluster (20 sites) were moderate but still a high value, based on area.Assisted Natural regeneration (squares per hectare) and natives planted (trees/ha) rates were moderate (low and high clusters, respectively) and high (middle cluster) in 20 sites. The lowest sites (12) focused mostly on restoration of wetland and removal of invasive species, while there was a slower rate of change in health, based on the results of Axelsson et al. (2024). The analyses showed a very hierarchical relationship between the multivariate restoration outcome scores, were indicative of low intercorrelation between ecological variables and revealed a predictable way in which restoration outcome scores relate to each intervention type.

As these correlation values suggest, all of these measured parameters are strongly correlated to each other, and could therefore all be used as a good proxy for successful overall restoration. Aparsimony also helps simplify the monitoring protocols and lower costs of data collection since the responses of these restored ecosystems can be captured through one of them and their responses are multi-faceted (Prakash et al., 2025). The second one is that because of the strong correlations we are aware that by recovering one positive variable; in this case biodiversity, we would be given the chance to show a higher level or/or higher outcome of another positive variable that would in turn be climate mitigation. Given that several ecosystem services are considered to be capable of being restored simultaneously, the combined or synergic effect of ecosystem services is appealing, and can be used as a rationale to choose a multifaceted restoration strategy, rather than a single purpose restoration approach.

Discussion

A research of type that is not theory/ model oriented, but is based on actual work done in the field: this is a strong addition to the theory and policy of ecosystem restoration and management. Theoretically, the positive correlation between Biodiversity - Carbon sequestration (level) and Biodiversity - sustainability index in this case species richness will emphasize the connection between the level of biodiversity and functions of the ecosystem (Orenstein et al., 2025). The study reveals that restoration is not merely the reverse of degradation, restoring ecosystem processes one by one, but also the establishment of cascades of restoration benefits: ecosystem processes get more benefit from each other with increasingly successful restoration.This research shows that restoration can restore single ecosystems processes but that ecosystem recovery also triggers ecosystem recovery – restoration of one ecosystem process will affect other ecosystem processes. Following the aforementioned, the near unidimensionality of the PCA (with 78.4% of variance explained) enables using a restricted number of indicators like composite sustainability function to pin point associate multi-dimensional restoration outcomes by a single indicator, thereby making the theoretical framework of restoration ecology more simple (Yildirim et al., 2026). The development and formulation of the forward-looking prediction of restoration trajectories in various restoration design and practices (imported and exported foundation species) as well as various environmental conditions are important, depending on clear theory.

Evidence-based recommendations are made in a policy/practitioner oriented way based on the knowledge that is gained. A score of 96 per cent of sustainability indicators forest management – by community and 89 per cent on the forest rehabilitation – was achieved when forest management and forest rehabilitation were developed at the same time (by community and by ecology) and 93 per cent for forest rehabilitation. Therefore it is crucial to invest in conservation measures that emphasise governance arrangements that can transform local people into effective stewards, with a 76.1% increase noted in this study in local people's involvement in the conservation area's management. Furthermore, Carbon sequestration as a co-benefit of Biodiversity conservation can be quantified, monetized and can be a strategy identified for the restoration project/programme to be part of a national carbon commitment, for instance the ratification of 'Nationally Determined Contributions' (NDC) that are committed under the Paris Agreement. The interventions that can be performed repeatedly, are in between the extreme approaches, those with intensive plantation approach have a sustainability index of 89 points and perform high investment of actions and those with other experimental approach have a sustainability index of 24 points and have low investment in actions. Additionally, with a heterogeneous array of programs, or with good correlation among some indicators, one could calculate multidimensional restoration success at the landscape level with just one measure (e.g., habitat vegetation index) without needing to measure an additional ecological indicator (i.e., there is the option not to measure certain ecological indicators).

Results are very good, but there are certain methodological limitations that need to be taken into account when interpreting the results. Recovery times for some ecosystem components may exceed 3 years and this length of monitoring may not be sufficient to fully document the recovery time. The potential for C sequestration mitigating climate change may also be overestimated where stands grow rapidly during initial phases of development then slower rates of C sequestration are observed when stands mature, and are also correlated with residual C sequestration rates as observed in some rehabilitations of mangroves (particularly in rehabilitations where C inputs are significant and remain high throughout the stand's life cycle) (Nasruddin et al., 2025). The relatively large and representative number of 50 restoration sites across 5 ecosystem types is large when compared to most single site studies, but it may be that the sites within the 5 different ecosystem types were not representative of the fine-scale ecological variation occurring in each individual type—such as variation among soil types, hydrologic regimes, and disturbance histories. Furthermore, the present research was mainly observational/ correlation study, the pre-post comparisons for restorations were limited and only few statistically significant comparisons between pre and post were reported for each of the restorations and individual pre-post comparisons within each of the restoration types may have been due to confounding factors such as favorable climate throughout the study period or natural recovery within each of the studied period, or due to chance. However, more often than not, rating of challenges (such as using Likert scales) as part of the subjective assessment by practicioners could also indicate biases at the site level, for instance about the degree to which the climate change is rated as constraint and this may be biased on the level of media coverage of global issues currently as compared to their localized effects on restoration outcomes (Babu & VijayKumar, 2024).

Based on the constraints of these restrictions, there are some aspects of future studies, which can help to corroborate and expand the findings from the current research. Long-term long-term follow-ups (long-term duration) to confirm or challenge the persistence (or acceleration or deceleration) of rapid recovery trajectories would also need to be done to determine if the rapid recovery trajectories persist, speed up or slow down with longer-term follow-up as restored ecosystems mature and encounter variable environmental pressures over time. All of these studies should include multiple observations of all ecological parameters over time to identify important thresholds and tipping points to successful restoration. But, the relationships between biodiversity recovery and provision of ecosystem services (e.g. carbon sequestration, water quality regulation) explained by functional trait composition should be explored more explicitly in future studies, and process based modelling could support this. The use of a landscape approach would be very helpful for informing restoration at a landscape scale; here, it would involve understanding how landscapes need to be designed – in terms of the optimal width of ecologic corridors and their connectivity between various categories of agricultural and urban land use systems – in order to scale-up the restoration beyond the limits of a particular project site. Habitat fragmentation was the factor rated as most acutely limiting (4.62 average score), where such complexity is most needed. Also, the various reported co-benefits of socioeconomic benefits, such as a 44.9% rise in family income, should be further studied for possible socioeconomic implication of the restorations and evaluated their differences among the various socio-economic groups in communities. Other dimensions that are less studied and should be included in species selection in the future are restoration planning and climate change adaptation, to be included in testing how resilient communities will be to climate change scenarios, increased drying frequency and greater variety of climate extremes (Axelsson et al., 2024). Finally, comparative studies should be carried out in a subregional or regional context for comparison, from multiple socio-political contexts to forest governance institutions, to enable people to understand how transferable CBFM is at a lower institutional capacity, and at various/other culture contexts/relevant attitudes towards CBFM.

Conclusion

This study clearly outlines the empirical evidence that a restoration/biodiversity conservation project at a location can improve three dimensions of ecological integrity; carbon sequestration, habitat quality and socioeconomic well-being; and can offer a roadmap to environmental sustainability. Through systematic assessment of the 50 restoration sites in the different ecosystem types, sustainability index was found to be 96 and 93 for community forest management and mangrove rehabilitation, respectively, suggesting that these are the best interventions. Outcomes from restoration interventions that incorporate a systems level approach (and involve the social sphere) have resulted in higher sustainable benefits at multiple scales, including a 46.5% increase in number of species, a 44.9% increase in C sequestration and a 100% increase in household income. We have a key role in developing sound and robust step-change, multi-variate empirical links between biodiversity recovery, ecosystem function enhancement and benefits to the community that builds a bridge from theory to practice, driving progress in restoration ecology and delivering practical information for practitioners developing peoples and resources-based conservation programs that are scalable.

Even with the impressive list of problems discussed in this study, however, it should not be forgotten that two of them following the list (climates change – 4.62, and habitat fragmentation – 4.46) have been assigned the mean constraint score for problems that indicate the need for continued study, over monitoring periods of more than three years. Future research should include long-term (decadal) time series to gain a better understanding of the processes of recovery under climate change conditions and increasing climatic stress to the ecosystems as a result of long-term ecological maturing. Despite this being a very unidimensional dataset (78.4% of variance in the first principal component), our correlation matrix indicated that new simplified monitoring techniques relying on only one functional indicator might have the potential of decreasing the complexity of monitoring and thereby alleviate the logistical and kinetic limitations of comprehensive monitoring tasks; yet, the mechanisms driving the relationships between functional indicator composition and ecosystem service provision are limited and are still to be addressed with process-based techniques.

References

Ardiyansah, A., Seeburrun, G., & Lambert, S. M. (2026). Mangrove conservation and social-ecological resilience in a community-based coastal landscape of indonesia. *Journal of Academic Biology and Biology Education*.

Axelsson, E., Grady, K., Alloysius, D., Falck, J., et al. (2024). Lessons learned from 25 years of operational large-scale restoration: The sow-a-seed project, sabah, borneo. *Ecological Engineering*.

Babu, K., & VijayKumar, R. (2024). Enhancing biodiversity stability through climate adaptive ecosystem management. *Biodiversity Reports: An International Journal*.

Egule, T. J., & Angaware, E. E. (2025). Rethinking environmental sustainability in the niger delta. *NIGER DELTA RESEARCH DIGEST*.

Kok, M., Alkemade, R., Bakkenes, M., Eerdt, M. V., Janse, J., Mandryk, M., Kram, T., Lazarova, T., Meijer, J. R., Oorschot, M., Westhoek, H., Zagt, R., Berg, M. V., Esch, S. V., Prins, A., & Vuuren, D. (2018). Pathways for agriculture and forestry to contribute to terrestrial biodiversity conservation : A global scenario-study. *Biological Conservation*, *221*, 137–150.

Kumari, V., Sharma, A., Devineni, L., Das, D., Dr. Rajesh Bhaskar Survase, & Ghode, N. (2025). Environmental sustainability development, protection and restoration: Challenges for a green environment. *International Journal of Environmental Sciences*.

Nasruddin, Baderan, D. W., Rahim, S., Rauf, A., & Hamidun, M. S. (2025). Toward regenerative coastal seascapes: Integrating blue carbon, restoration ecology, and spatial planning across marine and coastal ecosystems. *International Journal of Research and Review*.

Olaitan, A., Ibrahim, A., Pauz, H. B. M., Abiola, A. F., Hassan, M. S. N. A., Ofonedu, U. M., Adedigba, B., Morenike, T. A., Olukemi, A. D., Olubukola, N. M., & Rami, A. (2026). Integrating traditional ecological knowledge in biodiversity conservation. *Journal on Innovation and Sustainability RISUS*.

Orenstein, D., Haim, S. D. -, & Shachak, M. (2025). A whole system diversity - ecosystem function framework for conservation and restoration in an arid mediterranean ecosystem. *ARPHA Conference Abstracts*.

Prakash, Dr. P., Gambhir, Dr. V., Patil, A., Choudhary, R., Wani, T., Praharaj, Dr. N. K., & Garg, A. (2025). Multiscale modeling of pollinator habitat restoration incorporating taxon-specific and regional conservation priorities. *Journal of Animal Environment*.

Yildirim, D. T., Yildirim, A. B., Martin, D., Beccari, T., Vicente, O., Radecka, I., Tchuenbou-Magaia, F., Marks, R. S., Lal, R., Prakash, S., Mechler, A., Milkov, M., Georgieva, S., Iliev, I., Kaneva, R., Gokce, N., Yaneva, G., Agova, N., Ivanova, N., … Dundar, M. (2026). Integrated biotechnological strategies for planetary health and ecosystem restoration. *The EuroBiotech Journal*, *10*, 81–102.