



Ecosystem Restoration in Vietnam: Cost, Investment Returns and Carbon Mitigation Benefits

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Abbreviations

GDP	Gross Domestic Product
IUCN	International Union for Conservation of Nature
LDVI	Land Degradation Vulnerability Index
MEA	Millennium Ecosystem Assessment
PFES	Payment for Forest Ecosystem Services
SDG	Sustainable Development Goal
UNCCD	United Nations Convention to Combat Desertification

Executive Summary

Vietnam's valuable ecosystems, ranging from dense forests and grasslands to mangroves and croplands, are experiencing significant degradation due to deforestation, unsustainable land management practices, and climate-related stressors. This study assesses the economic and environmental impacts of ecosystem degradation that occurred between 2001 and 2020, estimates the financial investment required for restoring these degraded ecosystems, and quantifies the potential returns in terms of economic gains and carbon mitigation potential.

Between 2001 and 2020, approximately 9.5 million hectares of Vietnam's land underwent changes, with notable transitions including:

- Conversion of grasslands into woodlands, croplands, and agroforestry systems,
- Deforestation accounting for significant shifts, leading to losses in carbon stocks and ecosystem services.

Key Findings:

1. Economic Costs of Ecosystem Degradation

- Degradation led to economic losses totaling the equivalent of 9 billion US dollars, driven primarily by deforestation.
- Net carbon losses from above- and below-ground biomass during this period of 2001-2020 due to ecosystems degradation are estimated at 450 million tons.

2. Investment Needs for Restoration (2020-2050):

- The total financial investment required under the Base scenario is \$14.8 billion USD, with forests restoration accounting for the largest share (\$11.3 billion USD).
- Investment needs increase to \$15.6 billion USD under the Optimistic scenario and \$16.4 billion USD in the Pessimistic scenario, reflecting uncertainties in restoration costs and ecosystem values.

3. Economic Returns on Restoration Investments:

- The average benefit-cost ratio is 3.1 in the Base scenario, signaling economically viable returns.
- Under favorable conditions (Optimistic scenario), the ratio improves to 5.4, demonstrating high economic and environmental gains.
- The Pessimistic scenario, with reduced economic conditions and higher costs, yields a benefit-cost ratio of 1.5.

4. Hotspots and Restoration Potential:

- Spatial analysis identified key hotspots for restoration, enabling policymakers to target areas with the highest potential for economic and ecological returns.
- Restoration activities, particularly in forests and mangroves, can significantly enhance carbon sequestration, offering opportunities for carbon trading and green financing.

Conclusions and Recommendations:

Restoring Vietnam's degraded ecosystems presents a critical opportunity to achieve economic, environmental, and social benefits. Strategic investments in restoration of degraded forest, grasslands, and mangrove ecosystems will:

- Support biodiversity and improve rural livelihoods,

- Strengthen Vietnam's resilience to climate change,
- Enhance carbon sequestration, contributing to global climate goals.

Decision-makers can consider:

1. Channeling targeted investments in high-return areas for ecosystem restoration,
2. Promoting synergies across land management, biodiversity conservation, and climate mitigation efforts,
3. Leveraging carbon markets and public-private partnerships to mobilize financing for ecosystem restoration.

Vietnam's strong commitment to ecosystem restoration is currently playing an essential role for ensuring sustainable development and enhancing rural prosperity.

1. Introduction

1.1. Rationale and Significance

Climate change, biodiversity loss, and land degradation are deeply intertwined global challenges that no country can effectively address in separation. This holds true not only at the international scale but also within individual countries, including Vietnam. Without limiting global warming to 1.5°C, climate change risks becoming the predominant driver of declining agricultural productivity, deteriorating rural livelihoods, and severe biodiversity losses in the decades ahead. Vietnam, like many other countries, faces these interconnected threats, as its varied landscapes – spanning from mountainous highlands to fertile river deltas – are already experiencing changes in land use and cover patterns that exacerbate these vulnerabilities. Land degradation in Vietnam, manifesting in soil erosion, declining soil fertility, deforestation, and coastal zone degradation, is not only diminishing ecosystem services and biodiversity but also contributing to climate change through the loss of soil carbon and increased greenhouse gas emissions.

Vietnam, a country rich in biodiversity and home to extensive agricultural and aquaculture systems, faces significant challenges and opportunities in land management and ecosystem restoration. Forests, which cover 47% of Vietnam's land area (Martius et al., 2023), play a crucial role in maintaining ecological balance and serve as a key carbon sink, helping mitigate emissions. While forest cover has increased in recent decades due to the expansion of planted forests, land degradation, salinity intrusion, and unsustainable agricultural practices remain pressing concerns, particularly in areas like the Mekong Delta where intensive rice cultivation and aquaculture take place. Vietnam's government has prioritized sustainable land management, promoting crop diversification, limiting triple rice cropping, and converting low-productivity saline fields into integrated systems, such as rice-shrimp farming, to restore degraded ecosystems. These efforts aim to balance economic development with environmental sustainability by enhancing soil health, managing water resources, and reducing greenhouse gas emissions. Moving forward, targeted ecosystem restoration initiatives, coupled with improved data on land use changes and emissions, will be vital for Vietnam to achieve its climate commitments and ensure the resilience of its landscapes and food systems.

In Vietnam, as elsewhere, landforms a critical nexus that interconnects climate change, biodiversity loss, and land degradation, while also holding profound importance for agricultural productivity and food security. Agriculture remains a cornerstone of Vietnam's economy and livelihoods. Although the share of agriculture in Vietnam's Gross Domestic Product (GDP) has declined over recent decades, it still employs a significant proportion of the workforce and is vital for rural communities. Millions of smallholder farmers, including many women, depend on land-based livelihoods for income. Even as Vietnam makes impressive strides in poverty reduction and economic growth, poverty is still concentrated in rural and agriculturally dependent areas. Thus, addressing the land-climate-biodiversity-agriculture nexus through integrated and synergistic approaches is imperative for the attainment of the Sustainable Development Goals (SDGs) and the realization of a sustainable, climate-resilient, and prosperous Vietnam.

Adopting an integrated perspective – where efforts to manage land degradation, conserve biodiversity, adapt to and mitigate climate change, and enhance agricultural productivity are coordinated – is essential for creating cost-effective and transformative solutions. Such synergy can boost the returns on national investments, optimize the use of financial resources, and steer the country toward a greener and more resilient growth path. Ecosystem restoration in Vietnam is not merely an environmental strategy; it is an economic necessity and a social imperative. The country's diverse ecosystems – ranging from mangrove forests and tropical rainforests to rich agricultural terraces – have historically underpinned its food security, rural incomes, and cultural heritage. However, unsustainable practices, and escalating climate threats have accelerated environmental degradation. Restoring these degraded landscapes will not only revitalize essential ecosystem services such as water regulation, soil fertility maintenance, and carbon sequestration but will also protect and enhance the resilience of agricultural systems, helping farmers adapt to climate change and sustain their livelihoods.

1.2. Study Objectives and Research Questions

This study focuses on evaluating the costs and benefits of ecosystem restoration activities in Vietnam.

The research pursues three core objectives:

- **Objective 1:** Demonstrate the environmental and economic benefits of ecosystem restoration, including in terms of its carbon mitigation potential.
- **Objective 2:** Identify hotspots for ecosystem restoration programming. By mapping degraded areas and estimating investment needs, the study provides a tool for policymakers and investors to pinpoint priority locations for cost-effective action and to guide the development of financial strategies for land restoration investments.

These objectives guide the research in answering a set of practical, interrelated questions:

- What is the current extent and cost of land degradation in Vietnam? Where are the degradation hotspots, and how have these changed between 2001 and 2020?
- What are the total financing requirements for restoring degraded ecosystems in Vietnam?
- Which degraded landscapes offer the highest returns on investments in land restoration?

By systematically examining these questions, the study aims to contribute robust, actionable knowledge. This will support Vietnam's pursuit of sustainable land management solutions that simultaneously conserve biodiversity, enhance climate resilience, bolster agricultural productivity, and strengthen rural livelihoods.

2. Literature review

Vietnam has intensified efforts to restore degraded ecosystems and conserve biodiversity as part of its commitment to global environmental goals. Facing significant impacts from climate change, the country has developed legal mechanisms, strategies, and projects to protect natural forests, oceans, and mangrove ecosystems, while safeguarding endangered species. Vietnam aligns these efforts with international frameworks such as the Convention on Biological Diversity and has established a National Strategy on Biodiversity (2021-2030, with orientation to 2040) to ensure coordinated legal and institutional support for restoration initiatives. By engaging multiple stakeholders – including ministries, scientists, local administrations, and communities – and raising public awareness of biodiversity's role in sustainable development, Vietnam seeks to contribute to global conservation targets. Aligning policies with the UN Decade of Ecosystem Restoration further signals the country's intent to reverse biodiversity loss through sustainable management and enhanced cooperation (Anh Huyen, 2021). Vietnam has also taken significant strides towards Land Degradation Neutrality (LDN), aligning its national policies with global frameworks such as the UNCCD and Sustainable Development Goals. LDN initiatives are prioritized in regions with high land degradation risks, particularly the Northwest, Central Coast, and the Mekong Delta. Challenges remain, such as limited funding, legal gaps, and incomplete land use policies.

Moreover, despite these commitments, large-scale assessments reveal persistent challenges in addressing deforestation and forest degradation. Khuc et al. (2018) analyzed forest changes in Vietnam from 2000 to 2010, identifying approximately 1.77 million ha of forests lost and 0.65 million ha degraded. The most affected regions included the north central, northeast, northwest, and central highlands. Key drivers of forest loss – poverty, population growth, weak governance, and agricultural expansion – underscore the need to integrate poverty reduction, and improved governance into Vietnam's forest management policies.

Mangrove ecosystems are a key focus of restoration. Over the past three decades, an estimated 200,000 ha of mangroves have been reforested, but the outcomes have been mixed. Hai et al. (2020) found that while significant areas were replanted, poor site and species selection, inadequate understanding of hydrology, and lack of long-term monitoring limited ecological recovery. Monoculture planting, especially of *Rhizophora* species, often failed to restore full ecosystem functionality or biodiversity. Similarly, Pham et al. (2022) documented substantial successes in the Mekong Delta – high-resolution satellite imagery revealed a net increase of 11,184 ha of mangroves between 2015 and 2020 – yet this progress was accompanied by the loss of 16,138 ha due to aquaculture expansion, land

conversion, and coastal erosion. These findings highlight the vulnerability of restored mangroves to ongoing anthropogenic and climate stressors, emphasizing the need for co-management approaches, improved site selection, and rigorous monitoring frameworks.

Beyond mangroves, forest landscape restoration efforts extend to other regions and ecosystems. In Quang Tri Province, the International Union for Conservation of Nature (IUCN) applied the Restoration Opportunities Assessment Methodology (ROAM) to address degradation caused by acacia monocultures and unsustainable agricultural practices. The study identified 54,000 ha of priority areas for restoration and recommended measures such as enrichment planting, extended rotations, and soil and water conservation. These actions could increase carbon sequestration (up to 97 tCO₂e/ha) and enhance biodiversity, but financial, technical, and incentive-related hurdles still hinder long-term sustainability (IUCN, 2021).

Further north, the NATURE+ Vietnam Scoping Study (2023) examined the causes and context of land degradation in Lao Cai and Son La provinces. Although tree planting efforts since the 1990s have increased forest cover, the reliance on short-rotation monocultures of exotic species like *Acacia* and *Eucalyptus* has limited ecosystem services. Unsustainable agricultural practices – slash-and-burn cultivation, herbicide overuse, and clear-cut harvesting – along with weak governance and population pressure, have exacerbated degradation on sloping lands. Key lessons from past projects underscore the importance of agroforestry models, enhanced technical capacity, and alignment with national policies, such as Vietnam Forestry Development Strategy (2021–2030). Co-designing restoration solutions that integrate traditional knowledge with modern techniques, strengthening incentives for local participation, and improving enforcement and financial support are critical steps forward.

At a provincial scale, localized assessments reveal the complexity of degradation drivers and adaptation strategies. In Binh Thuan Province, Gobin et al. (2020) documented how climate variability – especially prolonged drought – and population pressures reshaped land use. Between 1990 and 2019, agricultural land expanded at the expense of forests, leading to desertification, soil erosion, and groundwater salinization. Wealthier households with irrigation access adapted by diversifying crops, but poorer communities remained vulnerable. Similarly, Nguyen et al. (2024) used a Land Degradation Vulnerability Index (LDVI) in Phu Yen Province, identifying vulnerable districts with steep slopes, poor soil quality, and low rainfall. Unsustainable terracing, inadequate water management, and climate stressors, such as high land surface temperatures and drought, intensified degradation risks. Both studies emphasize the importance of integrated monitoring, sustainable land use practices, and targeted policy interventions to build resilience in vulnerable areas.

Governance regimes also shape restoration outcomes. Nguyen et al. (2020) assessed how different forest governance models – involving state-based, community-based, and individual-based regimes – influenced land use/land cover changes, forest ecosystem services (FES), and their economic values in the Northwest uplands. Community-based governance outperformed private, individual-based regimes and matched state-based approaches in fostering carbon sequestration, sediment retention, and water yield benefits. While community-based and state-based scenarios supported natural forest expansion and enhanced ecosystem services, water yield declined under both due to increased forest cover. In contrast, individual-based regimes favored planted forests with limited FES improvements, reflecting weak incentives for sustainable management under Vietnam’s Payment for Forest Ecosystem Services (PFES) program. These results highlight the need for governance structures that balance environmental sustainability with socio-economic benefits, reinforcing the value of community engagement and well-designed incentive mechanisms.

3. Conceptual basis for economics of ecosystems restoration

The United Nations Convention to Combat Desertification (UNCCD) defines land restoration as “the process of avoiding, reducing, and reversing land degradation to recover the biodiversity and ecosystem services that sustain all life on Earth. Land restoration refers to a regenerative process along a continuum of land and water management practices adapted to local conditions and societal choices – applied to conserve natural areas, sustainably manage production landscapes, such as agriculture and forestry, and recover past ecological integrity” (UNCCD, 2022). This definition implies that land restoration efforts should not be limited to a single action – such as planting trees on a previously deforested site – but rather should strive to revive the full complexity of the original ecosystem. This includes re-establishing a diverse array of plant and animal species, restoring essential soil functions, re-creating structural habitat features, and re-establishing the intricate interconnections among various organisms and their

physical environment. In other words, while planting trees may help restore some ecosystem services, the true goal of restoration is to reassemble the entire mosaic of biotic and abiotic components that once thrived there, along with the ecological processes and interactions that sustained them over time (Mirzabaev and Wuepper, 2023).

This approach recognizes that ecosystems are more than just collections of species; they are dynamic networks of interacting elements – soil, water, plants, animals, and microorganisms – that together generate valuable ecosystem services (Table 1). These services form what is often referred to as “natural capital,” a concept underscoring that nature’s benefits have tangible economic, social, and cultural value (Mirzabaev and Wuepper, 2023). The Millennium Ecosystem Assessment (MEA) provides a widely recognized framework for understanding these benefits, classifying ecosystem services into four main categories: provisioning (such as food, timber, and freshwater), regulating (such as climate regulation, flood control, and pollination), habitat (which includes services that maintain biodiversity and life cycles), and cultural (such as recreational, spiritual, and aesthetic values). Within these categories, the MEA identifies 22 distinct types of ecosystem services that collectively underpin human well-being (Mirzabaev and von Braun, 2022).

To better capture the economic significance of these services, analysts often apply the Total Economic Value (TEV) approach. This method assigns monetary values to the full spectrum of ecosystem services, allowing decision-makers to more clearly recognize the economic losses incurred by degradation and the potential gains from restoration (MEA, 2005). By quantifying these values, stakeholders – from local communities to government policymakers – can make more informed choices about where and how to invest in restoration. In doing so, they can prioritize strategies that not only bring back forests, wetlands, and grasslands to a healthy, vibrant state, but also revitalize the essential functions – carbon storage, nutrient cycling, water purification, pollinator habitats, cultural identity, and more – that directly support human livelihoods and the broader socio-economic fabric (Mirzabaev et al., 2025).

Table 1. Millennium Ecosystem Assessment nomenclature of ecosystem services

Provisioning services	Regulating services	Habitat services	Cultural services
Food, Water, Raw materials, Genetic resources, Medicinal resources, Ornamental resources	Air quality regulation, Climate regulation, Disturbance moderation, Regulation of water flows, Waste treatment, Erosion prevention, Nutrient cycling, Pollination, Biological control	Nursery service, Genetic diversity	Esthetic information, Recreation, Inspiration, Spiritual experience, Cognitive development

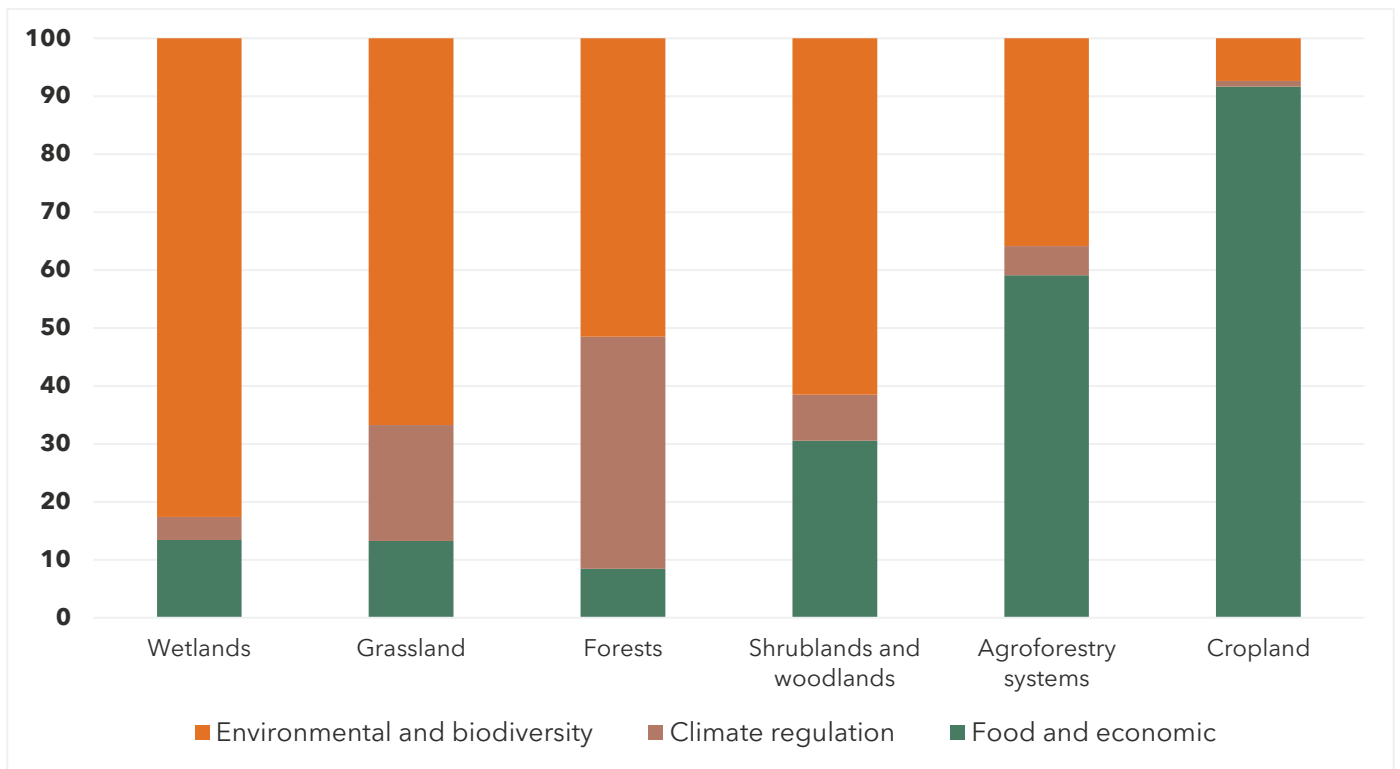
Source: MEA (2005)

Figure 1 presents a synthesized overview of how different types of ecosystems yield a spectrum of economic values, as assessed through the Ecosystems Services Valuation Database (ESVD) (Brander et al., 2024). The figure organizes these economic values into three primary categories: (1) food and other economic services, (2) climate regulation (including carbon sequestration), and (3) environmental and biodiversity-related services. This classification highlights that each ecosystem provides a distinctive balance of benefits. For instance, some landscapes may be particularly valuable for food production and economic returns, while others may excel at stabilizing the climate or preserving essential habitats for diverse species. Such a categorization underscores the multifaceted contributions that ecosystems make to human well-being and ecological resilience. By illustrating these differences, Figure 1 conveys that no single ecosystem excels in all service categories; instead, the value each environment offers depends on its inherent ecological features, the species it supports, and the human and natural processes that shape it.

Mangroves, for example, yield the vast majority – nearly 90% – of their total economic value through environmental and biodiversity services. This emphasizes their irreplaceable role in sustaining essential habitats, regulating water quality, and supporting a wide range of species. In comparison, the contribution of wetlands to food production is modest, and their role in climate regulation is minimal, further underscoring their primary function as biodiversity hotspots rather than as sources of agricultural output or substantial carbon sequestration.

Grasslands exhibit a more balanced value profile. Approximately 60% of their economic worth comes from environmental and biodiversity services, such as providing habitats for wildlife and maintaining soil health. Another 30% is derived from food and economic services, reflecting their utility in supporting grazing and other forms of productive land use. Although climate regulation makes up a smaller portion of the value delivered by grasslands, it still indicates their capacity to influence local and regional climate conditions.

Figure 1. Shares of economic values of ecosystem services in different ecosystems (in percentages)



Source: Mirzabaev et al. (2025a)

Forests stand out for their substantial contribution across all three service categories. Around half of their economic value is tied to environmental and biodiversity services, acknowledging forests’ critical importance as reservoirs of species richness and natural capital. They also deliver around 30% of their value through climate regulation, showcasing their vital role in carbon storage and stabilization of the global climate. Although smaller in proportion, the remaining 20% of their value is associated with food and economic services – such as timber, non-timber forest products, and other forest-derived resources – highlighting the multifunctionality of forest ecosystems.

Shrublands and woodlands share certain traits with forests in terms of the dominance of environmental and biodiversity services, which account for around 60% of their total value. However, these ecosystems also deliver roughly 20% each in terms of climate regulation and food and economic services, underscoring their ability to support both ecological integrity and human livelihoods, albeit at somewhat lower levels than forests.

Agroforestry systems, by design, lean more towards food and economic services, which make up about 60% of their value. This is largely due to the integration of tree crops with agricultural production, offering both economic benefits and improved land-use efficiency. Nevertheless, agroforestry systems still maintain a solid contribution – around 30% – to environmental and biodiversity services, along with a smaller yet meaningful input to climate regulation. This blend illustrates their potential as a sustainable land-use strategy that meets human needs while fostering ecological resilience.

In contrast, croplands are heavily skewed toward food and economic services, surpassing 90% of their value in this category. They deliver minimal environmental and biodiversity benefits and almost negligible climate regulation contributions. This pattern is consistent with the intensive use of croplands for producing food and other commercially valuable goods, often at the expense of broader ecological functions.

Figure 1 highlights the varying strengths and capacities of different ecosystem types. Mangroves and forests are pivotal for sustaining biodiversity and moderating climate; croplands and agroforestry systems excel at providing food and economic returns; grasslands, shrublands, and woodlands occupy more intermediate roles with a mix of values. These distinctions reinforce the importance of adopting targeted land management and conservation strategies that build upon each ecosystem’s inherent advantages. By doing so, it is possible to optimize the delivery of the ecosystem services that communities and economies depend on, ensuring that decisions about land use and restoration are informed by a nuanced understanding of each ecosystem’s unique value profile.

4. Research Approach and Methodology

4.1. Costs and Benefits of Land Restoration

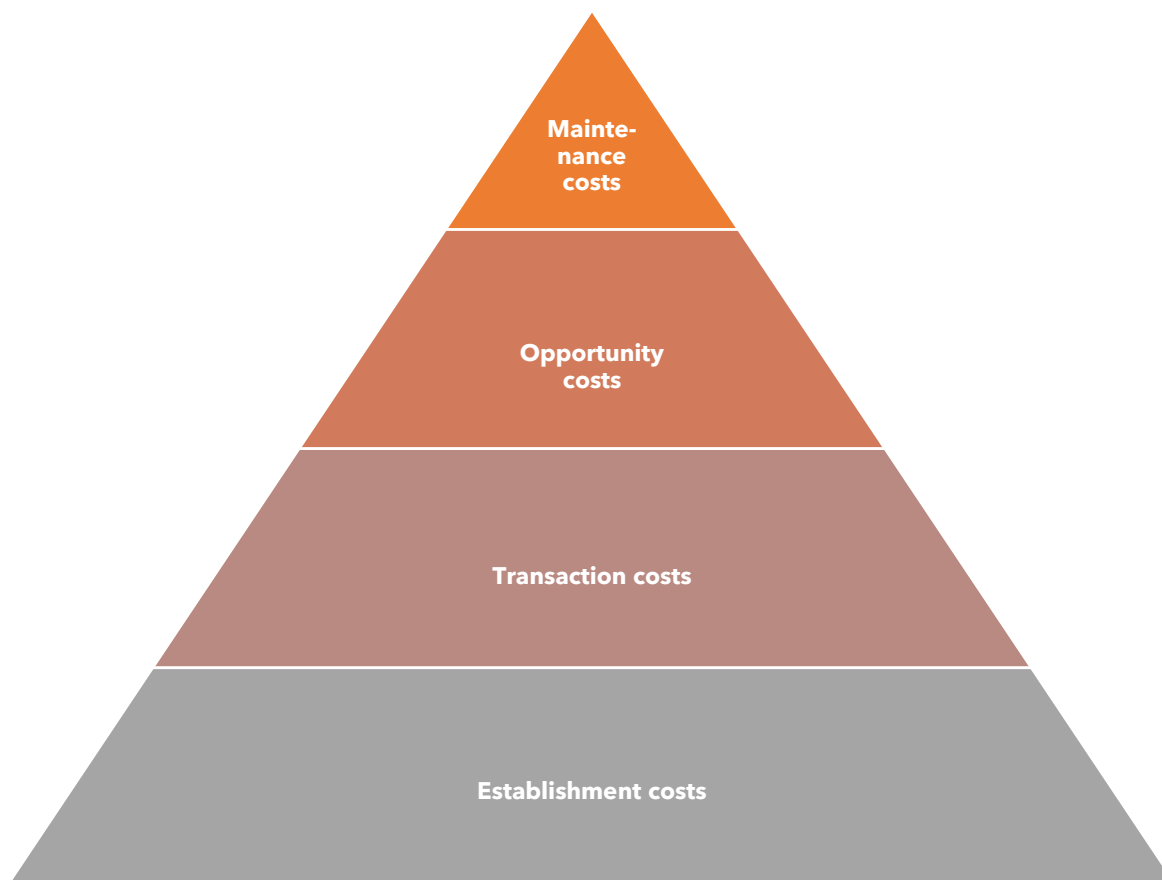
Restoring degraded ecosystems incurs four main categories of costs – establishment, maintenance, opportunity, and transaction costs – each of which can significantly influence the overall expense and viability of restoration efforts (Mirzabaev and Wuepper, 2023) (Figure 2).

Establishment costs refer to the initial expenses needed to initiate restoration activities. These may include preparing the land, acquiring materials like seeds or seedlings, and undertaking the labor required for tree planting, soil amendments, or other restoration practices. For instance, in a reforestation program, all one-time expenses associated with planting trees – such as buying saplings, paying for fieldwork, and ensuring proper soil conditions – would be considered establishment costs.

Maintenance costs arise after the initial setup and are tied to the ongoing upkeep of restored ecosystems. These can include costs for watering, weeding, pest control, monitoring plant health, and conducting periodic maintenance to ensure that restoration efforts remain effective over time. Although related to establishment costs, maintenance expenditures occur regularly and ensure that the initial investments lead to long-lasting ecological recovery.

Opportunity costs encompass the foregone benefits that would have been obtained if the land remained under its previous use. For example, converting a productive cropland into a reforested area means giving up the income that could have been generated from crops. Accounting for these opportunity costs is critical because it reveals the true economic trade-offs involved, ensuring that decision-makers are aware of what is being sacrificed to restore the land.

Figure 2. Types of costs for restoring degraded ecosystems



Transaction costs involve the expenses related to planning, organizing, and overseeing restoration initiatives. These may include identifying suitable sites, coordinating among multiple stakeholders, obtaining permits, conducting negotiations, and monitoring outcomes.

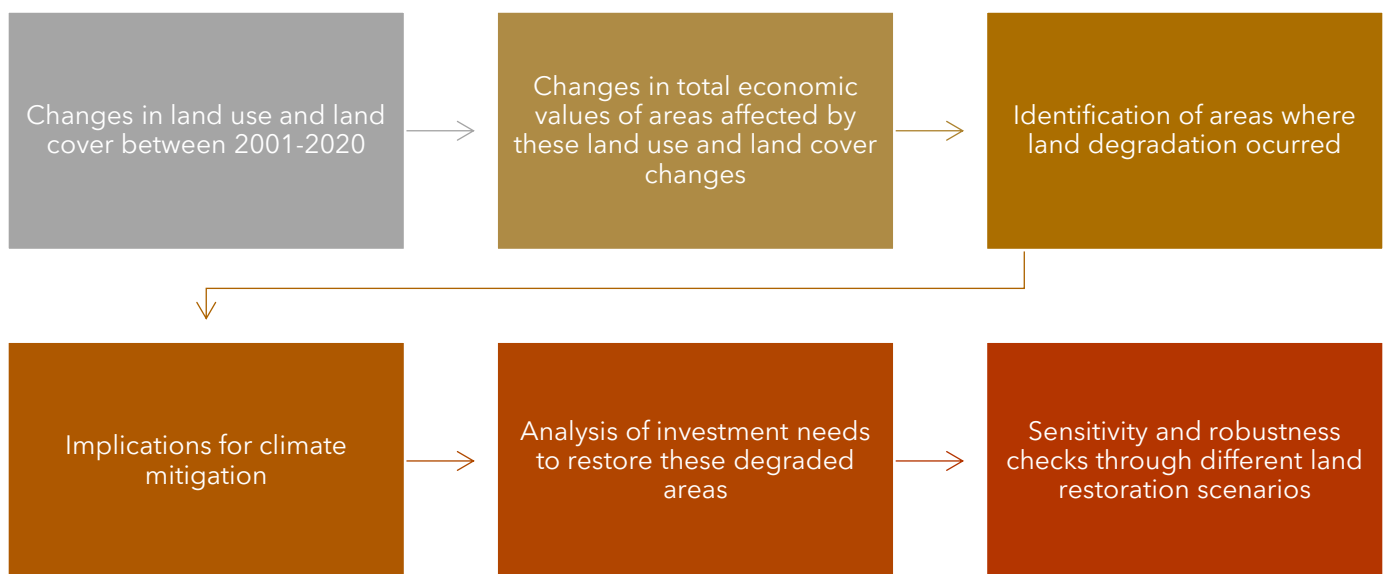
Minimizing transaction costs can be achieved through better coordination and synergy among various stakeholders and activities. By streamlining communication, sharing resources, and reducing duplicative efforts, it becomes possible to increase both the effectiveness (achieving the restoration goals) and efficiency (achieving them at lower costs) of land restoration projects. In this way, fostering synergies not only saves money but also enhances the likelihood of successful, long-term ecological recovery.

This analysis employed a multi-step approach to assess the costs of land degradation and the potential benefits of restoration (Figure 3):

First, high-resolution (500-meter) MODIS satellite data on land use and land cover (LULC) changes (Friedl and Sulla-Menashe, 2019) were examined for Vietnam over the period 2001–2020. The year 2001 served as a baseline, and 2020 as an endline, chosen due to the availability of consistent, comparable remote sensing data. Through this analysis, it was determined that about 9.5 million hectares experienced LULC changes within these two decades.

Second, the identified LULC changes were categorized by ecosystem type, including forests, woodlands, shrublands, mangroves and wetlands, grasslands, croplands, and barren lands. This classification enabled a detailed understanding of how various ecosystems expanded, contracted, or transitioned over the study period.

Figure 3. Analytical process for identification of land degradation hotspots, costs of land degradation, investment needs and returns from land restoration



Third, total economic values (TEVs) for each ecosystem type (Table 2) were applied to the observed LULC changes. Using this valuation framework, any transition resulting in decreased overall TEV was classified as land degradation. In other words, wherever land cover shifts led to reduced ecosystem services – from biodiversity support to carbon sequestration and beyond – those areas were flagged as degradation hotspots.

Fourth, an in-depth analysis of the implications of these changes followed. Above- and below-ground carbon fluxes were evaluated using data from Spawn and Gibbs (2010), allowing the study to quantify carbon-related impacts.

Fifth, the study estimated the investment required to restore these degraded ecosystems by incorporating cost data (Table 2). This provides practical insights into the financial outlays needed to reverse degradation, helping policymakers and stakeholders understand the potential scale and economic implications of restoration initiatives.

Finally, the sensitivity and robustness of the outcomes were tested by running optimistic and pessimistic scenarios. These scenarios varied key parameters, including ecosystem service values and restoration costs (Table 3).

Table 2. Ecosystem values and land restoration costs

Ecosystem values and land restoration costs (USD/ha)	Forests	Woodlands and shrublands	Mangroves and wetlands	Croplands	Grasslands
Ecosystem values	7,000	4,349	10,787	2,874	3,707
Establishment costs	1,000	300	4,000	500	250
Maintenance costs	250	200	300	100	100

Source: *Ecosystem Services Valuation Database (ESVD)*, Mirzabaev and Wuepper (2023)

Table 3. Scenarios and associated modelling parameters

Scenarios	Ecosystem values	Establishment and maintenance costs	Time horizon (years)	Discount rate (%)	Ecosystem survival rates (%)	Transaction costs
Base scenario	Table 3	Table 3	30	10	60%	25%
Pessimistic scenario	30% lower	30% higher	30	10	30%	25%
Optimistic scenario	30% higher	30% lower	30	10	60%	25%

Dealing with uncertainty in ecosystem values and restoration costs: We have used readily available information and data on the values of ecosystem services and restoration costs (establishment and maintenance costs) for Vietnam and applied the benefit-transfer¹ approach to impute those values for Vietnam based on the data from similar settings in Asia. Uncertainty caused by measurement errors and changing human behavior already exists even in very local studies (e.g. in one single given watershed, or protected area). However, in large-scale national studies which need to use the benefit-transfer approach, this uncertainty is further amplified. The only practical way to deal with this uncertainty is through scenario analysis. Therefore, we are testing the robustness of our findings by including 30% upward and downward ranges to address uncertainty in our findings (Table 3).

5. Results

There have been significant transitions across various land use and land cover (LULC) types over the period from 2001 to 2020 in Vietnam on the total area of about 9.5 million hectares (Table 4, Figure 4).

Table 4. Land use and land cover changes in Vietnam, 2001-2020

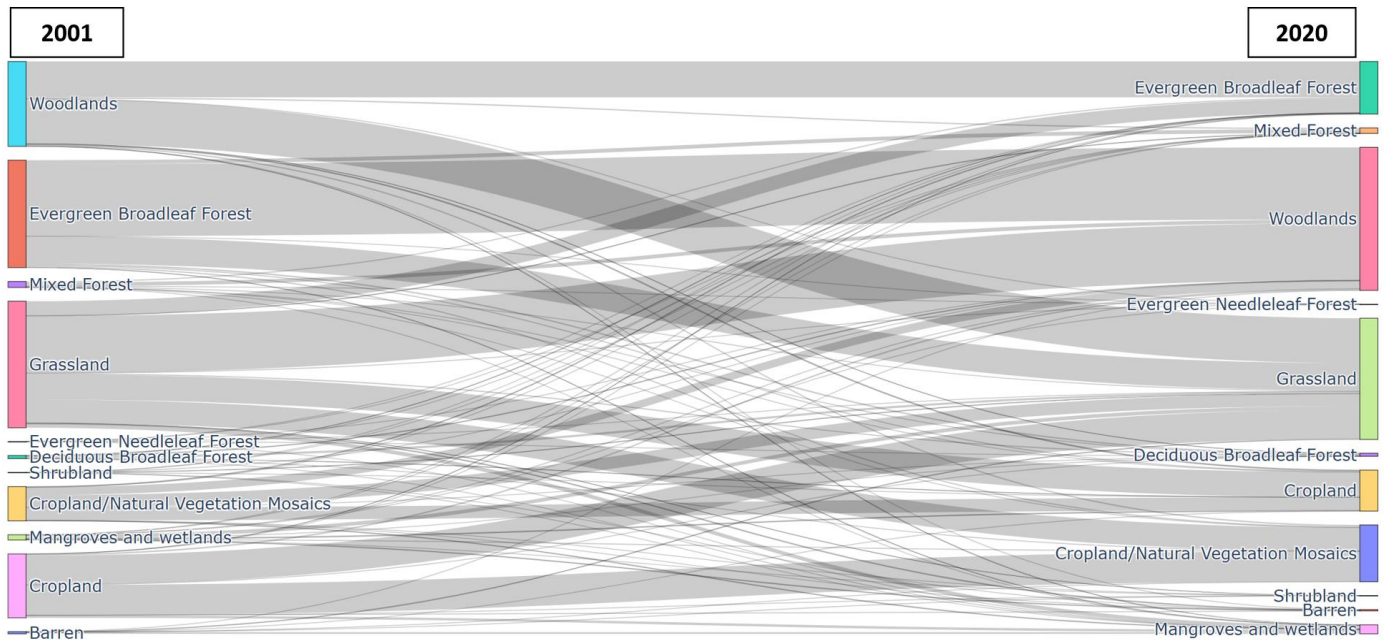
Land use and land cover in 2001	Land use and land cover in 2020											Total
	Evergreen Needleleaf Forest	Evergreen Broadleaf Forest	Deciduous Broadleaf Forest	Mixed Forest	Shrublands	Woodlands	Grassland	Mangroves and wetlands	Cropland	Cropland/Natural Vegetation Mosaics	Barren	
Evergreen Needleleaf Forest		148	44	222		534	163	222				1,334
Evergreen Broadleaf Forest	563		32485	84385		1585503	598861	5572	24453	26898		2,358,722
Deciduous Broadleaf Forest		4565		697		10033	46609	104	5157	1497		68,661
Mixed Forest	222	24957	2060			82281	20852	267	860	222		131,720
Shrubland		74		44		607	6595	15	15		89	7,439
Woodlands	1112	788958	4224	27669			986093	7217	19325	30070	89	1,864,756
Grassland	489	316288	26424	8818	3809	1253979		85526	550178	517974	14079	2,777,564
Mangroves and wetlands	311	2682	119	282	15	2149	81140		15354	2475	11975	116,500
Cropland		4016	445	104	563	33360	644048	51381		668145	2104	1,404,165
Cropland/Natural Vegetation Mosaics		13412	148	178	89	174357	269398	11678	284085		59	753,404
Barren					1319	44	9396	36783	15	30		47,587
Total	2,697	1,155,100	65,949	122,398	5,794	3,142,847	2,663,154	198,766	899,441	1,247,310	28,395	9,531,853

Source: based on data from Friedl and Sulla-Menashe (2019). Note: The definitions of the ecosystems are according to the International Geosphere-Biosphere Programme (IGBP), see Annex 1 for details

¹ The benefit-transfer approach is method used in ecosystem valuation to estimate the economic value of ecosystem services in one location or context by applying value estimates derived from studies conducted in a different location or context. It is often employed when primary valuation studies, such as contingent valuation or choice experiments, are too costly, time-consuming, or impractical to conduct.

The biggest changes involved shifts between grasslands and other land use and cover categories (2.7 million ha), with grasslands primarily shifting to woodlands (1.2 million ha), cropland (0.55), cropland/natural vegetation mosaics (0.51 million ha) - which broadly correspond to agroforestry systems, and forests (0.35 million ha). The second biggest area change involved deforestation, with about 2.2 million ha of forests shifting to grasslands and woodlands. There have also been important shifts from woodlands to forests (0.78 million ha) and grasslands (0.98 million ha). Two major trends in land use change in Vietnam of these two decades were deforestation when denser forests and shifting to less dense woodlands, and expansion of agroforestry systems in croplands.

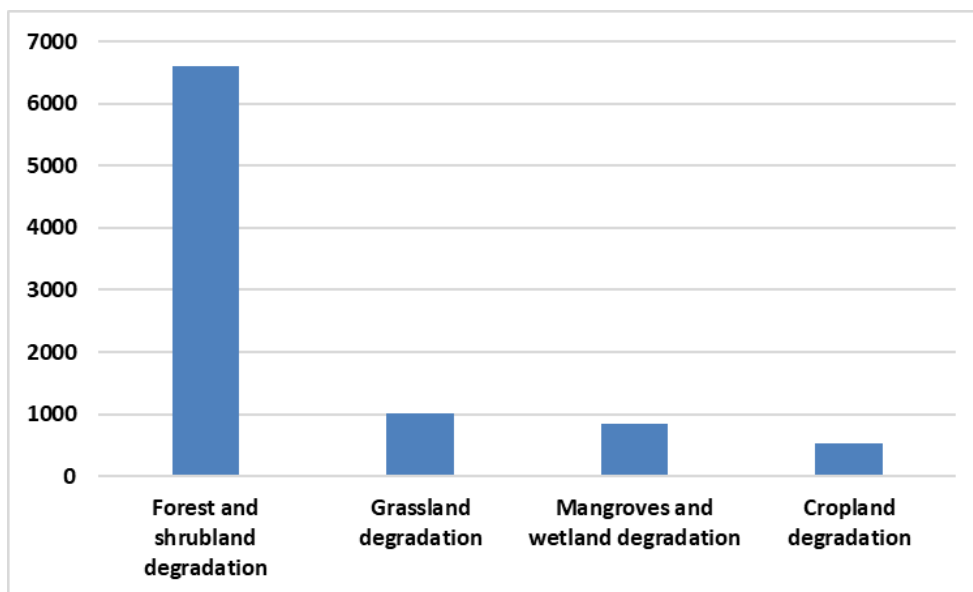
Figure 4. LULC changes in Vietnam, 2001 (left)-2020 (right)



Source: author's representation, based on data from Friedl and Sulla-Menashe (2019)

These land use and cover shifts led to ecosystem degradation with costs tolling the equivalent of 9 billion US dollars during this period. The biggest source of economic costs was due to deforestation through losses of forests, shrublands and woodlands (6.6 billion US dollars, followed by losses of grassland ecosystems, mangroves and wetlands, as well as croplands (Figure 5). Spatially explicit identification of the locations of ecosystem degradation are given in Figure 6.

Figure 5. Costs due to losses of valuable ecosystems in Vietnam (2001-2020), in millions of US dollars

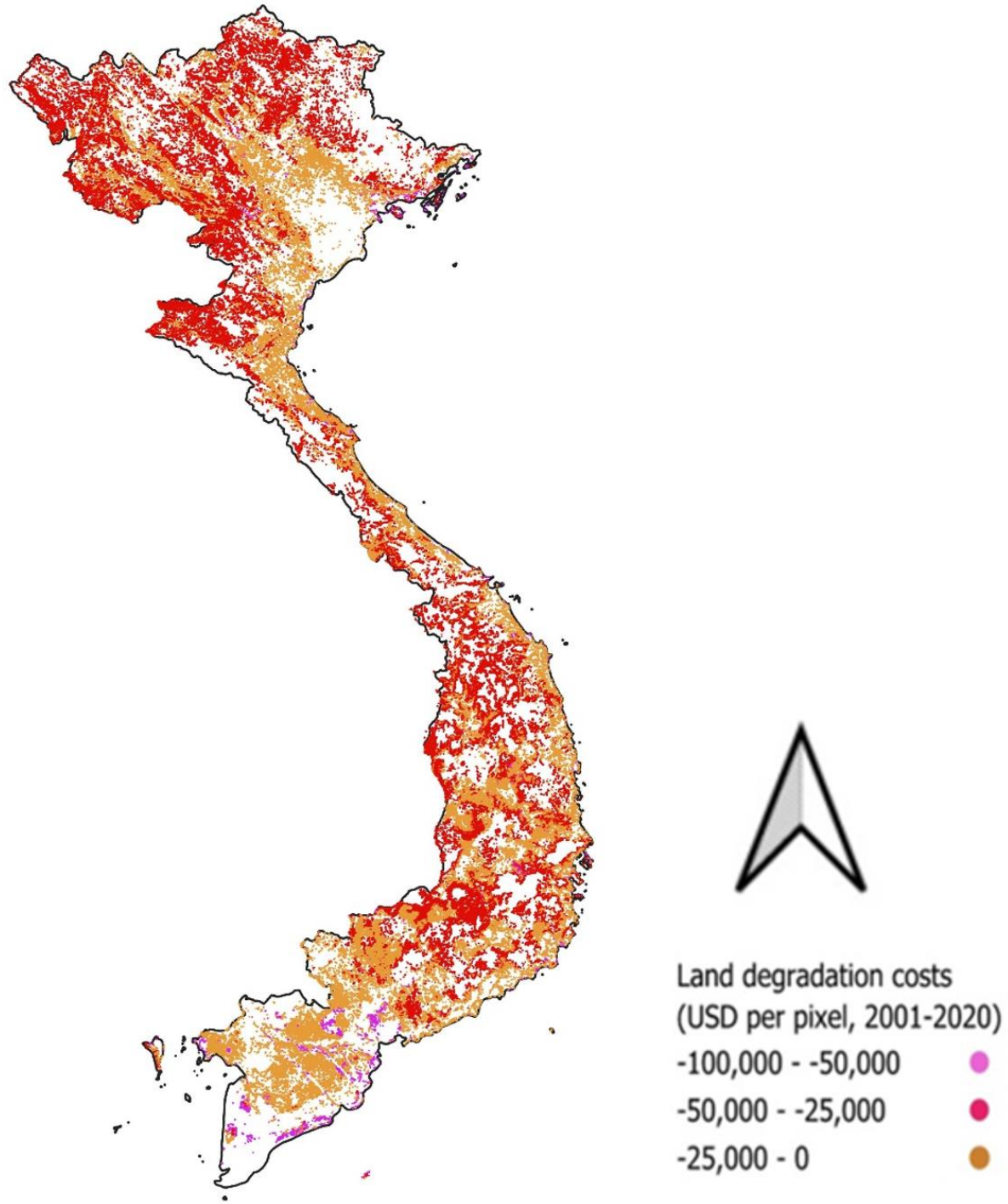


Source: author's analysis

As a result of this ecosystems degradation over the period of 2001-2020, the net losses in carbon in above and below ground biomass are estimated to equal about 450 million tons of carbon. The biggest source of carbon losses occurred due to deforestation.

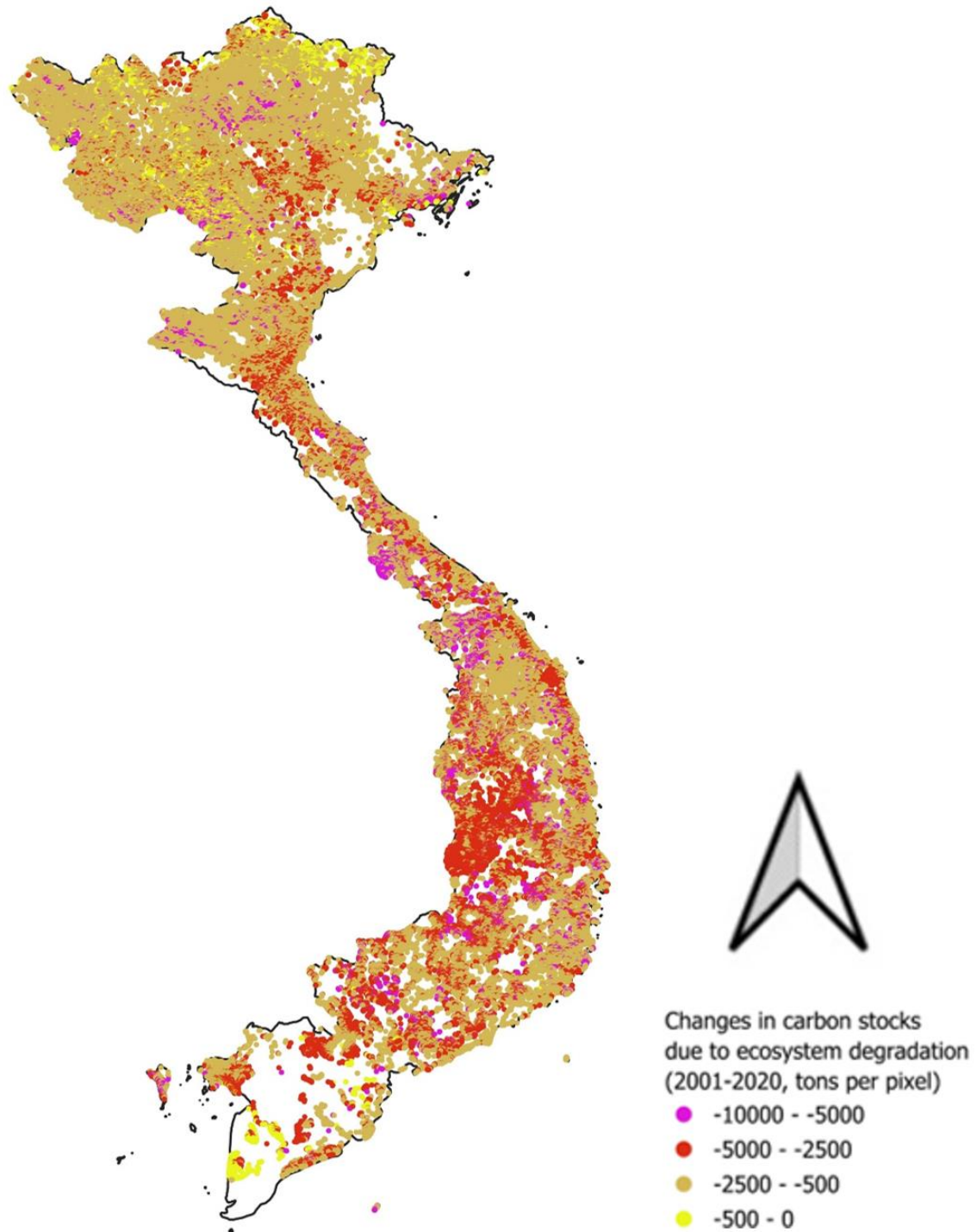
The results of the investment needs analysis for ecosystem restoration in Vietnam reveal substantial economically viable and environmentally sustainable opportunities for land restoration. The returns from land restoration activities will vary depending on future economic conditions (Table 5). In the Base scenario, the total investment required amounts to 14.8 billion US dollars, with the highest investment needs required for forest restoration. The average benefit-cost ratio in this scenario stands at 3.1 over the period of 2020-2050 for the whole region.

Figure 6. Hotspots of ecosystem degradation in Vietnam



Source: author's analysis, base scenario. Note: The depicted total area over which ecosystems degradation is equal to 4.4. million ha

Figure 7. Losses of carbon sinks in Vietnam due to ecosystem degradation (2001-2020)



Source: author's analysis using data from Spawn and Gibbs (2010). Note: The depicted total area over which ecosystems degradation is equal to 4.4. million ha

In comparison, the Optimistic scenario shows an increased total investment need of 15,583 billion US dollars, reflecting the opportunity of restoring a larger extent of degraded lands in an economically profitable and environmentally sustainable manner. This scenario also boasts an improved benefit-cost ratio of 5.4. Conversely, the Pessimistic scenario portrays a less favorable economic and climatic outlook, with total investment needs going up to 16.4 billion US dollars due to higher ecosystem restoration costs, while the average benefit-cost ratio drops to 1.5, signaling reduced economic returns and potential challenges in justifying investment under less favorable economic conditions (Table 5). Figure 8 presents a spatially explicit depiction of returns from ecosystem restoration investments under the base scenario over the period of 2020-2050.

Table 5. Investment needs in millions of USD for land restoration (2020-2050)

Restoration of	Base scenario	Optimistic scenario	Pessimistic scenario
Forests	11,257	11,257	15,493
Shrublands	1,511	2023	6
Mangroves and wetlands	965	937	876
Restoring grasslands	39	50	35
Croplands-natural vegetation mosaics	1,024	1311	1
Croplands	4	5	3
Total	14,800	15,583	16,414

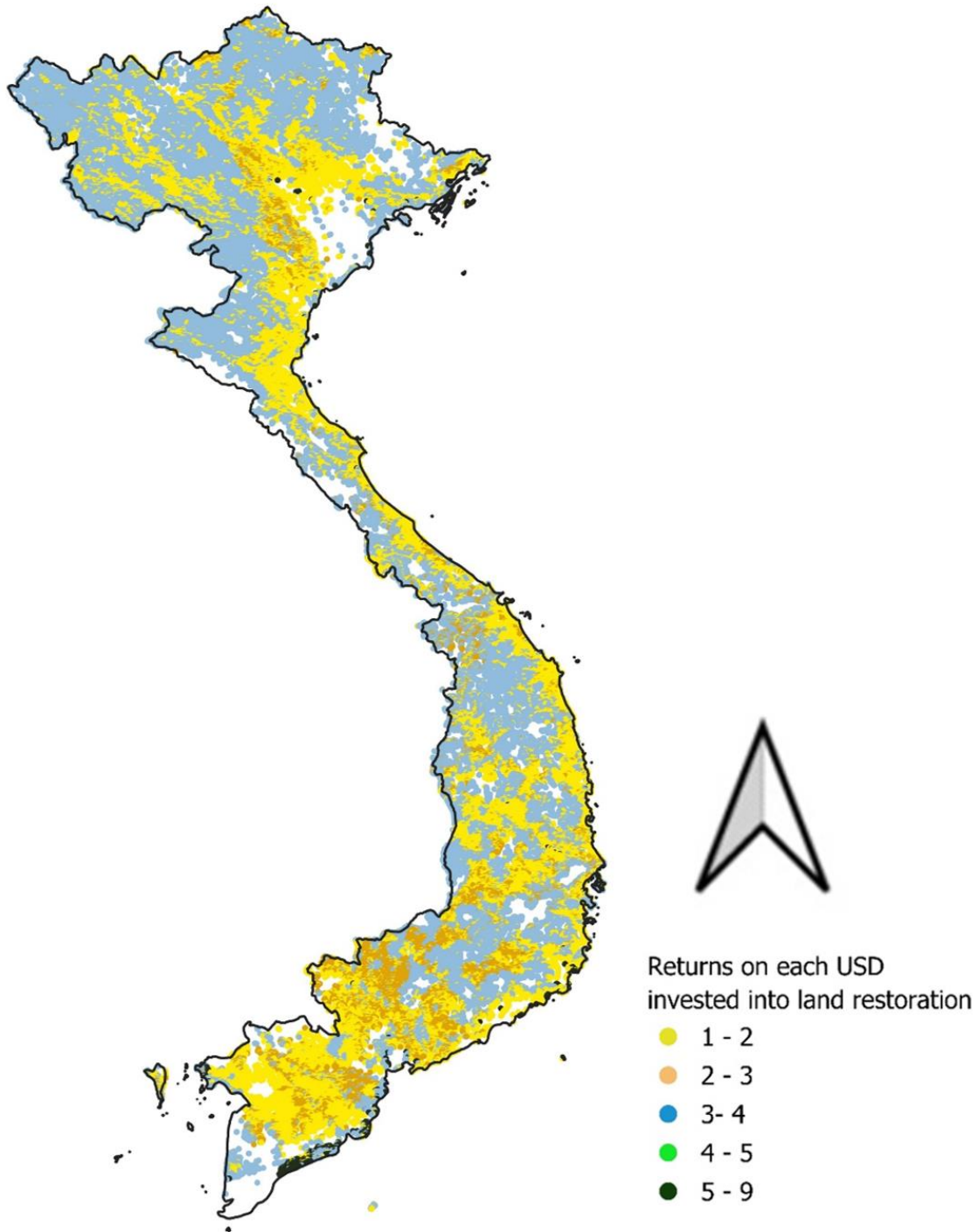
Source: author's analysis

Table 6. Benefit-cost ratios of investments for ecosystem restoration (2020-2050)

Restoration of	Base scenario	Optimistic scenario	Pessimistic scenario
Forests	4.1	7.6	1.5
Shrublands	1.4	1.9	5.5
Mangroves and wetlands	5.2	9.9	2.9
Restoring grasslands	8.1	11.4	4.4
Croplands-natural vegetation mosaics	1.4	2.0	4.0
Croplands	15.0	21.0	9.5
Total	3.1	5.4	1.5

Source: author's analysis

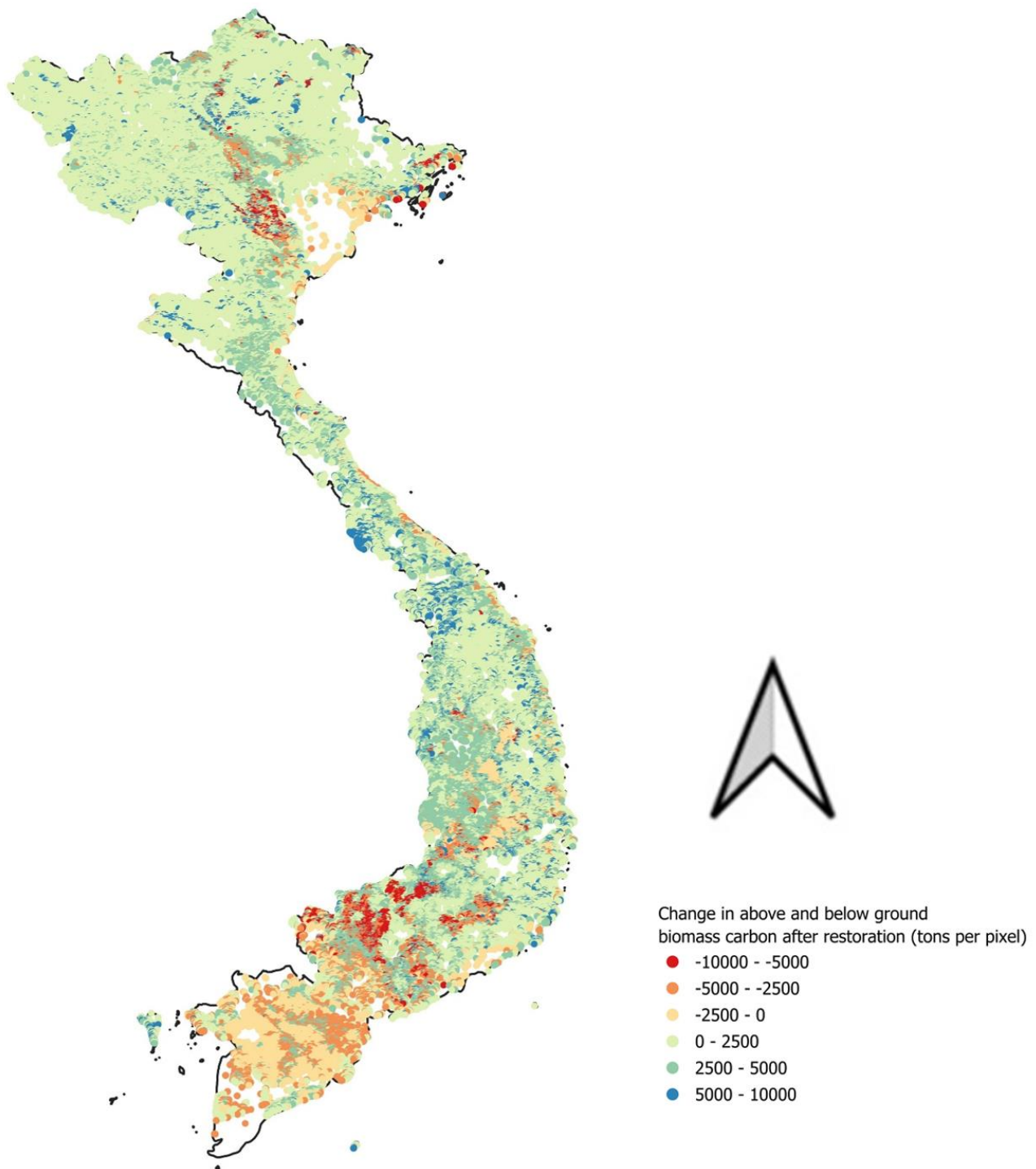
Figure 8. Return from each USD invested into ecosystem restoration in Vietnam under base scenario (2020-2050)



Source: author's analysis

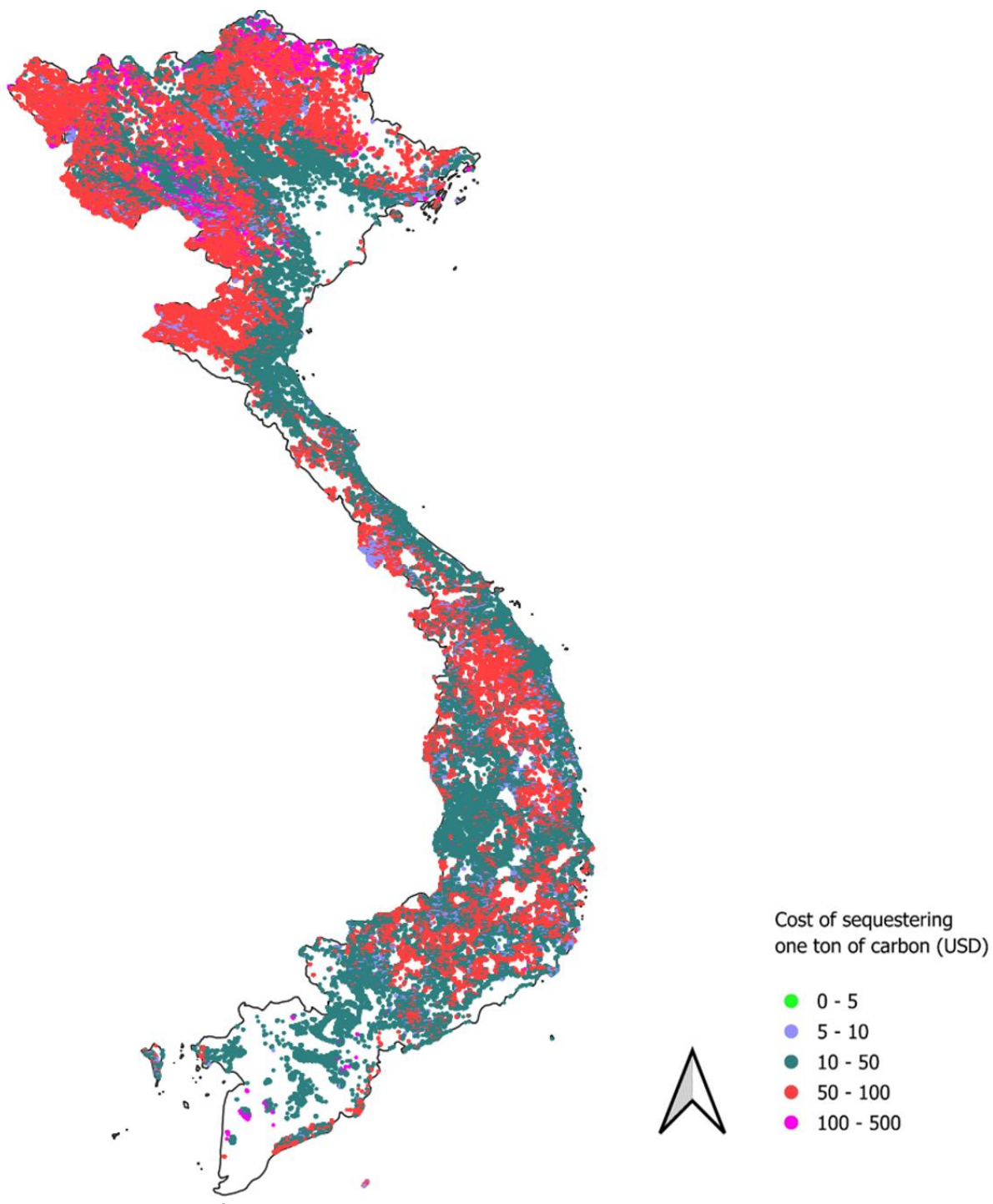
These restoration activities will also create important impacts in terms of gains and losses of above and below ground carbon in Vietnam (Figure 9). In most cases, land restoration activities will lead to additional carbon sequestration. This is visible in Figure 7. There is currently a growing interest in carbon trading and carbon offsets as a mechanism for funding land restoration activities. If the sole driver for restoration activities were carbon sequestration potentials, there are significant opportunities for economically competitive land restoration associated with reforestation in many parts of Vietnam (Figure 10).

Figure 9. Changes in above and below ground carbon due to land restoration activities in Vietnam



Source: author's analysis

Figure 10. Cost of sequestering one ton of carbon in USD



Source: author's analysis

6. Conclusions

Restoring Vietnam's degraded ecosystems offers a significant opportunity to achieve economic, environmental, and social benefits. The results of this study highlight the importance of strategic targeted investments in restoring forests, grasslands, and mangrove ecosystems, which can enhance biodiversity, improve rural livelihoods, and strengthen Vietnam's resilience to climate change. Between 2001 and 2020, land degradation led to economic losses of approximately \$9 billion and net carbon losses of 450 million tons. To reverse these trends, an estimated \$14.8 billion in financial investments will be needed under the Base scenario by 2050. Restoration activities are economically viable, with benefit-cost ratios ranging from 3.1 in the Base scenario to 5.4 in the Optimistic scenario, underscoring the significant returns on investment.

Ecosystem restoration in key hotspots, particularly forests and mangroves, can deliver substantial carbon sequestration benefits, creating opportunities for carbon trading and attracting green financing. Moving forward, decision-makers could prioritize investments in high-return areas, promote synergies between land management, biodiversity conservation, and climate mitigation, and leverage innovative financing mechanisms such as carbon markets and public-private partnerships. Vietnam's strong commitment to ecosystem restoration is essential for ensuring sustainable development, fostering rural prosperity, and contributing to global climate goals.

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Annex 1. Definitions of Land Use and Land Covers

Land use and cover	Description
Evergreen Broadleaf/Needleleaf Forests	Lands dominated by broadleaf/needleleaf woody vegetation with a percent cover >60% and height exceeding 2 m. Almost all trees and shrubs remain green year-round. Canopy is never without green foliage.
Closed Shrublands	Lands with woody vegetation less than 2 m tall and with shrub canopy cover >60%. The shrub foliage can be either evergreen or deciduous.
Open Shrublands	Lands with woody vegetation less than 2 m tall and with shrub canopy cover between 10% and 60%. The shrub foliage can be either evergreen or deciduous.
Wood lands	Lands with herbaceous and other understory systems, and with forest canopy cover between 30% and 60%. The forest cover height exceeds 2 m.
Croplands	Lands covered with temporary crops followed by harvest and a bare soil period (e.g., single and multiple cropping systems). Note that perennial woody crops will be classified as the appropriate forest or shrub land cover type.
Cropland/Natural Vegetation Mosaics	Lands with a mosaic of croplands, forests, shrubland, and grasslands in which no one component comprises more than 60% of the landscape
Grasslands	Lands with herbaceous types of cover throughout the year. Tree and shrub cover is less than 10%.
Barren lands	Lands exposed soil, sand, or rocks and has less than 10% vegetative cover during any time of the year.

Source: *International Geosphere-Biosphere Programme (IGBP) definitions of land use and covers*

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