THE ECONOMICS OF LAND DEGRADATION

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Economics of Harmonizing Land Restoration Activities across the Rio Conventions in Rwanda and Implications for Food Security

A Study for the Economics of Land Degradation Initiative

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Acronyms and Abbreviations

AFOLU	Agriculture, Forestry, and Land Use
BDF	Business Development Fund
BEST	National Biomass Energy Strategy
BRD	Development Bank of Rwanda
CBD	Convention on Biological Diversity
CoK	City of Kigali
COP	Conference of the Parties
CROM	Catchment Restoration Opportunity Mapping
EDPRS	Economic Development and Poverty Reduction Strategy
ETS	Emissions Trading System
FERM	Framework for Ecosystem Restoration Monitoring
FONERWA	Rwandan National Fund for Environment
FLR	Forest Landscape Restoration
FMES	Forest Sector Monitoring and Evaluation System
FSC	Forest Stewardship Council
FSSP	Forest Sector Strategic Plan
GBF	Global Biodiversity Framework
GCF	Green Climate Fund
GEF	Global Environment Facility
GGCRS	Green Growth and Climate Resilience Strategy
GDP	Gross Domestic Product
GHG	Greenhouse Gas
INES	Institute of Applied Sciences
IUCN	International Union for the Conservation of Nature
JLG	Joint Liaison Group
LAIS	Land Administration Information System
LDN	Land Degradation Neutrality
masl	Meters above sea level
MDBs	Multilateral Development Banks
MIDIMAR	Ministry of Disaster Management and Refugee Affairs
MIGEPGROF	Ministry of Gender and Family Promotion
MINADEF	Ministry of Defence
MINAFFET	Ministry of Foreign Affairs and International Cooperation
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government
MINEAC	Ministry of East African Community
MINECOFIN	Ministry of Finance and Economic Planning
MINEDUC	Ministry of Education
MINICOM	Ministry of Trade and Industry
MINIJUST	Ministry of Justice
MINILAF	Ministry of Lands and Forests
MININFRA	Ministry of Infrastructure
MINIRENA	Ministry of National Resources (now Ministry of Environment)
MINISANTE	Ministry of Health

MIS	Monitoring Information System
MITEC	Ministry of Information Technology and Communication
MoE	Ministry of Environment (formerly MINIRENA)
MoH	Ministry of Health
MYICT	Ministry of Youth and ICT
NAEB	National Agricultural Export Development Board
NBSAP	National Biodiversity Strategies and Action Plan
NCA	Natural capital accounting
NDC	Nationally Determined Contribution
NISR	National Institute of Statistics Rwanda
NLA	National Land Authority
NLUDMP	National Land Use and Development Master Plan
NST	National Strategy for Transformation
NTSC	The National Tree Seed Center
OTP	The Office of the Prosecutor
PES	Payment for Ecosystem Services
PIU	Project Implementation Unit
PM	Prime Minister (Office of)
PPP	Public-Private Partnership
PSF	Private Sector Federation
PSTA	Strategic Plan for Agriculture Transformation
RAB	Rwanda Agriculture and Animal Resources Development Board
RBS	Rwanda Standards Board
RDB	Rwanda Development Board
REG	Rwanda Energy Group
REMA	Rwanda Environment Management Authority
RHA	Rwanda Housing Authority
RFA	Rwanda Forestry Authority
RLMUA	Rwanda Land Management and Use Authority
RMPGB	Rwanda Mines, Petroleum and Gas Board
RNRA	Rwanda Natural Resources Authority
ROAM	Restoration Opportunities Assessment Methodology
RRA	Rwanda Revenue Authority
RSPO	Roundtable on Sustainable Palm Oil
RTDA	Rwanda Transport Development Agency
RURA	Rwanda Utilities Regulatory Authority
RWB	Rwanda Water Resources Board
RWf	Rwandan francs
RWFA	Rwanda Water and Forestry Authority
SDGs	Sustainable Development Goals
SEEA	United Nations System of Environmental-Economic Accounting
SLM	Sustainable Land Management
SOC	Soil Organic Carbon
SPCR	Strategic Programme for Climate Resilience
TEV	Total Economic Value
TNC	Third National Communication
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
WASAC	Water and Sanitation Corporation
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
WB	The World Bank

Executive Summary

Aligning Actions, Amplifying Impact: Synergies from Coordinated Land Restoration

Land degradation is a pressing global environmental issue, posing threats to food security, ecological stability, and sustainable development. The three Rio Conventions — the United Nations Convention to Combat Desertification (UNCCD), the Convention on Biological Diversity (CBD), and the United Nations Framework Convention on Climate Change (UNFCCC) — aim to address these challenges through land and ecosystem restoration. This study in Rwanda evaluates the potential for synergies from joint programming and implementation of land restoration activities under the Rio Conventions. It uses the Total Economic Value (TEV) framework approach for the valuation of ecosystem services and applies simulation modelling of transaction costs to identify synergies across land restoration activities. The study, thus, aims to provide policy-relevant evidence on opportunities for maximizing effectiveness, efficiency, and socio-economic impact from land restoration in Rwanda, with a particular emphasis on food security.

Collaboration between the Rio Conventions on land restoration is essential to achieve the goals of land degradation neutrality, biodiversity conservation, mitigating and adapting to climate change, and more broadly, achieving the Sustainable Development Goals (SDGs). There is an ample legal basis mandating harmonized and well-coordinated implementation of the three Rio Conventions. Land restoration is, arguably, the single most important activity where this coordination for boosting synergies and avoiding tradeoffs is essential. Synergies arise when actions to meet one Convention's objectives support those of another. Conversely, tradeoffs occur when actions towards one goal inadvertently harm another. In the context of land restoration, the promotion of synergies across the Rio Conventions implies that improved coordination helps increase the effectiveness and efficiency of land restoration activities, with direct implications on mobilizing much needed funding for land restoration. This is because more effective and efficient planning, implementation, and monitoring of land restoration will make land restoration more attractive for public, multi-lateral, and private sector investments.

Our findings indicate that Nationally Determined Contribution (NDC), Land Degradation Neutrality (LDN), and National Biodiversity Strategies and Action Plan (NBSAP) processes in Rwanda are overlapping and mutually complementary. Implementing them as separate processes at the national and global levels without concrete coordination mechanisms will likely result in lower effectiveness and efficiency of achieving their targets. Moreover, coordinated implementation will also help to avoid inherent tradeoffs. Specifically, Rwanda aims to conserve, sustainably manage, and restore 1,069,476 hectares of land under its LDN and 805,000 ha under its NDC. Moreover, Rwanda has also made a massive commitment to restore and improve 2,000,000 hectares of land under the Bonn Challenge. Similarly, Rwanda's NBSAP has such targets as "at least 10.3% of national territory holding biodiversity and ecosystem services is protected", "at least 50% of natural ecosystems are safeguarded, their degradation reduced", and "increase of forest cover up to 30% of the country". Given the political momentum coming with the new Global Biodiversity Framework (GBF), and the need for all states to review and adapt their NBSAPs according to the new framework, there is a window of opportunity to conduct this NBSAP revision in Rwanda in an integrated manner, while leveraging on other related agendas and targets through taking a significant step towards coherence, synergies, and efficiency.

Land-focused activities by NDC, NBSAP, and LDN processes in Rwanda can be categorised into conservation, sustainable management, and restoration categories, corresponding to the LDN hierarchy of avoiding, reducing, and reversing land degradation. In terms of synergy or tradeoff potential, the targets for land conservation are mostly synergistic, contributing to each other. However, tradeoff may occur if activities focused on maintaining forest cover are carried out through planting mono-species forests. For sustainable management of land resources, all objectives are synergistic and mutually supportive, with the only tradeoff potentially arising from the compliance with the National Land Use Master Plan 2050 due inconsistencies because some of these NDC, LDN, and NBSAP commitments were made before the adoption of the National Land Use Master Plan 2050, so this means that these commitments may be revised in future to bring them in compliance with the evolved national legal frameworks. Land restoration objectives primarily exhibit synergies, although a tradeoff may occur if land restoration practices involve the use of alien species or mono-species forest plantations.

Our results show that coordinated implementation of land-focused activities under the Rio Conventions can reduce transaction costs of land restoration by almost 56% in Rwanda. Specifically, coordinated implementation is estimated to save about 45.6 million US dollars per year compared to when the activities under the three Rio Conventions are carried out separately. There are five specific mechanisms for synergies: 1) A joint inter-agency working group can help ensure efficient resource usage, 2) An information exchange platform can facilitate improved communication and data accessibility, 3) A joint monitoring and evaluation system offers timely information sharing and recognizes contributions, 4) Joint planning and fund mobilization could streamline land restoration efforts, and 5) Joint research helps promote skill and data sharing and efficient resource usage. Through these mechanisms, well-coordinated and harmonized implementation can provide with significant efficiency gains for land restoration activities. More efficient implementation implies higher returns from land restoration, thus making it more attractive for various cooperation partners and investors to fund the activities contributing to LDN, NBSAP, and NDC processes in Rwanda.

Revitalizing Rwanda's Landscapes: Land Restoration for Resilient Agri-Food Systems

In a world grappling with the interlinked challenges of climate change, biodiversity loss, and land degradation, the need for coordinated action has never been more apparent. Harmonizing action on land by the three Rio Conventions is not only needed because of expected efficiency and budget savings but it is also necessary because of the inherent connection between these challenges. Rwanda, a country that has witnessed significant shifts in land use and land cover over the past two decades, stands as a testament to both the potential and urgency of addressing these issues.

Our results show that two key trends stand out in the dynamics of land use and land cover changes in Rwanda over the period between 2001 and 2020: 1) reduction in the areas of savannas and grasslands, and 2) significant expansion of agroforestry systems. Moreover, the area under natural forests also increased by about 3% over the last two decades through expansion of broadleaf forests to woody savannas and savannas. The urban areas expanded by about 30%, primarily by replacing croplands, grasslands, and savanna areas. Contrary to some suggestions, cropland expansion in Rwanda is occurring not through loss of natural forests, but through expansion of croplands on savannas and grasslands.

The data compiled on the re-establishment and maintenance costs for ecosystems restoration in Rwanda indicate that ecosystem re-establishment costs range from 304 US dollars per ha to 3,726 US dollars per ha depending on the ecosystem to be restored. Similarly, maintenance costs range from 34 US dollars per ha to 239 US dollars per ha. It is crucial to note that the costs of maintaining ecosystems in good condition are between three to 20 times lower than restoring them after their degradation. This highlights the importance of avoiding and preventing land degradation in the first place instead of degrading the ecosystems and trying to restore them afterwards.

The analysis shows that between 2001 and 2020, Rwanda gained in the values of natural capital in its ecosystems by about 125 million US dollars on the net balance. However, this net balance figure hides the fact that Rwanda experienced about 142 million US dollars' worth of loss of natural capital. Positive net balance was achieved because the expansion of agroforestry systems, forests, and wetlands was greater than their losses. Most of the gains in the values of natural capital represented by ecosystems were achieved in central areas of Rwanda, while losses more often occurred in peripheral areas.

The findings show that the costs of land degradation through land use change and through soil erosion in Rwanda reach an equivalent of about 2.2 billion US dollars per year. Investments of about 1.4 billion US dollars are needed to address ecosystem degradation and cropland soil erosion in the country. This also means that each dollar invested into land restoration and addressing soil erosion in Rwanda returns a total of about 1.53 US dollars. It is crucial to note that a major share of these investments, namely 810 million US dollars, are needed to be made into agroforestry systems on agricultural lands. In fact, expansion of agroforestry also serves as one of the key measures for combating soil erosion. Restoring forests and wetlands, expanding agroforestry systems to treeless croplands and grasslands were also found to be highly profitable. However, restoring shrublands, woody savannas and savannas which became croplands is not economically viable. Restoring cropland without agroforestry from grassland is also not profitable but becomes profitable when converted to cropland with agroforestry.

Cost benefit analysis of land restoration revealed the spatial distribution of areas with different economic returns from investments in land restoration. Some high return areas are observed along the shore of lake Kivu (the northern part of Nyamasheke District, southwest of Rubavu District and northwest of Rutsiro District), border of the Western and Southern Provinces (around the west of Muhanga) and southern part of Gisagara and Nyaruguru Districts near the border to Burundi. Analysis of such detailed spatially explicit representation of land restoration costs and benefits will help target most appropriate and economically efficient land restoration activities.

Furthermore, maintaining all croplands in Rwanda in good fertile condition would require recurring annual investments of 91 million US dollars. Expanding agroforestry systems to all croplands would imply an annualized cost of 123 million US dollars. However, these investments are worthwhile because gross benefit from them reach 168 million US dollars per year, and net benefits equal about 45 million US dollars per year. Of these net benefits, about 27 million US dollars per year occur in the form of additional food and agricultural commodities' production.

Finally, summarizing the overall investment needs in Rwanda based on the above calculations implies that to achieve restoration of degraded ecosystems, address soil erosion, and maintain croplands in good condition by avoiding their erosion would require annual investments of about 300 million US dollars until 2030.

Environmentally sustainable and economically profitable ecosystem restoration opportunities can help sequester about 13.5 million tons of carbon in Rwanda over a period of 30 years. This is about 2.5 times more than Rwanda's current annual greenhouse gas (GHG) emissions. The estimation shows that even considering that the value of land restoration investments is focused only on carbon sequestration, the cost of each ton of carbon sequestered in evergreen broadleaf forests in Rwanda is 7.74 US dollars, for wetlands 5,300 US dollars, and for agroforestry systems 137 US dollars. For comparison, each ton of carbon is currently (August 2023) trading at about 100 US dollars per ton under the European Union's Emissions Trading System (ETS). Restoring natural forests in Rwanda represent one of the most cost-effective carbon sequestration opportunities. Although the cost of each ton of sequestered carbon is higher in agroforestry systems, due to their extensive area coverage, agroforestry systems can provide nearly half of the additional carbon sequestration potential through land restoration in Rwanda. Restoring lost wetlands makes a broader economic sense, particularly from the perspective of biodiversity conservation. It appears, however, that from the carbon sequestration perspective in above and below ground biomass wetlands restoration will have rather modest effects in Rwanda. This point highlights that prioritization of areas to restore may result in diverging targeting options depending on each Convention action agendas.

Recommendations

The following suggested recommendations for collaborative synergies are based on the findings of this study for the consideration by concerned Ministries and other organization in Rwanda engaged in land restoration and at the international level by the Secretariats of the three Rio Conventions.

Synergy mechanism 1: A joint inter-agency working group for land.

Strengthening inter-Ministerial coordination on land conservation, sustainable land management (SLM), and land restoration in Rwanda. National dialogues and coordination mechanisms are essential for implementing international conventions and agreements effectively. Establishing such mechanisms can help streamline communication and cooperation among different stakeholders, including government ministries, agencies, sub-national administrations, private sector, civil society organizations, and local communities.

Establishing a national focal point for coordinating land-based activities (including the entire spectrum from conservation, SLM, to restoration) within the government, such as dedicated inter-ministerial committee headed by a high-level official, can help coordinate actions among different ministries and stakeholders engaged in land management from diverse angles. The focal point could also bring together currently existing land management-focused working groups which are operating in parallel, despite being usually composed of the same organizations and individuals.

Enhancing the mandate of the Joint Liaison Group among the Rio Conventions. At the Rio Conventions' level, the Joint Liaison Group was established to enhance coordination and cooperation among the Rio Conventions. Strengthening the

Joint Liaison Group's capacity and providing it with a more explicit mandate to facilitate collaboration on land restoration could help enhance synergies among the Rio Conventions.

Synergy mechanism 2: Joint research and planning of land target implementation.

Joint spatial mapping of lands for conservation, SLM, and restoration across the Rio Conventions. Full harmonization of Conventions' specific indicators on land can be a highly costly and lengthy process without clear and certain benefits and may not be feasible for some indicators. It may be a more optimal approach to accept these individual targets and differences as such and bring them together in one map, capturing the national commitments of land conservation, SLM, and land restoration under the three Rio Conventions in a spatially explicit manner. It is clear from this study's findings that predominant share of land conservation, SLM, and land restoration activities in Rwanda will occur on agricultural lands. Therefore, a coherent and salient integration of food security and (agro)-biodiversity implications is necessary.

Harmonizing national action plans for land conservation, SLM, and land restoration with the joint support of the three Rio Conventions can help outline Rwanda's land-related commitments, targets, and strategies for implementing, while serving as a joint roadmap for all stakeholders. Rwanda has a very rich basis to initiate such process, for example, restoration opportunity assessment methodology (ROAM) could provide the starting elements for this national coordination.

Synergy mechanism 3: Joint funding mobilization

Mobilizing resources for joint work on land conservation, SLM, and land restoration: Rwandan national organizations and the three Rio Conventions can work together to secure financial resources to support collaborative efforts on land, including from the Global Environment Facility (GEF), the Green Climate Fund (GCF), and other funding sources. An urgently needed and very specific topic for such finding could be joint spatially explicit mapping of NBSAP, NDC, and LDN commitments and the joint monitoring and evaluation of their implementation status.

Elaborating joint work programs and projects. At both the national level and at the Rio Conventions' level, the development of joint work programs and projects could be considered. In Rwanda this could be part of the National Plan for land conservation, SLM, and land restoration, and for the Rio Conventions, this could be part of the enhanced mandate of the Joint Liaison Group (JLG). This collaborative programming approach can help streamline efforts and help mobilize resources to expand implementation activities in a harmonized way.

Synergy mechanism 4. An information exchange platform and joint research

Facilitating knowledge and information generation and sharing: Creating a platform for the exchange of knowledge, information, and best practices related to land conservation, SLM, and land restoration between the national organizations in Rwanda can help bring land related information together in one place and provide open access to it. Such a publicly available source of rich information on all aspects of land conservation, SLM, and land restoration will help unleash various research activities that support evidence-based design of land management policies, but also help attract more investments by reducing information uncertainties and risks faced by both private and public investors. Maintaining and updating this platform could be part of the functions of the national land focal point in Rwanda.

Fostering capacity-building efforts. The secretariats of the Rio Conventions can collaborate on providing support for capacity building and strengthening on integrated approaches that address land objectives across the Conventions. This could include training, technical assistance, and the development of tools and guidelines for application of best practices of land conservation, SLM, and land restoration.

Increasing awareness and political will. Raising awareness of the benefits of collaboration and synergies among the conventions at the political level, including through high-level dialogues and meetings, to generate the necessary political will to support collaboration.

Synergy mechanism 5. A joint monitoring and evaluation (M&E) system

Monitoring of progress of land conservation, SLM, and land restoration and evaluating its outcomes. Establishing a joint mechanism for monitoring progress and evaluating the effectiveness of collaborative efforts in land conservation, SLM, and land restoration is the highest payoff synergy area for collaboration. The Framework for Ecosystem Restoration Monitoring (FERM) under the UN Decade on Ecosystem restoration is currently intending to provide an overarching mechanism for monitoring of broader impacts of land restoration on all dimensions of sustainable development. In addition, however, there is a need for a more targeted monitoring framework, tailored to the Rio Conventions, that is also well applicable in different country settings, with a clear focus on monitoring and measuring progress in the implementation of the targets under the LDN, NBSAP, and NDC processes, both at the national and international levels. A periodic publication on the state of land restoration in the world that documents the outcomes of such monitoring could be considered.

01 Introduction

Land degradation is currently threatening the very foundation of sustainable development, and therefore, is a global environmental issue that demands immediate action to address it. As the quality and productivity of our precious land resources decline due to primarily anthropogenic activities, the risk of jeopardizing food security, ecological stability, and socio-economic progress becomes all too real. The United Nations Convention to Combat Desertification (UNCCD), the United Nations Convention on Biological Diversity (CBD), and the United Nations Framework Convention on Climate Change (UNFCCC), also known as the Rio Conventions, have as their main objectives to address environmental challenges and ensure sustainable development in the world. In this regard, land and ecosystem restoration can serve as a key entry point for addressing the interlinked challenges of desertification, land degradation, drought, biodiversity loss, and climate change.

This study in Rwanda evaluates the potential for synergies from joint programming and implementation of land restoration activities carried out as part of Rwanda's contributions under the three Rio Conventions. The specific focus of the study is to identify areas where collaboration among the Rwandan National Organizations engaged in land restoration and across the three Rio Conventions can result in highest synergies in terms of improved effectiveness and efficiency of land and ecosystem restoration and will generate major positive socio-economic impacts on food security and sustainable development in Rwanda. For this purpose, the study aims to evaluate the costs and benefits of a joint national programming and coordinated implementation of the National Biodiversity Strategies and Action Plan (NBSAP), the Nationally Determined Contribution (NDC), and the Land Degradation Neutrality (LDN) targets, concentrating on conservation, sustainable management, and restoration of land resources and their impacts on food production in Rwanda.

1.1 Rationale and Significance

Achieving alignment and synergies in land conservation, sustainable land management (SLM), and land restoration across the three interrelated tracks of LDN, NDC, and NBSAP implementation in Rwanda remains a high priority area, also for ensuring food security and increased agricultural productivity. However, each Rio Convention pursues separate processes and differing objectives for land restoration activities. This leads to the overlap of proposed actions and, in some cases, duplication of efforts, with usually unquantified impacts on food production and agricultural productivity. Moreover, significant financing gaps exist to achieve the corresponding land restoration targets. Increased investments are needed for the large-scale implementation of planned land restoration activities, including agroforestry, and soil and water conservation measures, requiring innovative approaches for attracting national, international, and private sources of funds.

There is a substantial potential for synergies through integrated efforts for land restoration (WOCAT et al. 2022, Wiese-Rozanov 2022). For example, the identification of the most suitable locations for the implementation of restoration measures can be optimized and done based on environmental suitability and economic profitability, allowing for higher efficiency and more positive impacts for food security and agricultural productivity (Mirzabaev et al. 2022). In that regard, there is a need for better understanding of possible pathways to leverage synergies among various land restoration activities, including how financing can be pooled and invested much more efficiently to close the funding gap for land restoration and SLM in Rwanda. Ultimately, this study intends to outline the opportunities for enhancing the implementation of the NBSAP, NDC, LDN, and the UN Decade on Ecosystem Restoration in Rwanda. Finally, through the example of Rwanda, the study also intends to provide evidence-based information to help design locally fine-tuned land restoration policies in other countries around the world.

1.2 Study Objectives and Research Questions

The study aims to evaluate the economic costs of siloed programming and implementation processes for land restoration and land management activities under the Rio Conventions land restoration targets, and the social, environmental, and economic benefits, focusing particularly on food security, from joint programming and implementation of the land restoration commitments contained in the NBSAP, NDC, and LDN.

The study seeks to address the following mutually supportive set of research questions:

1. What is the extent and cost of land degradation in Rwanda?
2. What are the total financing needs and current funding gaps for restoring degraded land in Rwanda?
3. Which degraded locations provide highest returns for land restoration investments? How does avoiding land degradation compare with degrading and then restoring land?
4. How does the current segmented approach to land restoration compare in economic terms with the coordinated planning and implementation?
5. What are the policy recommendations for promoting land restoration and sustainable land management through coordinated planning and implementation?

This study was carried out in several stages (Table 1). The initial stage was ***scoping***, which involved comprehensive discussions about the scope of the study with all involved parties. The study proposal was also brought forward for discussion during a side-event at the UNCCD Conference of Parties (COP) held in Abidjan, Ivory Coast, in May 2022.

Following the scoping phase, the research moved into the ***preparation stage***. This involved obtaining a research permit to conduct the study in Rwanda, specifically in affiliation with the Ministry of Agriculture and Animal Resources (MINAGRI). Other key aspects of this stage included a review of relevant literature, conduction of expert and stakeholder interviews in Rwanda, and data collection.

Subsequently, the ***research*** was carried out. This involved an analysis of land use and land cover changes from 2001 to 2020. It also examined incurred food production, biodiversity, and carbon sequestration tradeoffs over the same period. Further analysis included the cost of land degradation, benefits of soil conservation, SLM, and land restoration planning for the 2020-2050 time horizon. Additionally, targeting of locations for environmentally sustainable and economically profitable land restoration was conducted, alongside an analysis of the carbon sequestration impacts of such restoration.

The research also accounted for cropland soil erosion costs and benefits, based on a literature review, and the total investment needs for soil conservation, SLM, and land restoration. It reviewed the legal, governance, and institutional structures for land restoration in Rwanda and at the level of the Rio Conventions.

The research stage also included a critical monetary and qualitative evaluation comparing the current separate approach to land restoration with a more integrated approach involving coordinated planning and implementation. This assessment was crucial to highlight potential efficiencies and enhanced outcomes associated with a more collaborative approach to land restoration. By juxtaposing the two approaches, the research aimed to shed light on the most effective strategies for land restoration in Rwanda and inform similar efforts at the international level. Following this, and other analyses, policy recommendations were formulated to avoid tradeoffs and enhance synergies for land restoration both within Rwanda and globally.

The next stage was stakeholder validation. The findings of the study were discussed at a stakeholder workshop in Kigali, Rwanda, in March 2023.

TABLE 1

Organization of the research

Research stages	Research elements
Scoping	• Discussions about the scope of the study with ELD Secretariat, Rwandan partners, Rio Convention Secretariats. • Discussion of the study proposal during a side-event at UNCCD COP in Abidjan, Ivory Coast, in May 2022.
Preparation	• Obtaining of research permit to conduct the study in Rwanda in affiliation with the Ministry of Agriculture and Animal Resources (MINAGRI). • Literature review. • Expert and stakeholder interviews in Rwanda. • Data collection.
Research	• Analysis of land use and land cover changes (2001-2020), • Analysis of incurred food production, biodiversity, and carbon sequestration tradeoffs (2001-2020). • Analysis of cost of land degradation, benefits of soil conservation, SLM, and land restoration (Planning time horizon of 2020-2050). • Targeting of locations for environmentally sustainable and economically profitable land restoration. • Analysis of carbon sequestration impacts of land restoration. • Inclusion of cropland soil erosion costs and benefits of addressing cropland soil erosion based on literature review. • Analysis of total investment needs for soil conservation, SLM, and land restoration. • Analysis of legal, governance and institutional structures for land restoration in Rwanda and at the level the Rio Conventions. • Monetary and qualitative evaluation comparing the current separate approach to land restoration vs. coordinated planning and implementation, • Formulation of policy recommendations for avoiding tradeoffs and boosting synergies for land restoration in Rwanda and at the international level.
Stakeholder validation	• Presentation of study findings at the CBD COP in Montreal, Canada, in December 2022, and incorporation of feedbacks. • Discussion of study results during stakeholder workshop in Kigali, Rwanda, in March 2023, and incorporation of feedbacks. • Presentation of the study at Climate Change Conference in Bonn, Germany, in June 2023, incorporation of feedbacks.
Peer review	• Round of peer reviews of the study through the ELD Secretariat and by MINAGRI-Rwanda.
Finalization of the study	• Addressing of peer review comments and suggestions, finalization of the study.

Feedback from this discussion was incorporated into the study. The research results were also presented at the Convention on Biological Diversity (CBD) Conference of the Parties (COP) in Montreal, Canada, in December 2022 and at the Climate Change Conference in Bonn, Germany, in June 2023. Feedback from these events was similarly incorporated into the study.

Following the validation phase, a round of peer reviews was carried out by the ELD Secretariat and MINAGRI-Rwanda. The peer review comments and suggestions were addressed and incorporated into the study.

The study report is structured as follows. In Chapter 2, we provide an overview of the concepts and methods applied in this study. Chapter 3 evaluates the opportunities for synergies across the three Rio Conventions in the Rwandan context, including an overview of current land restoration commitments by Rwanda under the three Rio Conventions and other processes, such as the Bonn Challenge. This is followed by Chapter 4 with the analysis of the costs and benefits of land restoration and targeting of the areas that are most suitable for synergistic restoration efforts because of high economic profitability and environmental sustainability of land restoration activities in these locations. Chapters 6 and 7 study the governance system for land restoration and highlight synergy scenarios for how the institutional setting for land restoration could be optimized to increase the effectiveness and efficiency of land restoration. We provide recommendations emerging from the findings of the study in Chapter 8. Finally, the report's technical annexes provide more detailed descriptions of the study's theoretical framework, methodology, and data sources. This research methodology has been specifically designed in a way to make it globally relevant and thus also applicable to other countries around the world for conducting similar evaluations.

02
Approach and methodology

2.1 Conceptual framework: Land restoration as an integrated approach to Rio synergies

2.1.1 Economics of land restoration

Land restoration is "an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability" (Society for Ecological Restoration 2004). 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). Thus, land restoration aims to restore not only one element of the previously degraded ecosystem, e.g., planting trees on a deforested area, but all previous functions and components of the degraded ecosystem – the variety of trees, the richness of biodiversity, symbiotic and functional relationships between various components of the degraded ecosystem.

Restoration of specific components of the ecosystem, e.g., only planting trees, helps recover some of the lost ecosystem services, but not all of them. Restoration can be classified into active and passive. Passive restoration is when degraded ecosystem is set aside, e.g., enclosed, allowing it to recover by itself. Active restoration is when more direct human interventions are carried out to restore a degraded ecosystem (e.g., through reforestation). Passive ecosystem restoration is less costly than active restoration but takes significantly more time than active restoration. Restoration of degraded ecosystems is often compared against conservation to avoid their degradation in the first place. Restoration is usually more expensive than conservation (Mirzabaev and Wuepper 2023). Restoration involves both re-establishment costs and subsequent maintenance costs. On the other hand, conservation only involves maintenance costs. Maintenance costs are considerably lower than re-establishment costs, often representing only a small fraction of re-establishment costs (WOCAT 2022). Hence, conservation needs to be preferred to first degrading the ecosystem and then trying to restore it. This is especially true because it may not be possible to restore all services and functions of a degraded ecosystem due to irreversibilities. Moreover, there is also conceptual overlap between restoration and conservation, as conservation tools can be used to allow for restoration (Mirzabaev and Wuepper 2023).

Ecosystems make up the natural capital. Loss of natural capital means less resources available for economic growth (Daly *et al.* 2009), hence, the need for restoring this essential capital base for economic production. Total Economic Value (TEV) is a highly apt analytical framework for measuring both direct costs and indirect costs (externalities) caused by ecosystem degradation (MEA, 2005). The Millennium Ecosystem Assessment (MEA) classifies ecosystem services into 22 types under provisioning (or direct use values), regulating, habitat, and cultural ecosystem services (indirect or non-use values) categories.

The implementation of various land restoration activities comes with various associated costs. The success of land restoration interventions is dependent on optimising resources and reducing costs. There are five major types of land restoration costs: acquisition, establishment, maintenance, opportunity, and transaction costs (Iftekhar *et al.* 2016).

Acquisition costs are the costs for acquiring land for conservation or land restoration purposes from usually private owners. Establishment costs are the costs incurred to set up ecosystem restoration technologies and practices. They often include such costs as site preparation, seeding and planting. For example, establishment costs of reforestation programs include all the upfront costs related to planting trees. On the other hand, those costs that are subsequently incurred regularly for caring after these trees are called maintenance costs. There are considerable variations in the establishment and maintenance costs of ecosystem restoration technologies and practices depending both on the location and the type of technology.

Opportunity costs are the cost associated with the loss of benefits derived from the use of that land before restoration. For example, if a reforestation program is carried out by replacing a cropland, the benefits which were previously received from crop production in this area need to be accounted for as opportunity costs and included in the analysis (Mirzabaev and Wuepper 2023).

Transaction costs include the costs related with identification of suitable sites for restoration, planning, negotiating, and organizing restoration programs, monitoring and evaluating the restoration results. Transaction costs can represent up to 50% of total land restoration costs (Coggan *et al*. 2010). Therefore, it is important not to omit them in the economic analysis of land restoration programs (McCann *et al.* 2005, Falconer and Saunders 2002). Creation of synergies across the activities by various actors involved in land restoration would primarily imply the reduction of these transaction costs of land restoration. Thus, creation of synergies helps increase land restoration effectiveness (whether land restoration target is achieved) and efficiency (whether land restoration target is achieved at the lowest costs).

2.1.2 Land restoration and theory of transaction costs

The transaction cost theory traces its roots to the seminal work by Coase (1937) and later developments by Williamson (1975, 1985). Transaction costs are a function of i) establishing partnerships and coordination, ii) asset specificity, i.e., specific nature of the good or service to be provided (in our case, land restoration), iii) uncertainty, including asymmetric information available to different stakeholders in land restoration process, iv) and monitoring and enforcement costs (Paul and Vandeninden 2012).

The underlying assumption of the theory is bounded rationality and opportunistic behaviour of actors (Cuypers et al. 2021, Williamson 2010). Bounded rationality assumes that acquiring information comes at a cost and the capacity of actors to analyse and understand information is limited and different. Therefore, different actors have access to different sets of information at any point in time. For example, the benefits of ecosystem restoration and adverse effects of deforestation may not be appreciated by communities that depend on fuelwood and charcoal extraction for their livelihoods. Sensitising communities on the benefits of ecosystem restoration comes at a cost.

Opportunistic behaviour assumes that actors in a transaction have the tendency to seek their self-interest. Actors are unwilling or unable to share information, or they selectively share information with their counterparts to influence decision-making (Cuypers et al. 2021). For example, projects engaged in land restoration may not have the funds and operational scope for a long-term monitoring of their outcomes. Moreover, they are interested in reporting only successful outcomes and not reporting restoration failures. Furthermore, land restoration does not happen automatically, for example, immediately after planting trees. Land restoration can only happen if the planted trees survive and grow for at least the next 30-40 years. Since no such long-term monitoring system is usually put in place by any specific project, national governments and international organizations need to spend resources on monitoring and enforcement.

The implementation of land restoration projects in many developing countries is often done with financial support from cooperation partners. Donor funds for implementation of projects are observed to come with high transaction costs, includ-

ing reporting procedures, registration, transfer of funds, monitoring and evaluation, etc. (Paul and Vandeninden 2012; High Level Forum 2003). Inefficient and complex hierarchies or institutional structures of organizations that implement these interventions further increase transaction costs. Therefore, forming thematic groups and harmonising review procedures and tools can reduce transaction costs (High Level Forum 2003).

If stakeholders in land restoration do not have aligned programs and schedules, it increases the asset specificity (e.g., physical, human and temporal) and thus the transaction cost. However, if there is alignment, asset specificity decreases towards zero and it reduces transaction costs. For example, governments would expect tree planting to be done early in the rainy season so that survival of the trees is high, but this period is also when farmers cultivate their farms, so implementation of the program will be adversely affected.

Similarly, if stakeholders have information asymmetry, it increases uncertainty and thus increases transaction costs because of the cost of establishing contracts and documentations. To illustrate, this may occur when compensation is paid to farmers for partaking in land restoration, but farmers do not appreciate the fact that they will be restricted in the kind of activities that they engage in on their land in the long-term. However, if uncertainty is reduced through partnerships or cooperation over time, it reduces transaction costs.

In addition, weak harmonisation of processes between stakeholders results in duplication of review and reporting processes and thus increases transaction costs. When multiple agencies demand documents and undertake periodic evaluation of the land restoration program, it increases transaction costs as implementers would have to be present for these evaluations, although different agencies are evaluating similar things. If there is improved harmonisation of processes and frameworks transaction costs decline. Sharing of information and streamlining processes reduce transaction costs. The investment costs to reduce transaction costs should not exceed the savings from establishing this system (Lawson 2009).

2.2 Research approach and methodology

2.2.1 Costs and benefits of land restoration

Methodologically, our analysis of the costs of land degradation and the benefits from land restoration is based on the Millennium Ecosystem Assessment's classification of ecosystem services, which includes 22 types of services grouped into provisioning and non-provisioning categories (cf. Annex 2 for detailed elaboration of the applied methodology). Non-provisioning services encompass regulating, habitat, and cultural ecosystem services, while provisioning services include food production, water provision, and the extraction of medicinal, genetic, and ornamental resources (Mirzabaev and von Braun 2022). In Rwanda, provisioning services, such as food production, dominate the ecosystem services derived from croplands, while non-provisioning services account for more than half of the total value of services from other ecosystems. Non-provisioning services, including air quality and climate regulation, pollination, and erosion prevention, fall under the category of regulating services. Data was collected on economic values of these ecosystem services for such biomes as forests, shrublands, woody savannas and savannas, croplands, grasslands, agroforestry systems, and wetlands. These economic data were then combined with high-resolution (500 meters) remotely sensed MODIS satellite data on land use and land cover changes (Friedl and Sulla-Menashe 2019) to trace their observed economic implications (both costs of land degradation and gains from land improvement) during the period of 2001-2020.

Subsequent analysis focused on assessing costs and benefits of restoring degraded lands. The analysis focused on the net present values (NPV) of the anticipated benefits resulting from land restoration activities. The time horizon for evaluating the costs and benefits of land restoration was taken to be 30 years (2020-2050), with the discount rate of 10%, and transaction costs estimated at 25% of the total implementation costs. The costs of land restoration include establishment costs, maintenance costs, opportunity costs of lower-value biomes being replaced, and transaction costs. The data for these land restoration costs for each ecosystem was collected from various sources (Annex 2). The trajectory of ecosystem recovery after restoration was determined for different biomes, considering factors such as establishment period (i.e., time needed for restored ecosystems to regain their full potential), staggered entrance into full potential after restoration, and survival rates (e.g., of planted trees). Annex 2 provides a detailed elaboration of the methodology and describes the data sources used in the analysis.

2.2.2 Economic analysis of synergies from coordinated land restoration

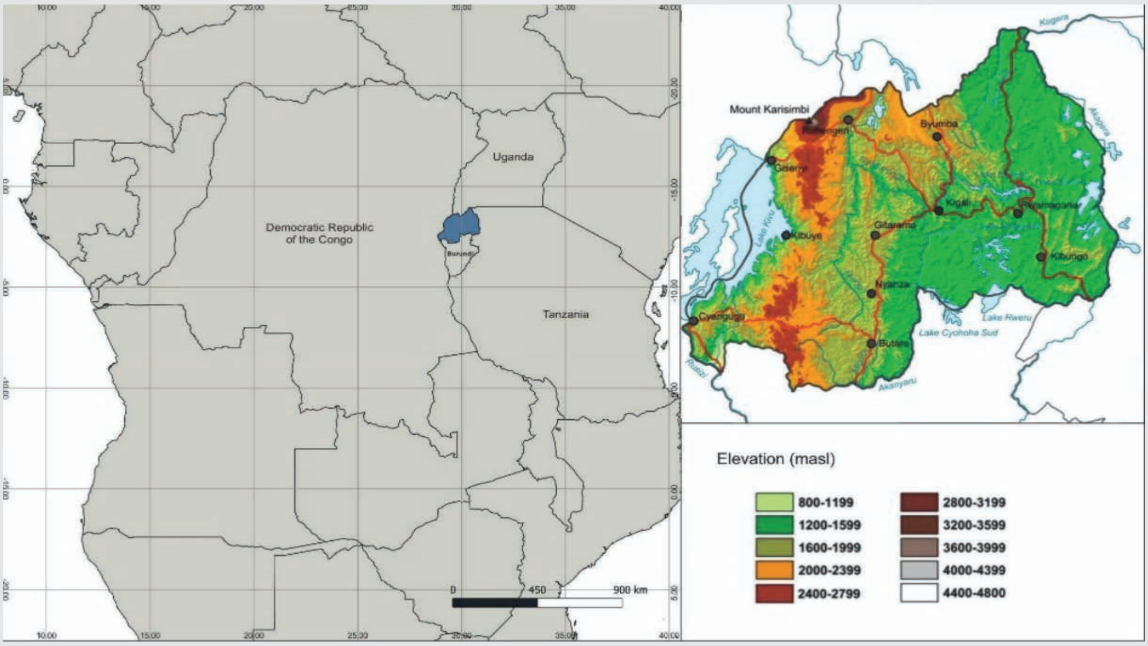
This analysis explores the costs and benefits of coordinated and uncoordinated land restoration activities under the three Rio Conventions using the theory of transaction costs. The literature review and stakeholder discussions revealed that transaction costs make up, on average, approximately 25-35% of land restoration project costs in Rwanda. This suggests an efficient organization of land restoration activities. However, transaction costs can vary significantly among participants in the land restoration activities under the three Rio Conventions. Therefore, it is crucial to consider these variations in transaction costs when assessing the potential benefits of coordination.

The methodology involves several steps. Firstly, we accounted for variation in transaction cost shares in land restoration activities by conducting Monte Carlo simulations (see Rubinstein and Kroese (2016) for more details on Monte Carlo method). Average transaction costs of 35% were used, with a standard deviation of 10% around this value. The simulations involved 10,000 iterations, allowing for changes in the shares of transaction costs within the total land restoration costs. This sampling accounts for the uncertainty and fluctuations in transaction costs. Secondly, we accounted for variability in the benefits of coordinated land restoration. Coordination can reduce transaction costs, but the extent of reduction depends on the level of collaboration and the nature of these costs. Reductions in transaction costs are assumed to range from 0% (no benefit from coordination) to 75% for different cost types and were evaluated through 10,000 Monte Carlo simulations to determine the distribution of potential outcomes. Thirdly, we modelled variations in each type of transaction costs by multiplying the transaction costs by the proportions of each specific transaction cost type (monitoring and enforcement, research and capacity building, awareness raising, coordination and administration, funding mobilization), the baseline costs without coordination for each cost type were estimated. This allows for evaluating the distribution of costs across different transaction cost types in the absence of coordination. Then, we identified reductions in each transaction cost through coordination. Coordination efforts lead to reductions in transaction costs, which vary for each cost type. The reduction factor follows a normal distribution, ensuring that

FIGURE 1

Rwanda´s location and topography

Source: Adapted from MIDIMAR (2015) and WB (2017).



the reduction falls within the range of 0% to 75% reductions in overall transaction costs. Finally, we compared coordination vs baseline (business as usual) scenarios. Based on the steps above, the expected values of transaction costs under coordination and no coordination were calculated. These calculations consider the high variability of costs and the benefits of collaboration across different actors in Rwanda. Annex 2 provides a detailed elaboration of the methodology and describes the data sources used in the analysis.

2.3 Study area and geographic context

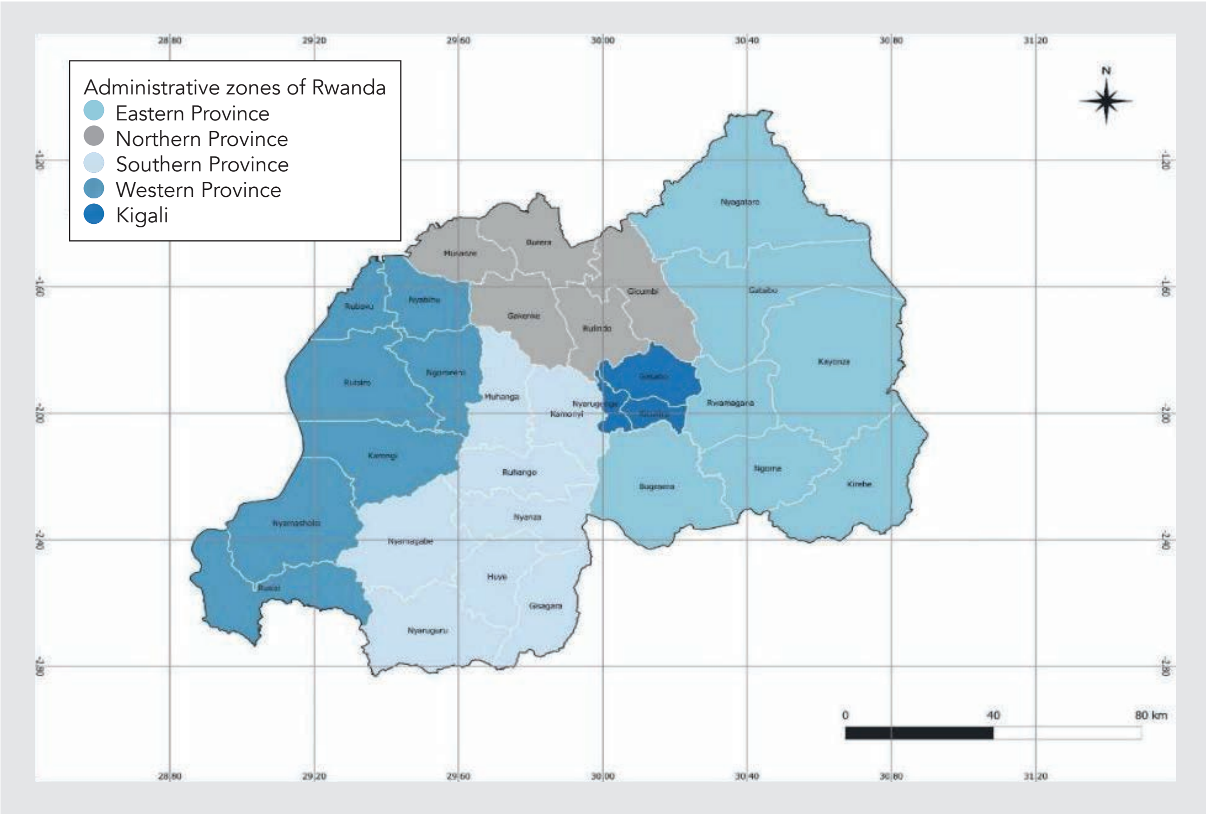
Rwanda, also known as "the land of a thousand hills", is a landlocked country located in Central Africa, in the Great Lakes region, with an area of 26,338 km2, of which 30.4% is covered by various types of forests (Singh et al. 2015, MoE and IUCN 2019, Bagstad et al. 2020). It shares borders to the north with Uganda, to the south with Burundi, and to the east and west with Tanzania and the Democratic Republic of Congo, respectively (NISR, 2014).

Rwanda's topography ranges from 900 meters to 4,500 meters above sea level (masl) and comprises four main zones: the Congo-Nile Ridge, the Central Plateau, the eastern lowland zone, and the Bugarama plain (Figure 1). The country's west is dominated by a mountainous area that runs from north to south and whose altitude fluctuates between 1,500 and 2,500 masl. In the northwest is the country's highest peak, Mount Karisimbi, with 4,507 masl, and is also part of the chain of Virunga Volcanoes. In the central area, the altitude ranges between 2,000 and 1,500 meters, with a predominance of rolling hills, while the eastern part of the country is made up of savannahs and plains (between 1,500- and 1,000-meters altitude). The lowest point, at 900 meters, is in the Bugurama plain (on the banks of the Rusizi river), in the southwest of the country (NISR, 2014; REMA, 2011).

In the climatic aspect, even though Rwanda is close to the equatorial zone, the country enjoys a moderate tropical climate, with considerable differences throughout the territory due to the varied topog-

FIGURE 2

Rwanda´s administrative zones map
Source: Adapted from WB (2017).



raphy. The average annual temperature in Rwanda ranges from 15-17°C in the high-altitude areas (in the west). However, in the Volcano region, the temperature can drop to 0°C in some areas, with an average annual rainfall of more than 1500 mm. In the Eastern plateau, the temperature fluctuates between 20°C to 21°C and from 17.5°C to 19°C in the Central plateau, with an average rainfall of about 1000 mm per year. Nevertheless, precipitation is very variable, resulting in frequent periods of drought. In the case of the lower areas of the east and southeast of the country, although the temperature ranges from 23°C to 24°C (Bugarama plain), during the months of February, July, and August, it can exceed 30°C. In addition, rainfall here varies between 700 and 970 mm per year, much less than in the Volcano region. According to the latest estimates, and in comparison, with 1970, the average temperatures have increased by 1.4°C, and this trend is projected to continue due to climate change (REMA, 2011; MoE, 2017).

At the administrative level, Rwanda is divided into four provinces and the city of Kigali. Rwanda's administrative structure is further subdivided into districts (30), sectors (416), cells (2,148), and villages (14,837), the districts being the basic political-administrative unit (Figure 2). Villages, on the other hand, are the smallest political-administrative entity and, therefore, the closest to the population and where the population's problems, priorities, and needs are identified and addressed. In the case of the cells, the management falls on technicians with a political team that acts as decision-makers. The sectors are the level of administration in which the people participate through their elected representatives. Their primary function is to promote coordination between higher and lower levels for planning, executing, and supervising development services and activities (NISR, 2014).

03
Rio synergies: A case for action internationally and in Rwanda

Collaboration between the Rio Conventions on land restoration is essential to achieve the goals ofLDN, biodiversity conservation, mitigating and adapting to climate change, and more broadly, achieving the Sustainable Development Goals (SDGs). There is a potential for both synergies and tradeoffs across the land-focused activities of the Rio Conventions. Synergies arise when actions to meet one Convention's objectives support those of another. For example, land restoration can simultaneously enhance biodiversity (CBD), sequester carbon (UNFCCC), and combat desertification (UNCCD). Conversely, tradeoffs may occur when actions towards one goal inadvertently harm another. For instance, planting non-native trees for carbon sequestration might help combat climate change but could negatively affect local biodiversity. By collaborating, the conventions can coordinate their efforts, maximizing positive synergies and minimizing negative tradeoffs. This joint approach ensures a balanced perspective, promoting SLM practices that benefit people and nature. In the context of land restoration, the promotion of synergies across the Rio Conventions implies that improved coordination helps increase the effectiveness and efficiency of land restoration activities (Figure 3), with direct implications on mobilizing much needed funding for land restoration. This is because more effective and efficient planning, implementation, and monitoring of land restoration will make it more attractive for public, multi-lateral, and private sector investments.

Coordination also needs to include other initiatives implementing land restoration activities. In the case of Rwanda, it is particularly important to coordinate land restoration activities under the Rio Conventions with those carried out by various other actors under the Bonn Challenge (cf. section 3.2.4.1). Overall, Rwanda's national land restoration targets under the Bonn Challenge significantly exceed those under the Rio Conventions' processes

FIGURE 3

Monetary implications of achieving synergies

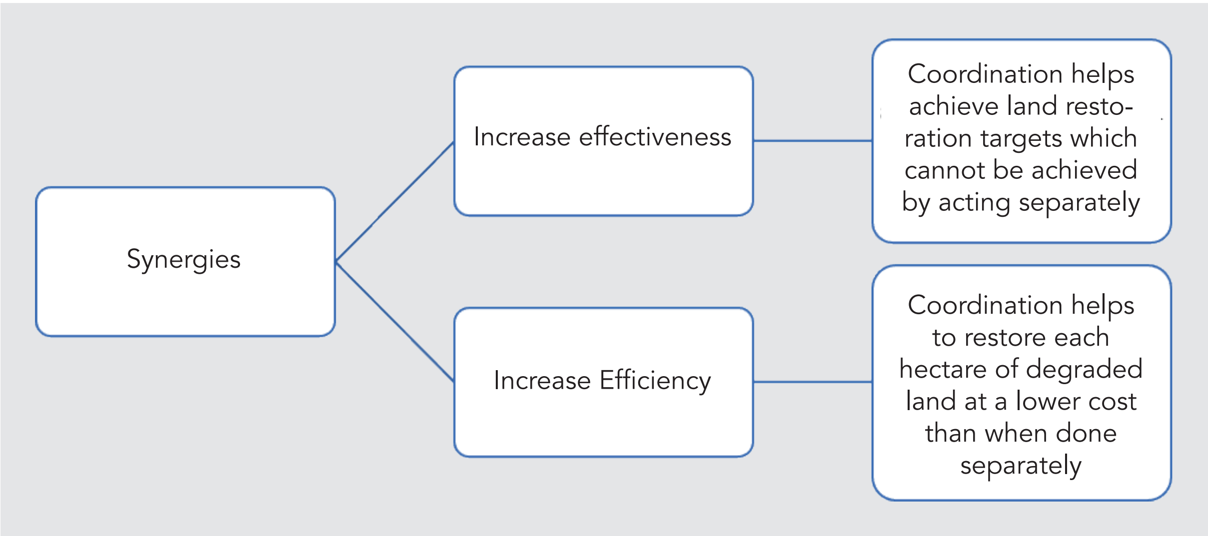


TABLE 2

Rwanda's land conservation, SLM, and restoration targets (in hectares)

*Source: calculated based on Rwanda's NDC, LDN, and NBSAP documents, as well as IUCN reports for the Bonn Challenge. Note: *Rwanda's NBSAP has such targets as "at least 10.3% of national territory holding biodiversity and ecosystem services is protected", "at least 50% of natural ecosystems are safeguarded, their degradation reduced", and "increase of forest cover up to 30% of the country" but since no baseline for these targets is given, it was not possible to unambiguously calculate corresponding areas for action in hectares. **The number for the Bonn Challenge overlaps several categories of land management presented here.*

Land management categories	LDN	NBSAP*	NDC	Bonn Challenge**
Increase forest land	105,352	*	17%	
Expand agroforestry	158,028		8%	
Restore degraded land	269,500	*		2,000,000
Crop rotation			600,000	
Terracing and anti-soil erosion	461,115		165,000	
Multi-cropping			40,000	
Biodiversity conservation	75,481	*		
Total	1,069,476		805,000	2,000,000

(Table 2). In total, Rwanda's commitments to land restoration under LDN, NDC, and the Bonn Challenge amount to 3.87 million ha, this exceeding the total territory of Rwanda (2.63 million ha), indicating that these are overlapping commitments rather than separate commitments.

There are currently no explicit targets with baseline and corresponding area for conservation, SLM, and restoration activities under Rwanda's NBSAP, with the current targets being given as share of the country's territory without baseline references. However, given the political momentum coming with the new Global Biodiversity Framework (GBF), and the need for all states to review and adapt their NBSAPs according to the new framework, there is a window of opportunity to do this NBSAP revision in Rwanda in an integrated manner, leveraging on other related agendas and targets through taking a significant step towards coherence, synergies, and efficiency.

3.1 Legal basis for collaboration across the three Rio Conventions

There are numerous decisions serving as the legal basis for collaborations by the Rio Conventions on land restoration (Janishevski 2020). Some of these are selectively indicated below.

UN General Assembly:

- UNGA Resolution 57/260 (2003) called for further collaboration and cooperation among the Rio Conventions to address sustainable development challenges,
- UNGA (2009) noted the need for enhanced co-operation among the Rio Conventions,
- UNGA (2012) adopted "The Future We Want" and encouraged coordination and cooperation between the Rio Conventions as well as other multilateral environmental initiatives.

CBD decisions:

- XII/20 called for collaborating with UNFCCC and others to promote ecosystem-based approaches to climate change adaptation,
- XI/21 urged promoting synergies between biodiversity and climate-change policies and measures,
- X/35 encouraged supporting activities identified in national capacity self-assessments (NCSAs) that promote synergies among the three Rio Conventions at the sub-national, national and regional level, within dry and sub-humid lands,
- GBF - promotes coherence, complementarity and cooperation between the CBD and other relevant multilateral agreements to contribute to and promote its implementation in a more efficient and effective manner.

UNCCD decisions:

- Decision 9/COP12 called for leveraging of synergies among the Rio Conventions and promoting partnerships with other international agencies and bodies,
- UNCCD decision 8/COP15 acknowledged that the implementation of the UNCCD benefits from strong and effective collaborations to create synergies with relevant organizations and international instruments,
- UNCCD decision 3/COP15 called for integrated spatial planning and policy coherence among the Rio Conventions.

UNFCCC decisions:

- COP 2007 in Bali highlighted that enhancing the implementation of the framework calls for enhanced coordination under the Joint Liaison Group with UNCCD and CBD,
- COP 2010 in Cancun urged for promoting synergy and strengthening engagement with national, regional and international organizations.

Joint Liaison Group (JLG) of the Rio Conventions

The secretariats of the UNFCCC, the CBD and the UNCCD established a Joint Liaison Group in August 2001 to enhance coordination among the three conventions. The JLG aims to collect and share information on the work programmes and operations of each convention. The responsibility for organizing and chairing meetings rotates among the secretariats. JLG could play an essential role in helping harmonize land restoration related activities by the Rio Conventions.

As we can see from these selective examples, there is an ample legal basis mandating harmonized and well-coordinated implementation of the three Rio Conventions. Land restoration is, arguably, the single most important activity area where this coordination for boosting synergies and avoiding tradeoffs is essential.

3.2 Rwanda's action programs under the Rio Conventions

3.2.1 National Biodiversity Strategies and Action Plan (NBSAP)

In March 1995, Rwanda ratified the CBD, which according to its article 6 stipulates the obligation to develop a NBSAP. The first one was developed in 2003 and by the end of 2016, after a review and alignment with the CBD Strategic Plan for Biodiversity and the Aichi Biodiversity Targets (2011-2020), it was further updated. These actions were carried out by the Ministry of Environment through Rwanda Environment Management Authority (REMA). The NBSAP identified five key goals with specific strategies. Based on these goals, the NBSAP proposes 19 targets at the national scale, 10 have been identified as closely related to the land-based objectives (Table 3).

The NBSAP has a long-term vision towards 2040 in line with the CBD strategic plan, a time window that differs from that chosen, for example, in Rwanda's NDC. The objectives were established based on national needs and priorities highlighted under a participatory process. Three national workshops

TABLE 3

Targets under the NBSAP
Source: Adapted from MoE (2016).

	National Biodiversity Strategy and Action Plan (NBSAP)
Protected and conservation areas	**Target 1:** By 2020, at the latest, the Rwandan population, at least in districts adjacent to protected areas, is aware of the values of biodiversity and ecosystem services and understands the steps for their sustainable use and conservation.
	Target 2: By 2020, the values of biodiversity and ecosystem services for at least two selected protected areas have been determined and integrated into planning processes, i.e., poverty reduction strategies and national economy.
	Target 9: By 2020, at least 10.3% of national territory holding biodiversity and ecosystem services is protected considering the landscape approach to maintain biological diversity.
Sustainable management of land and water resources	**Target 3:** By 2020, at the latest, positive incentives for biodiversity conservation and sustainability towards local communities development is boosted and applied, and harmful incentives are eliminated.
	Target 6: By 2020, fishing and aquaculture, agriculture, and forestry are managed sustainably taking into consideration ecosystem specificities to ensure biodiversity conservation.
	Target 11: By 2020, the genetic diversity of priority cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.
Ecosystem restoration	**Target 5:** By 2020, at least 50% of natural ecosystems are safeguarded, their degradation and fragmentation significantly reduced.
	Target 7: By 2020, pollutants including those from excess nutrients are controlled and their harm has been brought to levels that are not detrimental to ecosystem function and biodiversity.
	Target 8: By 2020, invasive alien species and their pathways are identified and prioritized invasive alien species controlled or eradicated.
	Target 14: By 2020, the ecosystem resilience and the contribution to carbon stocks have been enhanced by increasing forest cover up to 30% of the country and restoration of other ecosystems thereby contributing to climate change adaptation and mitigation.

were organized with stakeholders, including the public sector (central and local government), the private sector and NGOs involved in biodiversity conservation and management. Regarding location, although the proposed targets are on a national scale, the documents reviewed propose a prioritization in specific areas and surrounding zones within the conservation framework given their close relationship with tourism (one of the major economic sectors in Rwanda), among which the following stand out: Akagera National Park, Nyungwe National Park, Mukura and Gishwati Forests, Volcanoes National Park, Rugezi Wetland Complex, Buhanga Forest Reserve, Rweru–Mugesera Wetlands, Mashyuza Natural Forest, Lake Kivu Islands, Akagera Wetland Complex and Ibanda-Makera Remnant Forest.

In terms of budget and financing, the development of the NBSAP targets does not have a designated budget to implement each proposed objective. Throughout the document two aspects are mentioned: (1) that biodiversity funding in Rwanda comes mainly from the government budget, financial support from development partners, as well as from national and international NGOs. However, it is emphasized that it is extremely complex to assess the financial contributions from the government as the budget allocations are distributed among the various departments of the State (ministries, public institutions, etc.), and (2) although the actions do not have a specific budget, a total amount to carry out the strategy, approximately 7,910 billion Rwandan francs (7.1 billion US dollars), is estimated, and the sources of funding are elaborated (MoE, 2016).

3.2.2 Nationally Determined Contribution (NDC)

In November 2015, Rwanda submitted its first intended NDC, which was updated in 2016 following the Paris Agreement, thus becoming its first NDC. In 2020, Rwanda submitted an updated NDC. The

TABLE 4

Adaptation measures under NDC

Source: Adapted from MoE (2020).

	National Biodiversity Strategy and Action Plan (NBSAP)	
	Sector	Adaptation Measure
Protected and conservation areas	Land and Forestry	Promote afforestation / reforestation of designated areas.
Sustainable management of land and water resources	Agriculture	Develop climate resilient crops and promote climate resilient livestock.
		Develop climate resilient postharvest and value addition facilities and technologies.
		Strengthen crop management practices (disease prevention, diagnostic, surveillance, and control).
		Develop SLM practices (soil erosion control; landscape management).
		Expand irrigation and improve water management.
	Water	Strengthen national water security through water conservation practices, wetlands restoration, water storage and efficient water use.
		Develop and implement a catchment management plan for all level 1 catchments.
		Develop water resource models, water quality testing, and improved hydro-related information systems.
	Land and Forestry	Integrated approach to planning and monitoring for SLM.
		Develop a harmonized and integrated spatial data management system for sustainable land use management.
Ecosystem restoration	Land and Forestry	Improve forest management for degraded forest resources.
		Development of agroforestry and sustainable agriculture (control soil erosion and improved soil fertility).

TABLE 5

Mitigation measures under NDC
Source: Adapted from MoE (2020).

	Nationally Determined Contribution (NDC)	
	Sector	**Mitigation Measure**
Protected and conservation areas		–
Sustainable management of land and water resources	AFOLU (Agriculture): Crops and managed soils	Soil and water conservation (crop rotation): Continuous crop rotation of up to 600,000 ha, leading to prevention of soil erosion and reduction of CO_2 and N_2O emissions and carbon sequestration in soils.
		Improved fertilizer use: Increased use of organic waste in soil fertilizers, supported by target to apply composting within all agricultural households by 2030, and more judicious chemical fertilizer use and promotion of ferti-gation to enhance fertilizer uptake.
		Soil and water conservation (terracing): Installation of land protection terracing structures on 165,000 ha of sloping arable areas to present soil erosion, leading to reduction of CO_2 and N_2O emissions and carbon sequestration in soils.
		Soil and water conservation (multi-cropping): Multi-cropping of coffee and bananas on up to 40,000 ha, leading to prevention of soil erosion and reduction of CO_2 and N_2O emissions and carbon sequestration in soils.
Ecosystem restoration	AFOLU (Agriculture): Crops and managed soils	Conservation tillage: Reduction in vertical movement of soil, leaving more crop residue on the soil surface, thereby reducing soil erosion, reduction of CO2 and N2O emissions and carbon sequestration in soils.

public institution responsible for its development and coordination is the Ministry of Environment (MoE). While the total cost for the NDC adaptation measures identified by Rwanda until 2030 is estimated at about 5.3 billion US dollars, for the land-based adaptation measures (Table 4), it is estimated at 3.6 billion US dollars, namely for water (0.5 billion US dollars), agriculture (2.8 billion US dollars), forestry (0.2 billion US dollars) sectors, respectively (MoE, 2018b; MoE, 2020).

According to the latest inventory in the Third National Communication, the total GHG emissions in Rwanda, excluding the forestry sector, were estimated at 5.33 million tons of carbon equivalent per year in 2015. The agricultural sector accounted for 55% of this total, being a priority sector for mitigation measures. Mitigation measures have been categorized into unconditional and conditional. The former, those that will be supported and applied at the national level, are expected to reduce emissions by 16%. On the other hand, conditional mitigation measures, or those that require international support and financing and therefore their fulfilment is not assured, represent 22% by 2030. Mitigation measures identified in the agriculture, forestry, and land use (AFOLU) sector represent 49% of the total potential, while within the sector, soil conservation measures - including terracing (20%), conservation tillage (9%), multi-cropping (3%), and crop rotation practices (24%) - represent about half of the mitigation potential (Table 5).

TABLE 6

Targets under the LDN

Source: Adapted from MoE (2018c).

	Land Degradation Neutrality (LDN)	
	National	**Sub-national**
Protected and conservation areas	National Forest Cover increased from 29.6% (2015) to 30% (2024) and maintained at 30% by 2030	Nyaruguru: Increasing trees by afforestation and agroforestry, fruit trees, tree species diversification
Sustainable management of land and water resources	AFOLU (Agriculture): Crops and managed soils	Soil and water conservation (crop rotation): Continuous crop rotation of up to 600,000 ha, leading to prevention of soil erosion and reduction of CO_2 and N_2O emissions and carbon sequestration in soils.
	Level of land productivity and soil organic carbon (SOC) at country level maintained and improved by 2030 compared to 2015 baseline	Nyagatare: Development and management of improved pasture and promotion of irrigation
	Area under agroforestry increased from 6% in 2015 to 12% in 2030	Huye and Gisagara: Reorganization of settlement, rainwater harvesting, agroforestry, inputs (fertilizers), capacity building for land tenure, agroforestry, improved agronomic practices, use of manure
	Ensure the compliance to the national land use master plans	Rubavu in lake Kivu border: Develop soil erosion control measures including afforestation and agroforestry
	Reduce the conversion of forests and wetlands into other land cover classes by 2030 (no net loss)	Ngororero and Rutsiro in Congo: Develop soil erosion control measures such as radical and progressive terraces, reforestation, and agroforestry
	Reduce the conversion of cropland and grassland into artificial surfaces by 2030 (no net loss)	Nyaruguru: Improve organic matter by use of manure and liming, improved agronomic practices
	Improve the land productivity on 28,200 ha of forest area, 30,600 ha of grassland, and 202,700 ha of cropland currently showing declining productivity, moderate decline and stressed productivity through SLM practices	–
Ecosystem restoration	Increase of land protected against soil erosion from 1,034,509 ha in 2018 to 1,495,624 ha in 2024	–
	The percentage of land designated for biodiversity conservation will be increased from 10.13% in 2017 to 10.3% in 2020	–
	Degraded forests rehabilitated from 4,379 ha in 2017 to 12,379 ha by 2024	–

While the total estimated cost of the NDC mitigation measures identified by Rwanda until 2030 is estimated at 5.7 billion US dollars, for the selected measures (Table 5), the estimate is 1.8 billion US dollars, all of which are categorized as unconditional and therefore included in national policy planning and budgeted in sectoral plans (MoE, 2018b; MoE, 2020).

3.2.3 Land Degradation Neutrality (LDN)

In November 2017, Rwanda launched its LDN target setting process by developing a comprehensive work plan and specific budget. These actions were carried out by the Ministry of Environment (MoE) through Rwanda Water and Forestry Authority (RWFA) with the establishment of a national LDN working group, composed of members from various interested parties. The latest update of the targets was done in 2018 and is contained in the document Final Country Report of the LDN Target Setting Programme in Rwanda. At the national level Rwanda has set LDN targets aiming to be a net land degradation-neutral country by 2030. However, while Rwanda recognizes that efforts to meet the targets should be made at the national scale, solutions should focus on high priority areas and therefore targets have been set at the sub-national scale, too. Therefore, both scales of targets have been considered in this report (Table 6). Our analysis in the coming sections suggests that Rwanda is already net land degradation neutral.

Following the general recommendation to start the baseline assessment in 2015, three indicators were used: soil organic carbon (SOC) storage above and below ground, land cover change, and net primary productivity (ELD, 2020). The results showed that in the framework of carbon reserves, it is the areas that changed from forested areas to cropland and artificial surfaces that show the most negative trend at the national level (a decrease of 8% and 43%, respectively). In the case of productivity, the decrease is estimated at 3% while the increase is 49% of the national area. Finally, in the case of land cover change, there is an estimated 339% increase in land covers that have been converted into artificial surfaces. Forest cover has increased by 3%, while cropland cover has decreased by 10%.

Unlike the NDC and NBSAP, no specific information related to budgets or schedules was found in the case of the LDN, even though, according to the Annexes of the published document, there is a Country Work Plan LDN Activity Schedule and Budget prepared in 2017 (MoE, 2018c).

3.2.4 Rwanda's other land restoration commitments

3.2.4.1 The Bonn Challenge

The Rwandan government also committed to restoring the ecological health of 2 million hectares of its territory from "border to border" (IUCN, 2020). Thus, in 2011, Rwanda officially joined the Bonn Challenge. This global commitment was initiated by the German government and the International Union for Conservation of Nature (IUCN) and initially aimed to restore 150 million hectares globally by 2020. In 2014, through the New York Declaration on Forests, this goal was expanded to a global target of 350 million ha by 2030. The benefits of meeting the targets worldwide range from sequestering an additional one gigaton of carbon equivalent annually, increasing crop yields by 30% on up to 50 million hectares, to reaching 84 billion US dollars per year in net benefits to local and national economies. Rwanda was the first country in Africa to sign the pledge (Dave et al., 2019; Stepman, 2020).

According to the second barometer of the Bonn Challenge, between 2010-2019, the baseline year for on-the-ground implementation of strategies at the national level, Rwanda has managed to restore 708,628 hectares (Dave et al., 2019). With this, through articulated work between small farmers, grassroots organizations, government agencies, and NGOs, Rwanda has achieved more than a third (35%) of its pledge. According to Dave et al. (2019), there are a total of 44 projects and programs that have allowed this progress on the ground. These include afforestation, improved management of public and private forest plantations, construction of terraces, protection of riverbanks, protection of buffer zones, irrigation of slopes, protection of lakeshores, and protection of natural forests. However, most projects focused on agroforestry initiatives (Dave et al., 2019).

The impacts of achieving the third part of the pledge undertaken through the Bonn Challenge range from climatic to the country's biodiversity, socio-economic, and even in the development of a political framework. For example, the hectares restored to date have realized a total cumulative removal of about 28 million tons of carbon during the period 2011 – 2018 (Dave et al., 2019), this can be compared to about 5.3 million tons of annual GHG emissions by Rwanda during the same period. In the case of biodiversity, it is estimated that eight of the projects were implemented in national parks or protected areas and therefore had more significant impacts on the biodiversity of those regions. These include Volcanoes National Park, Akagera National Park, Lake Kivu, Cyamudongo Forest, and Gishwati National Park and Landscape. For the measurement of socio-economic impacts, it was determined that during the period 2017-2018, 22,325 jobs were created in the forestry sector. In addition, during the period 2013-2018, FONERWA estimated the creation of 137,562 green jobs in 36 of the projects analysed. In the case of the policy framework, a total of 27 policies, strategies, and plans were identified. Most of them depend on the MoE, the former Ministry of Lands and Forests (MINILAF), the Ministry of Infrastructure (MININFRA), and the MINAGRI.

The land restoration targeting areas and benefit-cost analysis that we present in this study focuses on the ecosystems which were degraded between 2001 and 2020 and were not restored under these initiatives. Those ecosystems which were degraded after 2001 but were already restored by these efforts are not captured in this analysis.

3.2.4.2 Forest landscape restoration (FLR)

Achieving the goals proposed by the Bonn Challenge requires clear and multidimensional processes; therefore, the global commitment proposes implementing the FLR approach. According to the Bonn Challenge, this is a "continuous process of restoring the ecological functionality of degraded and deforested landscapes, which improves the well-being of the people who live in these places" (IUCN, 2022). Rwanda adopted this approach as the fundamental basis of its strategy to achieve the goal of restoring 2 million hectares in the country under the Bonn Challenge. Thus, Rwanda seeks to provide ecological integrity and human well-being through multifunctional landscapes, treating the landscape as a mosaic of different land uses where restoration activities should complement and not displace existing uses (MINIRENA et al., 2014).

To guide and plan FLR implementation, Rwanda has followed two formal frameworks at the national level: (i) it applied the Restoration Opportunities Assessment Methodology (ROAM) since 2014 as a flexible and affordable framework to identify and analyse areas that are ready for FLR and to identify specific priority areas across its territory; (ii) in 2018, it completed its target-setting process for the UNCCD LDN targets. In addition, the country used the ROOT tool, developed by the Natural Capital Project, to support decision-making on potential restoration impacts in Rwanda. For monitoring, the government has implemented two national platforms. These are the Forest Sector Monitoring and Evaluation System (FMES) under the RWFA and the monitoring information system (MIS) of MINAGRI (Dave et al., 2019).

Between 2011-2018, a total of US$ 530,762,526 has been invested in FLR in Rwanda, of which 51.7% (US$ 274,479,097) represent public investments, US$ 188,555,240 (35.61%) are projects co-financed by international donors and the government, and 12.6% (US$ 67,490,843) are of international donors. Meanwhile, the contribution of the private sector and non-profit organizations was low: US$ 216,680 (0.041%) and US$ 20,665 (0.004%), respectively (Dave et al., 2019).

3.3 Synergies and tradeoffs across the Rio Conventions' targets in Rwanda

Land-focused activities by NDC, NBSAP, and LDN processes in Rwanda can be categorised into conservation, sustainable management, and restoration, corresponding to the LDN hierarchy of avoiding, reducing, and reversing land degradation (Table 7, Figure 4).

Achieving these three categories of targets by NDC, LDN, and NBSAP processes in Rwanda requires an integrated approach that recognizes their in-

TABLE 7

Synergies and tradeoffs of the three Rio Conventions' land management targets in Rwanda

Land management types	Protected and conservation areas	Sustainable management of land resources			Ecosystem restoration	
Synergy or Tradeoff potential	These targets are mostly synergistic contributing to each other. Tradeoff may occur if the activities on maintaining forest cover would be done through planting mono-species forests.	All objectives under this category are synergistic and mutually supportive. The only tradeoff may occur with compliance with the National Land Use Master Plan 2050 due to inconsistencies.			Primarily synergies, tradeoff may occur if land restoration practices are done with alien species or mono species forest plantations.	
Land Degradation Neutrality (LDN)	Maintain forest cover at 30% of the national area.	Improve land productivity and SOC.	Increase agroforestry area.	Ensure the compliance to the national land use master plans.	Increase of land protected against soil erosion.	Degraded forests rehabilitated.
		Reduce the conversion of forests and wetlands.	Reduce the conversion of cropland and grassland into artificial surfaces.	Improve the land productivity through SLM practices.	Land designated for biodiversity conservation will be increased.	
National Biodiversity Strategy and Action Plan (NBSAP)	Awareness of the values of biodiversity and ecosystem services and knowledge of sustainable use and conservation.	Positive incentives for biodiversity conservation and sustainability are boosted and applied and harmful incentives are eliminated.			At least 50% of natural ecosystems are safeguarded, their degradation and fragmentation significantly reduced.	Invasive alien species controlled or eradicated.
	Determine values of biodiversity and ecosystem services and integrated into planning processes.	Fishing and aquaculture, agriculture, and forestry are managed sustainably taking into consideration biodiversity conservation.			Increase of forest cover up to 30% of the country.	
	At least 10.3% of national territory is protected.	Safeguard genetic diversity.			Pollutants and excess nutrients are controlled.	

Land management types	Protected and conservation areas	Sustainable management of land resources			Ecosystem restoration	
Nationally determined contribution (NDC)	–	Crop rotation	Improved fertilizer use, organic compost, and judicious chemical fertilizer application.	Terracing	Conservation tillage	
		Integrated approach to planning and monitoring for sustainable land management.	Develop sustainable land management practices.	Multi-cropping	Wetlands restoration	
		Develop a harmonized and integrated spatial data management system for sustainable land use management.	Improve Forest Management for degraded forest resources.	Agroforestry and Sustainable Agriculture		

terdependencies and tradeoffs. Table 7 provides an overview of the NDC, LDN, and NBSAP targets under these three categories. It highlights the synergy or tradeoff potential between these targets and the specific actions and goals related to LDN, NBSAP, and NDC in Rwanda.

In terms of synergy or tradeoff potential, the targets for protected and conservation areas are mostly synergistic, contributing to each other. However, tradeoffs may occur if activities focused on maintaining forest cover are carried out through planting mono-species forests.

Targets under the category of sustainable management of land resources can all be synergistic and mutually supportive (Table 7), with the only tradeoff potentially arising from the compliance with the National Land Use Master Plan 2050 due to potential inconsistencies because some of these NDC, LDN, and NBSAP commitments were made before the adoption of the National Land Use Master Plan 2050, so this means that these may be revised in future to bring them in compliance with evolving national legal frameworks. Ecosystem restoration primarily exhibits synergies, although a tradeoff may occur if land restoration practices involve the use of alien species or mono-species forest plantations.

Although all the three Rio Conventions pursue land conservation, sustainable management, and restoration objectives, each has its prevailing emphasis: LDN has a bigger concentration on sustainable land management, NBSAP focuses more on conservation, and NDC has a bigger emphasis on land restoration (Figure 3). There are also major overlaps in the specific contents of the targets pursued by the Conventions (Figure 5). There are three action areas in the targets that are common to all the three Rio Conventions, such as maintaining and improving forests, adopting sustainable land management practices in croplands, and protecting biodiversity. There are also several target overlaps between pairs of the Conventions.

The LDN targets include maintaining forest cover at 30% of the national area, improving land productivity and SOC, increasing agroforestry area, and ensuring compliance with national land use master plans. The objectives also encompass reducing the conversion of forests and wetlands, as well as cropland and grassland, into artificial surfaces, and increasing the protection of land against soil erosion. Furthermore, degraded forests are targeted for rehabilitation.

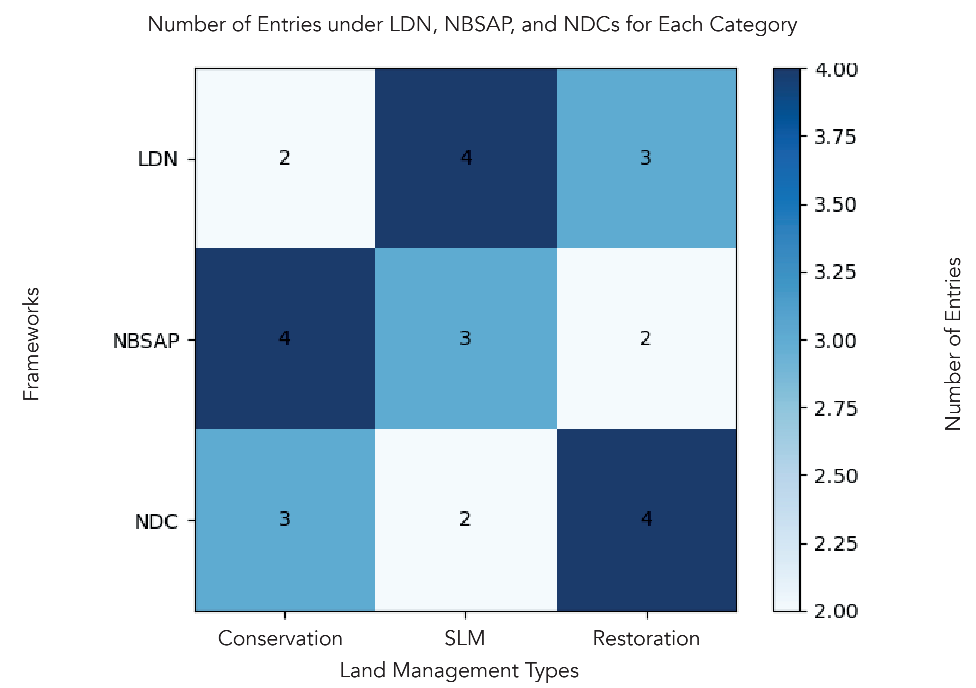
Under the NBSAP, the objectives focus on raising awareness of the values of biodiversity and ecosystem services, sustainable land use and conservation, and implementing positive incentives while eliminating harmful ones. The safeguarding of at least 50% of natural ecosystems and the significant reduction of degradation and fragmentation are also emphasized. Control or eradication of invasive alien species is another key target, along with determining the values of biodiversity and ecosystem services integrated into planning processes. The sustainable management of fishing, aquaculture, agriculture, and forestry, considering biodiversity conservation, is also highlighted, as well as increasing forest cover up to 30% of the country and controlling pollutants and excess nutrients.

The NDC section does not provide specific targets for protected and conservation areas but emphasizes an integrated approach to planning and mon-

FIGURE 4

Focus of the three Rio Conventions on different aspects of land management

Note: figures represent the number of adopted targets under each category



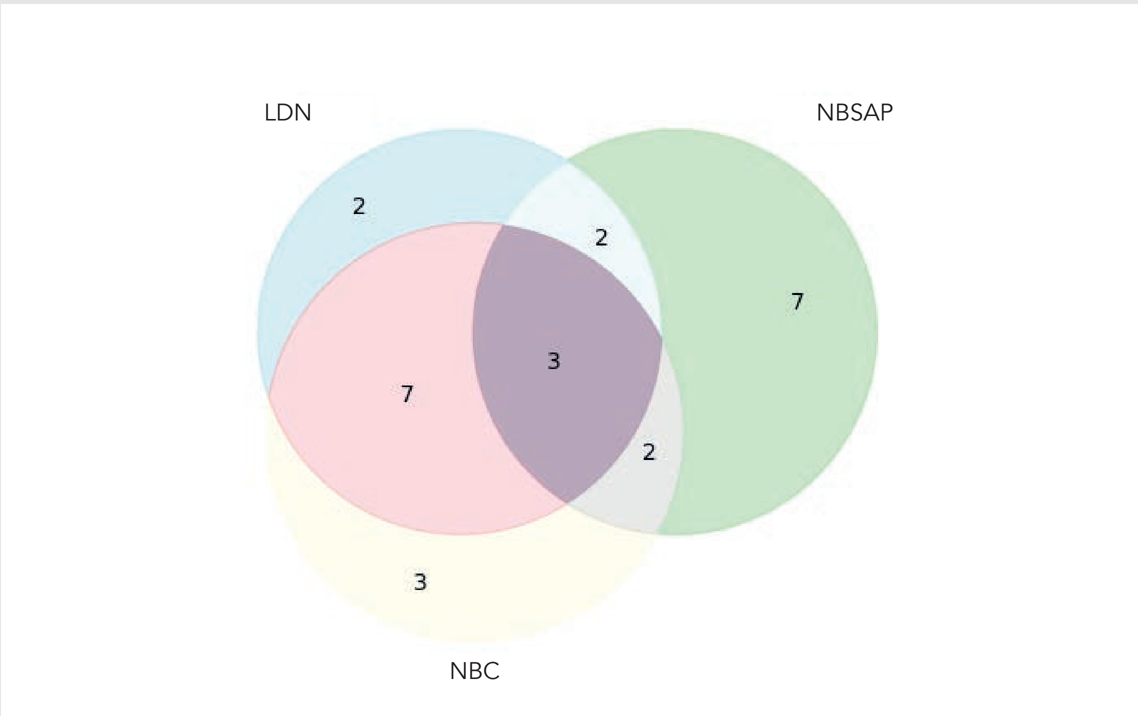
itoring for sustainable land management. It calls for the development of SLM practices, improved forest management for degraded forest resources, and the implementation of agroforestry and sustainable agriculture. Additional actions include crop rotation, improved fertilizer use, terracing, conservation tillage, multi-cropping, wetlands restoration, and the development of a harmonized and integrated spatial data management system for sustainable land use management.

Overall, it is abundantly clear that NDC, LDN, and NBSAP processes are overlapping and mutually complementary. Implementing them as separate processes at the national and global levels without concrete coordination mechanisms will likely result in lower effectiveness and efficiency of achieving their objectives. Moreover, coordinated implementation will also help avoid potential tradeoffs inherent in these land-related targets.

FIGURE 5

Overlaps in similar land management targets across the Conventions in Rwanda.

Note: figures represent the number of overlaps in objectives pursued by NDC, LDN, and NBSAP land-focused targets in Rwanda. The colors are meant to clearly separate overlap areas between the three Conventions and beyond that do not have any inherent meaning.



04
Land degradation in Rwanda

Land degradation in Rwanda is primarily occurring in two major forms: through soil erosion in croplands and through land use and land cover change where higher value ecosystems are replaced by lower value ecosystems, such as through deforestation.

Soil erosion in croplands is particularly rampant. Agriculture is a crucial economic activity in Rwanda, but current farming practices are leading to severe soil erosion in some parts of the country. Soil erosion depletes the fertility of the land, leading to reduced agricultural productivity. With the removal of topsoil, essential nutrients are lost, thus degrading the quality of the soil, compromising crop yields and subsequently threatening food security. Additionally, soil erosion can lead to water pollution and sedimentation in nearby bodies of water, further impacting the local ecosystem and biodiversity.

The second major form of land degradation in Rwanda involves the change in land use and land cover. This process is typically driven by factors

FIGURE 6

Erosion risk in Rwanda

Source: Adapted from RWB and IUCN (2022) and WB (2017).

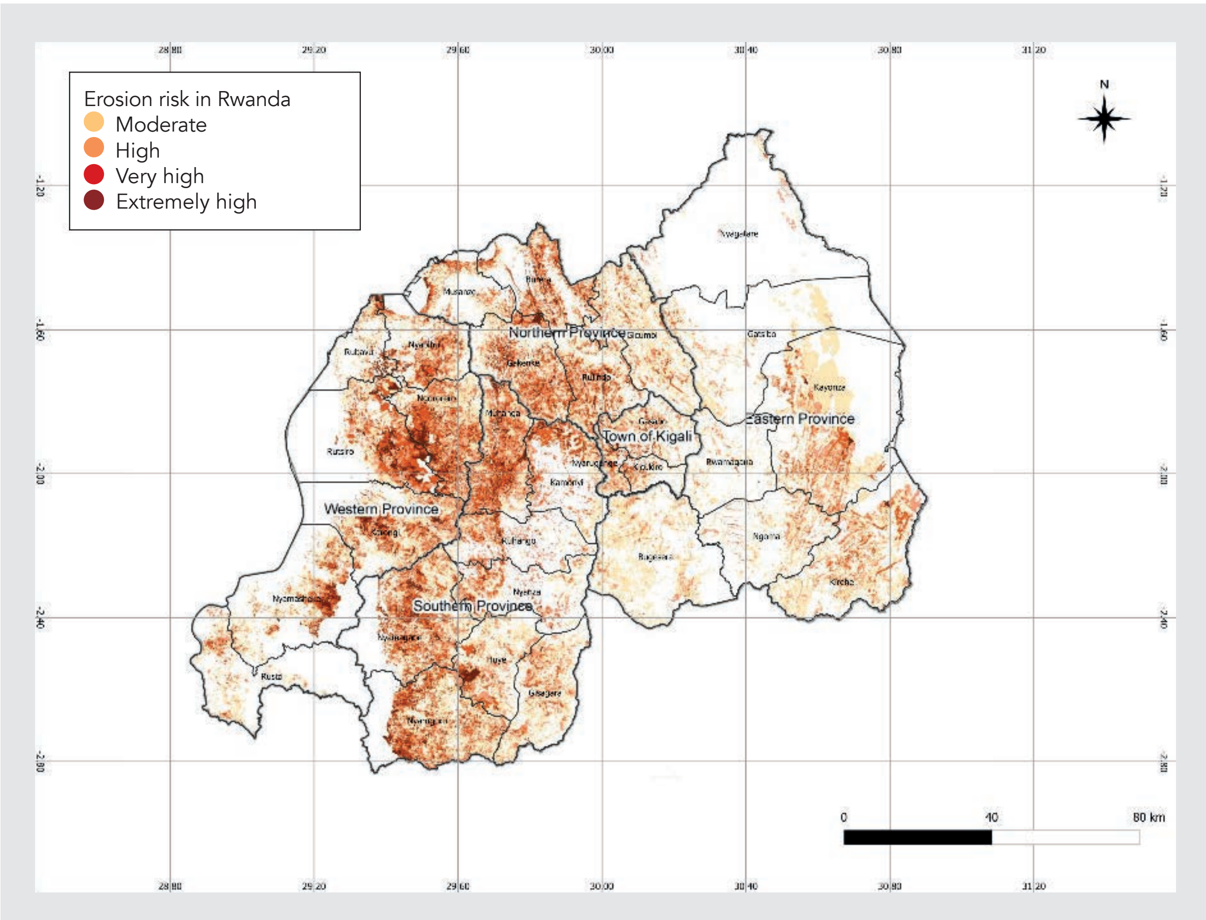


TABLE 8

Erosion risk per province in Rwanda (ha)
Source: Adapted from RWB and IUCN (2022).

Erosion level	East	North	South	West	Kigali	Total
Moderate	187,634	83,527	127,571	99,355	18,908	516,995
High	55,016	54,269	106,498	72,223	12,797	300,802
Very High	16,924	37,011	70,262	60,571	5,663	190,431
Extremely High	1,593	12,358	26,786	29,392	1,812	71,941
Total	261,166	187,165	331,116	261,542	39,179	1,080,168
Share of erosion risk in each province	29%	59%	56%	54%	54%	42%

such as population pressure, economic development, and demand for agricultural and living space. Deforestation and land cover change significantly impact the environment and biodiversity. Forests are vital carbon sinks, helping to mitigate climate change by absorbing carbon dioxide. Their loss contributes to global warming. Furthermore, forests and wetlands are home to a diverse range of species, and their conversion often results in habitat loss, threatening biodiversity.

In the following sections , firstly, we review the current state of soil erosion in Rwanda by evaluating existing literature. Secondly, we present our own analysis of land use and land cover changes in Rwanda during the period between 2001-2020 together with their economic and environmental implications.

4.1 Soil erosion

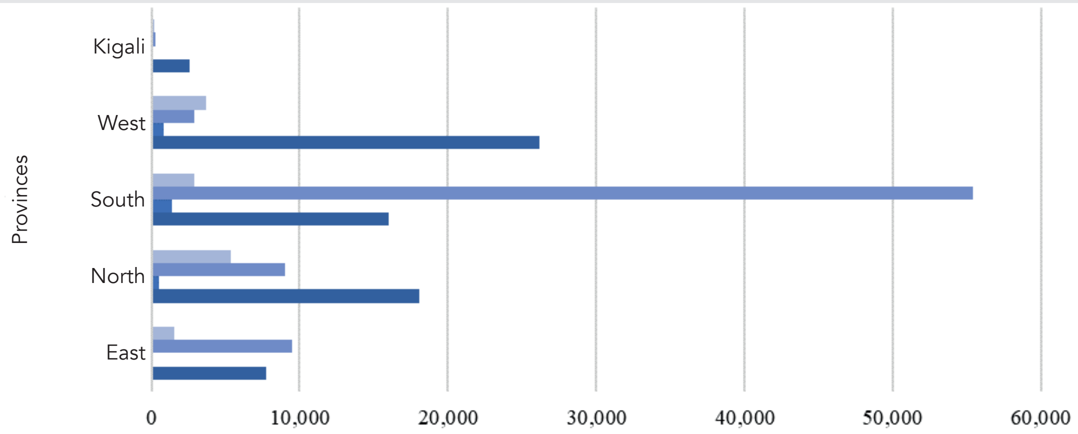
According to the MINAGRI, small farmers (those with plots of less than 2 hectares) cultivate on slopes with gradients of up to 55%, resulting in more than 50% of the country's cropland currently showing signs of erosion. Consequently, this situation significantly reduces the capacity of such land to produce food and fiber. In 2009, MINAGRI reported that soil erosion caused a total loss of approximately 15 million metric tons of topsoil annually (Stainback et al. 2012). The estimated annual average is 25-32 tons per hectare per year (Berry and Olson 2003, Kabirigi et al. 2017, RWB and IUCN 2022).

In mid-2018, the Rwandan government developed the Catchment Restoration Opportunity Mapping (CROM) model, intending to map the areas with the highest risk of erosion, using six types of classification: (1) No risk, (2) Low risk, (3) Moderate risk,

FIGURE 7

Sources of soil erosion in Rwanda

Source: Adapted from RWB and IUCN (2022) and WB (2017).



	East	North	South	West	Kigali
Severe gullies	1,517	5,350	2,879	3,669	168
Rill erosion	9,493	8,981	55,416	2,879	270
Landslide	117	474	1,397	828	7
Gullies	7,700	18,081	15,986	26,127	2,539

Severe gullies, Rill erosion, Landslide, Gullies

(4) High-risk, (5) Very high risk and (6) Extremely high erosion risk areas. Although the CROM represented a significant advance in the framework of spatial identification of these areas, the model needed to consider those zones as already protected against erosion or the erosive characteristics that prevailed, making it difficult to implement specific strategies and thus reducing its effectiveness. Faced with this information gap, the government improved the model. So, in 2021, using World View images and applying visual image interpretation techniques, erosion was mapped in very high details throughout the 30 districts of the country.

The results, as seen in Figure 6, show that about 1.1 million ha are at moderate to extremely high risk of erosion. Only about 0.28 million ha are protected against erosion by implementing various control techniques (RWB and IUCN, 2022). A detailed analysis shows that the province with the highest soils erosion risk index is the Northern province, with 59% of its territory at risk (Table 8). In comparison, the Eastern province represents the province with the lowest percentage at the national level (only 29% of its territory). A breakdown of the main erosive features throughout the country identifies that these lands are being affected primarily by gully erosion, followed by gullies, severe gullies, and landslides (Figure 7).

Agricultural areas planted with seasonal crops show a high rate of soil erosion (61% of the total), followed by forests (22%) and urbanized areas (8%), the latter mainly concentrated in the Western province. More than 745,000 hectares of agricultural land experience some erosion each year. Annual productivity losses are significant for bananas (67,000 tons), potatoes (26,000 tons), maize (22,000 tons) and beans (15,000 tons). The total economic loss in agricultural productivity due to severe erosion in the country was estimated to be about 37.9 billion Rwandan francs (RWf) each season (at 2021 prices), i.e., about 35 million US dollars (RWB and IUCN, 2022). According to a study conducted by IUCN, the monetary value of topsoil per ton fluctuates between 30 thousand and 50 thousand Rwandan francs (i.e., between 34 and 57 US dollars per ton), i.e., the country loses annually 810 billion Rwandan francs (RWf) (744 million US dollars) due to soil losses (RWB and IUCN, 2022).

4.2 Land dynamics: land use and cover change

We used MODIS satellite data on land use and land cover at 500-meter resolution to trace the dynamics of land use change in Rwanda over the period of two decades from 2001 to 2020 (cf. Annex 2 for details). Our analysis is broadly consistent with the findings from the previous studies, for example, those used in the LDN target setting process, and shows significant land use land cover changes in Rwanda over the last two decades (Figure 8, Table 9).

Table 10 represents the changes in the areas of each land use and land cover category between 2001 and 2020. Two key trends stand out: 1) reduction in the areas of savannas, grasslands, and croplands without agroforestry, 2) significant expansion of agroforestry systems (corresponding to cropland/natural vegetation mosaics category in the MODIS satellite data). The area under natural forests, here corresponding to evergreen broadleaf forests, increased by about 3% over the last two decades. This came about through expansion of broadleaf forests to woody savannas and savannas. The urban areas expanded by about 30%, primarily by replacing croplands, grasslands, and savanna areas (Tables 9 and 10).

These land use and land cover changes resulted in significant tradeoffs between food production, carbon sequestration, and biodiversity. In most cases, these tradeoffs were settled to favor food production at the expense of carbon sequestration and biodiversity. Tradeoffs between food production, carbon sequestration, and biodiversity are a common challenge in sustainable land use and environmental management, particularly in a developing country like Rwanda. To increase food production

FIGURE 8

Rwanda land use and cover in 2001 (a) and 2020 (b)

Source: based on data from Friedl and Sulla-Menashe (2019).

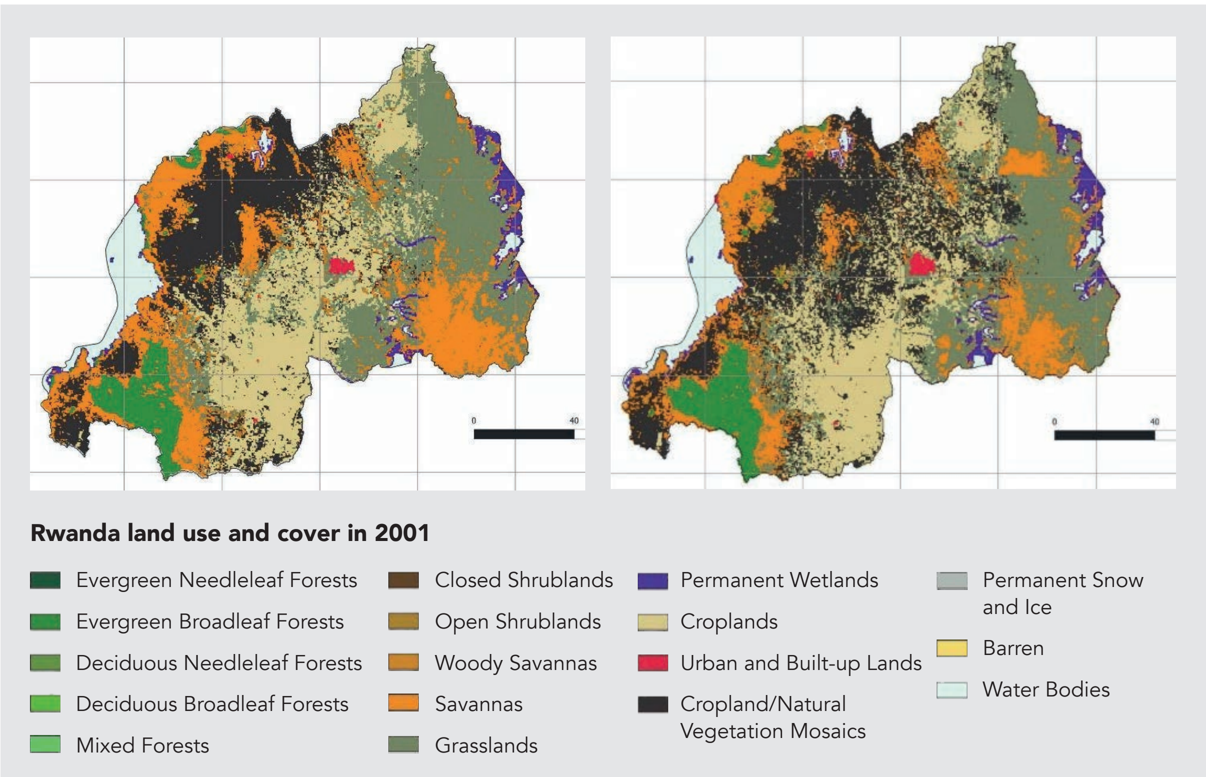


TABLE 9

Land use and land cover change matrix in Rwanda, 2001-2020

Source: MODIS satellite data on land use and land cover. Note: we are considering cropland/natural vegetation mosaics as agroforestry systems.

Ecosystems in 2001, hectares	Evergreen Needle-leaf Forest	Ever-green Broadleaf Forest	Closed shrubland	Open shrubland	Woody savannas	Savannas	Grassland	Perma-nent wetlands	Cropland	Urban areas	Cropland/ Natural Vegeta-tion	Barren	Water bodies	Total
Evergreen Broadleaf Forest	0	122,169	0	0	3,940	6,454	272	208	0	0	176	0	0	133,220
Mixed Forest	0	128	0	0	0	0	0	0	0	0	0	0	0	128
Closed shrubland	0	0	0	0	0	160	112	400	0	0	16	0	0	689
Woody savannas	0	4,148	0	0	4,484	4,324	64	288	0	0	32	0	0	13,341
Savannas	16	8,697	0	208	7,864	313,543	117,493	7,992	9,209	1,089	81,777	0	0	547,888
Grassland	0	240	16	16	400	66,386	427,513	2,803	54,662	1,137	91,483	0	0	644,656
Permanent wetlands	0	224	0	0	496	2,418	1,522	71,063	32	0	0	96	2,370	78,222
Cropland	0	0	0	0	32	3,267	38,022	16	420,418	1,281	126,510	0	0	589,546
Urban areas	0	0	0	0	0	0	0	0	0	9,690	0	0	0	9,690
Cropland/ Natural Vegetation Mosaics	0	609	0	0	144	34,722	13,854	16	65,777	16	376,358	0	0	491,496
Barren	0	0	0	0	0	0	0	272	0	0	0	368	96	737
Water bodies	0	0	0	0	0	0	0	1,618	0	0	0	96	122,474	124,187
Total	**16**	**136,215**	**16**	**224**	**17,361**	**431,276**	**598,851**	**84,676**	**550,098**	**13,213**	**676,352**	**561**	**124,940**	**2,633,800**

TABLE 10

Net changes in ecosystems' extent in Rwanda (ha)
Source: Modis satellite data on land use and land cover.

Ecosystems	2001	2020	Difference, in ha
Evergreen Needleleaf Forest	0	16	16
Evergreen Broadleaf Forest	133,220	136,215	2,995
Mixed Forest	128	16	-112
Closed shrubland	689	224	-464
Woody savannas	13,341	17,361	4,020
Savannas	547,888	431,276	-116,612
Grassland	644,656	598,851	-45,805
Permanent wetlands	78,222	84,676	6,454
Cropland	589,546	550,098	-39,447
Urban areas	9,690	13,213	3,523
Agroforestry systems	491,496	676,352	184,856
Barren	737	561	-176
Water bodies	124,187	124,940	753
Total	**261,166**	**187,165**	**1,080,168**

to feed the growing population, areas that were previously woody savannas or grasslands have often been converted into croplands. While this has boosted food production, it has also led to a decrease in carbon sequestration and biodiversity.

4.3 Ecosystem assets: Rwanda's natural capital values

The review of available literature and compiled databases on the values of ecosystem services show that the highest value ecosystem category in Rwanda is broadleaf forests, with one hectare of broadleaf forest producing annually ecosystem services with an estimated worth of 3,350 US dollars (Annex 2). The second most valuable category is permanent wetlands: 3,187 US dollars per hectare per year. Croplands with agroforestry (cropland/natural vegetation mosaics) on average provide 1,069 US dollars' worth of ecosystem services (Annex 2).

Our analysis shows that between 2001 and 2020, Rwanda gained in the values of natural capital in its ecosystems by about 125 million US dollars on the net balance (Table 11, Figure 10). However, this net balance figure hides the fact that Rwanda experienced about 142 million US dollars' worth of loss of natural capital. Positive net balance was achieved because the expansion of agroforestry systems, forests, and wetlands was bigger than their loss.

Rwanda has been very successful in expanding agroforestry systems in croplands and in conserv-

FIGURE 9

Incurred tradeoffs between food production, carbon sequestration, and biodiversity.

Note: the underlying analysis compares the economic estimations of food production, carbon sequestration, and biodiversity values of different ecosystems, using compiled data on economic values of ecosystem services by different land use and land cover categories in Rwanda (Annex 2).

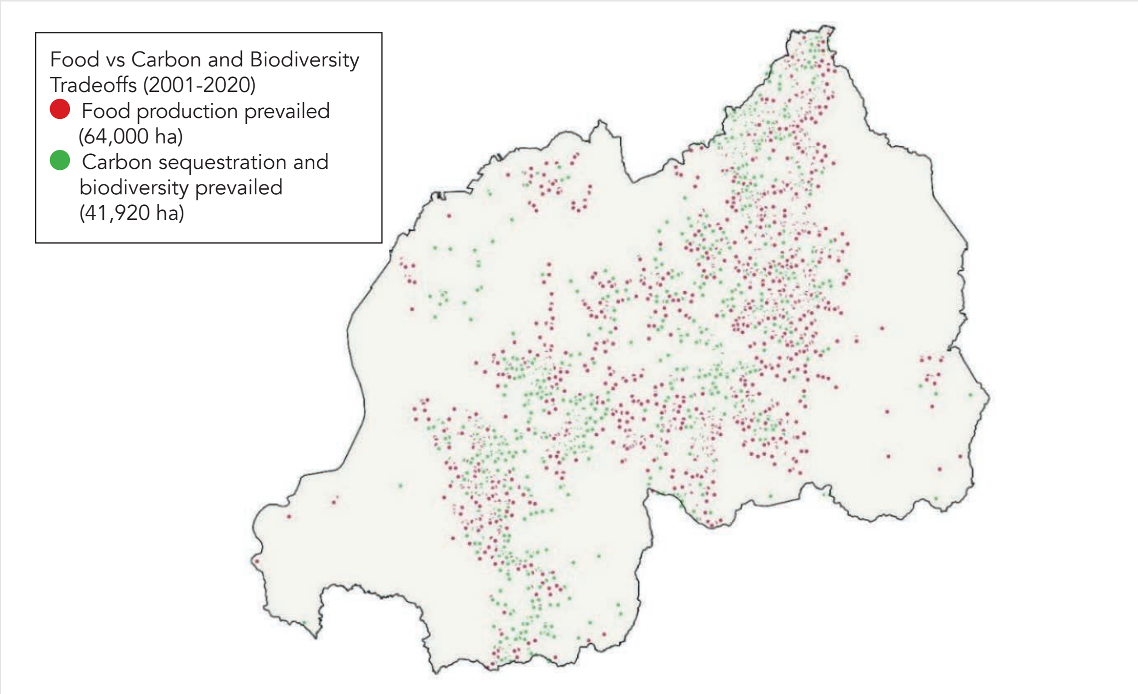


TABLE 11

Changes in the Total Economic Value of ecosystems in Rwanda, 2001-2020

Author's note: the underling analysis is described in Section 2.2.1 and Annex 2.

Ecosystems	2001-2020		
	Losses (USD)	Gains (USD)	Net change value (USD)
Evergreen needleleaf forests	0	24,296	24,296
Evergreen broadleaf forests	-29,530,110	37,245,530	7,715,420
Closed shrubland	-29,037	4,148	-24,889
Open shrubland	0	4,148	4,148
Woody savannas	-16,593	108,924	92,332
Savannas	-31,931,700	17,726,520	-14,205,180
Permanent wetlands	-12,128,120	31,023,910	18,895,790
Cropland	-3,650,089	5,247,579	1,597,490
Agroforestry systems	-64,688,830	176,235,000	111,546,170
Total	**-141,974,478**	**267,620,056**	**125,645,577**

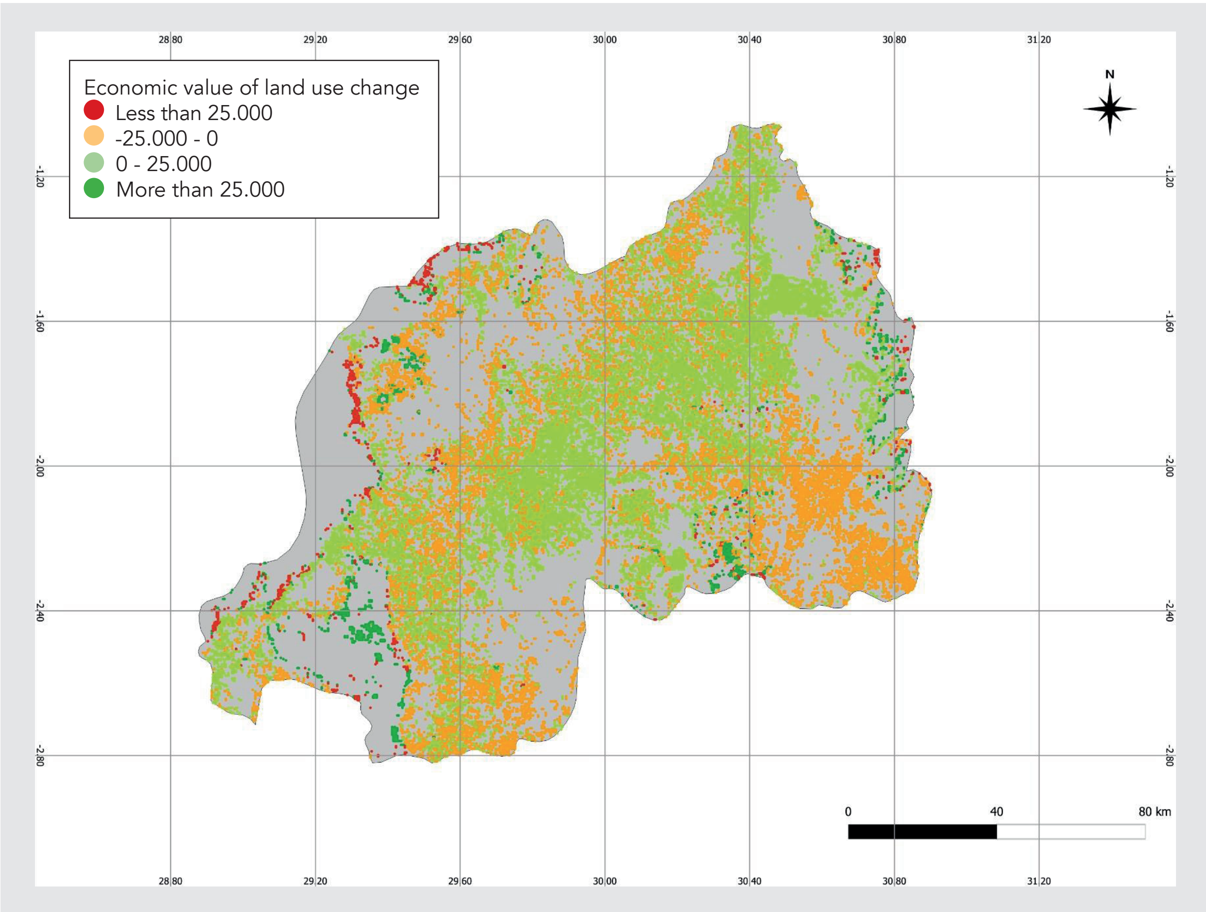
ing its natural forests. There has been uncompensated net loss of savanna areas primarily to agroforestry expansion. Contrary to some suggestions, cropland expansion in Rwanda is occurring not through loss of natural forests, but through expansion of croplands on savannas and grasslands.

In 2014, Rwanda decided, as part of its commitments under the Gaborone Declaration for Sustainability in Africa (2012), to initiate natural capital accounting (NCA), with land being one of the priority sectors. This allows a broad understanding of land value trends and an assessment of the associated tradeoffs. Thus, the country, within the framework of the United Nations System of Environmental-Economic Accounting (SEEA), joins the global partnership led by the World Bank (WB), the Wealth Accounting and the Valuation of Ecosystem Services (WAVES) (Government of Rwanda, 2018). The analysis and information provided here can also be used for integration and continuous monitoring of the values of natural capital represented by various ecosystems in Rwanda. The novel contribution of applying this spatially explicit approach would lie in possibility for a highly granular accounting of natural capital gains and losses at a very local level (Figure 10), which cannot be done for the usual measures of economic activities such as Gross Domestic Product (GDP). Figure 10 highlights an emerging pattern that most of the gains in the values of the natural capital represented by ecosystems were achieved in central regions of Rwanda, while losses more often occurred in peripheral region.

FIGURE 10

Economic value of land use change, US Dollars per pixel (each pixel is about 15 ha)

Source: authors.



05
Costs, benefits, and targeting of land restoration

5.1. Current context of land restoration assessments in Rwanda

5.1.1. Restoration Opportunities Assessment Methodology (ROAM)

Implementing Rwanda's restoration commitment requires a comprehensive and systematic analysis of the available opportunities. The ROAM developed by IUCN and WRI intends to provide such a framework. ROAM follows a multidimensional process that begins with identifying environmental challenges at both national and regional scales, followed by a geospatial analysis incorporating more than a dozen national datasets representing the geographic and topographic characteristics of the country. The process then includes an economic analysis modelling the costs and benefits of degraded and restored land uses. The land uses that benefit most from restoration were identified as the following: traditional agriculture, poorly managed woodlots and plantations, and deforested lands (MINIRENA et al., 2014).

The ROAM framework also identified the five most appropriate restoration interventions and transitions that could improve the ecological and economic productivity of degraded lands in Rwanda. Taken together, they would represent about 1.5 million hectares of land restoration opportunities in Rwanda. The first (1) intervention is based on implementing agroforestry on steep slopes together with other measures such as radical and progressive terracing. This strategy aims to reduce erosion on land highly susceptible to soil loss, seeking to stabilize soil fertility. The restoration opportunity under this type of intervention is estimated at the national level at 705,162 hectares (MINIRENA et al., 2014). The second (2) of the interventions identified is agroforestry on flat or gently sloping land. This aims to integrate trees with crops to improve soil fertility and water quality. In the case of pastures and rangelands, the objective is to provide shade for livestock and increase the availability of trees for firewood and other domestic uses. The restoration opportunity under this type of intervention is estimated at 405,314 hectares nationally (MINIRENA et al., 2014). The third (3) intervention proposed through the ROAM framework focuses on improving silviculture and rehabilitation of existing forest plots and plantations up to 0.5 hectares in area. Two types of transitions for poorly managed plots and plantations are suggested: using spacing systems and spacing accompanied by erosion and fire prevention practices. The objective in both cases is focused on improving and intensifying fuelwood and timber production in Rwanda, emphasizing Eucalyptus and pine (Pinus) as the main tree species exploited for this purpose at the national level. For Eucalyptus plantations, approximately 255,930 hectares have restoration potential at the national level. In the case of pine plantations, restoration opportunities on a total of 17,849 hectares at the national level were suggested (MINIRENA et al., 2014). Protecting and restoring natural forests and safeguarding protected areas is the fourth (4) intervention proposed through the ROAM framework. For this purpose, two types of transitions are established in the natural forests; the first one is the implementation of 100 meters of newly planted forest around the closed natural forest as buffer areas. Under this transition, the detected opportunities totals 3,456 hectares. The second transition involves restoration within the reserves and national parks. Here the opportunities are 10,477 hectares (MINIRENA et al., 2014).

The fifth (5) intervention proposed through ROAM is divided into five separate strategies: the establishment or enhancement of protective forests in areas of medium slope between 20-55% (12-30°);

in areas of high slope (>55% or >30°); in riparian and buffer zones planting native tree species to create 20-meter buffer zones; replacing existing Eucalyptus trees with native tree species within 20 m of watercourses; and in the case of wetland margins planting native species at 50 meters. All the above strategies aim to prevent erosion in the case of ridges and slopes and to protect water bodies (rivers and wetlands) from the harmful effects of erosion. Given the country's topography, the opportunities detected for improvements in medium and high slope areas total more than 42,000 hectares on a national scale. In the case of areas close to water bodies, the potential for implementing 20-meter buffer zones totals 23,000 hectares at the national level. In the case of wetland areas at the national level, approximately 57,362 hectares have potential (MINIRENA et al., 2014).

The ROAM framework provides a good entry point for spatially explicit identification of areas for conservation, SLM, and restoration under the NBSAP, NDC, and LDN processes. Currently, there is no such direct and explicit link in Rwanda. Moreover, ROAM framework categories and restoration interventions are in some cases overlapping, but in some others are very different from those identified under the NBSAP, NDC, and LDN processes, although there is a potential for their harmonization. Availability of nationally designed ROAM frameworks in several other countries around the world offers similar opportunities for harmonization.

5.2. Targeting land restoration for environmental and economic sustainability

The analysis that we conducted under this study is broadly consistent with the findings of the ROAM approach presented above and complements it by adding some specific novel nuances. The underlying philosophy of the ROAM approach as applied in Rwanda is to carry out interventions that will help sustainably manage existing land uses and land covers, e.g., focusing on implementing measures that help avoid soil erosion in existing croplands and pasture lands or improving degrading forest plantations. Our analysis complements the ROAM approach by focusing on restoration of those ecosystems which were already fully degraded and converted into a different land use. Hence, we focus on the most problematic areas of land degradation in Rwanda. Based on the analysis of land use and land cover changes that was presented in Chapter 4, we identified that the extent of such areas is about 295,010 hectares in Rwanda.

Knowledge of land use changes between 2000-2021, associated changes in the values of ecosystem services provided by each location, as well as the information on the restoration costs enables us to conduct a detailed ex ante modelling of costs and benefits of restoring these degraded ecosystems in Rwanda in an environmentally sustainable and economically profitable way. Table 12 shows the outcomes of this modelling conducted using a 30-year time horizon, a discount rate of 10%, and accounting for establishment, maintenance, and opportunity costs of land restoration. In addition to these, we make a novel contribution by identifying and accounting for transaction costs of land restoration, i.e. those costs associated with research and information, design and implementation, funding mobilization, support and administration, contracting, monitoring and evaluation, awareness raising and education, enforcement activities that are essential to successful land restoration but were so far not included in the scientific literature on the costs and benefits of land restoration (Annex 2).

The results show that there is a need for investment of about 923 million US dollars in total until 2030 to restore these degraded ecosystems in economically profitable and environmentally sustainable way. Each dollar invested into land restoration may yield about 1.39 US dollars of returns. It is crucial to note that the predominant share of these investments, namely 810 million US dollars, is needed to restore lost agroforestry systems on agricultural lands. In fact, expansion of agroforestry is also one of the key measures for combating soil erosion from agricultural lands. Restoring forests and wetlands and expanding agroforestry systems on cropland and grassland are highly profitable. However, restoring shrubland, woody savanna and savanna which became cropland does not make economic sense.

Restoring cropland without trees from grassland is also not profitable but becomes profitable when these are converted to cropland with agroforestry (Table 12). Based on this analysis, we conclude that there are significant opportunities for land restoration activities in Rwanda that are both environmentally sustainable and economically profitable (Table 12). The key logic of the analysis here is that we restore higher value ecosystems which were degraded into a lower value ecosystem. An example for this would be when broadleaf forests were degraded and became shrubland or grassland. We

TABLE 12

Costs and benefits of land restoration in Rwanda (in millions of US dollars)

Notes: Also includes 25% transaction costs. Discount rate is 10%. Analysis period is 30 years.

Ecosystem to be restored	Cost of restoration	Benefits of restoration	Benefit-cost ratio	Restoration is from:
Broadleaf forest	58.85	141.69	2.47	Shrubland, woody savanna and savanna, agroforestry systems, grassland.
Wetland	53.99	108.51	2.03	Shrubland, woody savanna and savanna, cropland without trees, grassland and barren land.
Shrubland, woody savanna and savanna	845.89	659.5	0.77	Grassland and cropland without trees.
Agroforestry systems	810.05	1029.88	1.28	Shrubland, woody savanna and savanna, cropland without trees, and grassland.
Standard cropland	233.44	65.29	0.28	Grassland.
Total of profitable restoration opportunities	923	1280	1.39	

TABLE 13

Investment needs for sustainable cropland management

Source: authors. Note: the analysis is conducted by multiplying the extent of cropland areas with per hectare costs of their annual maintenance in good condition, as well as establishment and maintenance costs, and annual benefits from agroforestry systems. The data underling this analysis are given in Annex 2.

Cost categories	Investment needs, million US dollars
Annual maintenance costs of croplands in good condition	91
Annual cost of expanding agroforestry to all croplands (Time: 30 years)	123
Annual gross benefits from expanding agroforestry to all croplands	168
Annual net benefits from expanding agroforestry to all croplands	45
of which, in terms of additional food and other products	27

are considering the full social value of ecosystem services in the analysis, i.e., accounting for both market traded provisioning services such as food and fodder, and for non-provisioning services which are usually not traded in the markets, such as carbon sequestration value, biodiversity, water regulation, pollination, and many others.

Table 13 presents the costs and benefits of maintaining all croplands in Rwanda in good condition through erosion control practices, such as terracing, conservation agriculture, etc. as well as expanding agroforestry systems to cover all croplands. The results show that there is a need for recurring annual investments of 91 million US dollars for maintaining all croplands in Rwanda in good fertile condition. Expanding agroforestry systems to all croplands will require an annualized cost of 123 million US dollars (the analysis is conducted for the period of 30 years). However, these investments are highly worthwhile because gross benefits from them reach 168 million US dollars per year, and net benefits equal about 45 million US dollars per year. Of these net benefits, about 27 million US dollars per year are in the form of marketable benefits such as food and agricultural commodity production.

Figure 11 gives a spatially explicit representation of overall investments needs for land restoration in Rwanda, while Figure 12 highlights economic profitability of these investment needs in each location. In Figure 12, for instance, some green spots (return on investment is more than 3 times) are observed in the northern part of Nyamasheke district near the shore of lake Kivu as well as Akagera village next to Akagera National Park. Some yellow spot areas spread along the shore of Lake Kivu in

FIGURE 11

Cost of restoring degraded lands

Source: authors.

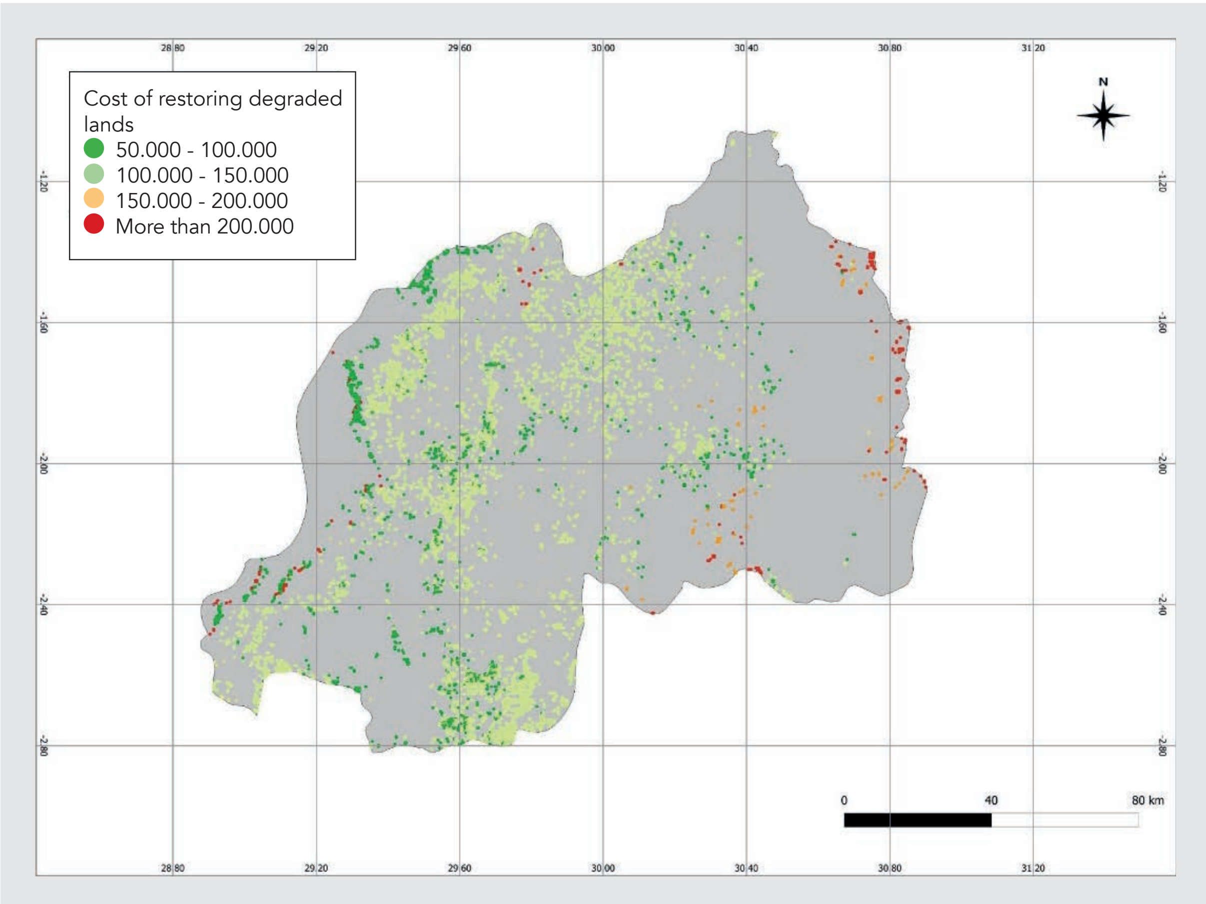
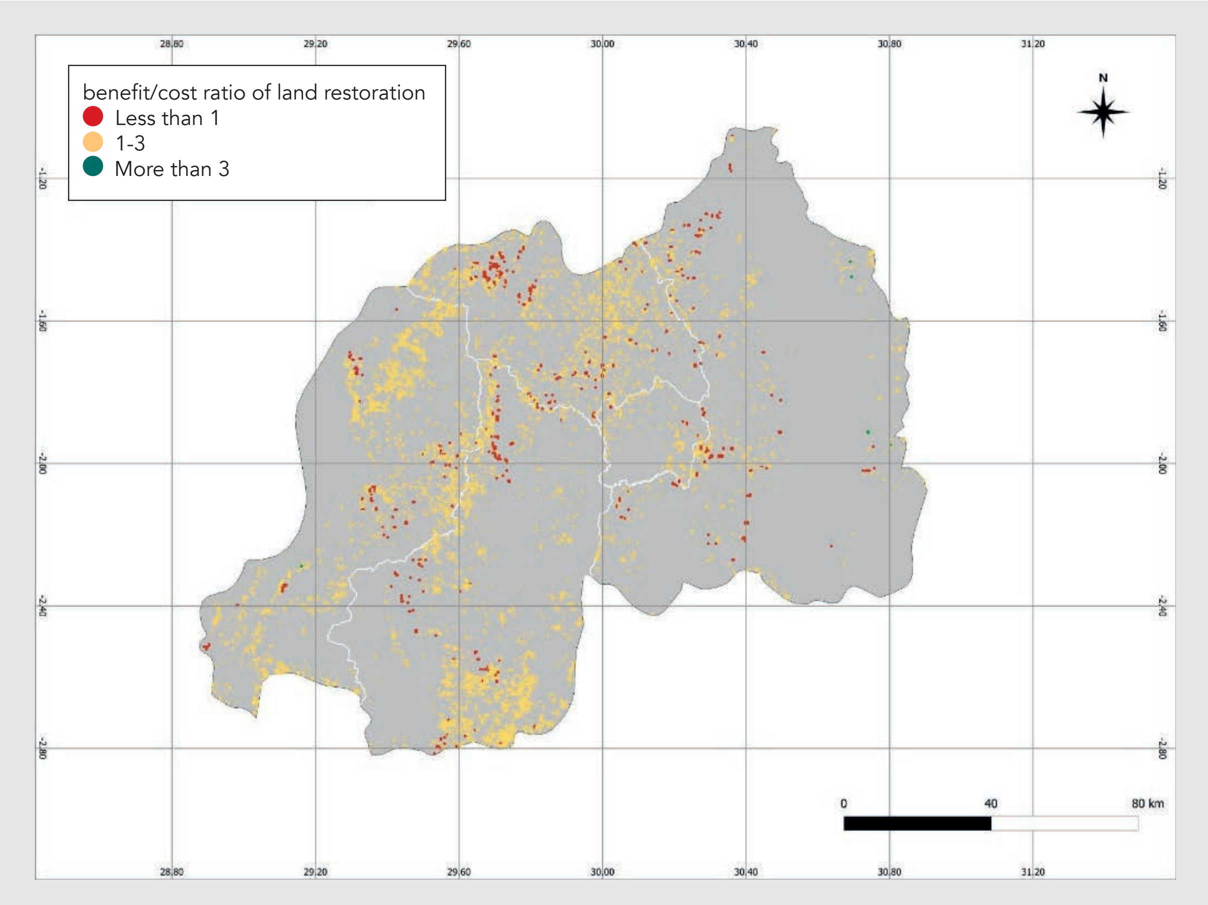


FIGURE 12

Benefit/cost ratio of land restoration

Source: authors.



Rubavu and Rutsiro, border of Western and Southern Provinces (around the west of Muhanga) and southern part of Gisagara and Nyaruguru Districts near the border to Burundi. Such detailed spatially explicit representation of land restoration costs and benefits will enable most appropriate targeting of land restoration activities depending on both country priorities and economic returns from such land restoration investments.

In addition to the overall economic profitability of investment needs, we analysed their impacts in terms of carbon sequestration both in terms of physical amounts of sequestered carbon but also in terms of associated economic values. Land restoration opportunities that we found to be environmentally sustainable and economically profitable can help sequester about 13.5 million tons of carbon in Rwanda over a period of 30 years (Figure 13, Table 14). This is about 2.5 times more than current total annual GHG emissions by Rwanda. Our estimation shows that even when we consider that land restoration investments value is only concentrated in carbon sequestration, the costs of each ton of carbon sequestered in evergreen broadleaf forests in Rwanda is 7.74 US dollars, for wetlands 5,300 US dollars, and in agroforestry systems 137 US dollars. For comparison, each ton of carbon is currently (April 2023) trading at about 100 US dollars per ton under the European Union's Emissions Trading System (ETS).

This establishes a clear hierarchy of land restoration if we target carbon sequestration alone. Restoring natural forests in Rwanda represent one of the most cost-effective carbon sequestration opportunities. Although the costs of each ton of sequestered carbon are higher in agroforestry sys-

FIGURE 13

Carbon sequestration potential from land restoration in Rwanda, in tons per pixel

Source: authors. Note: Each pixel is about 15 ha.

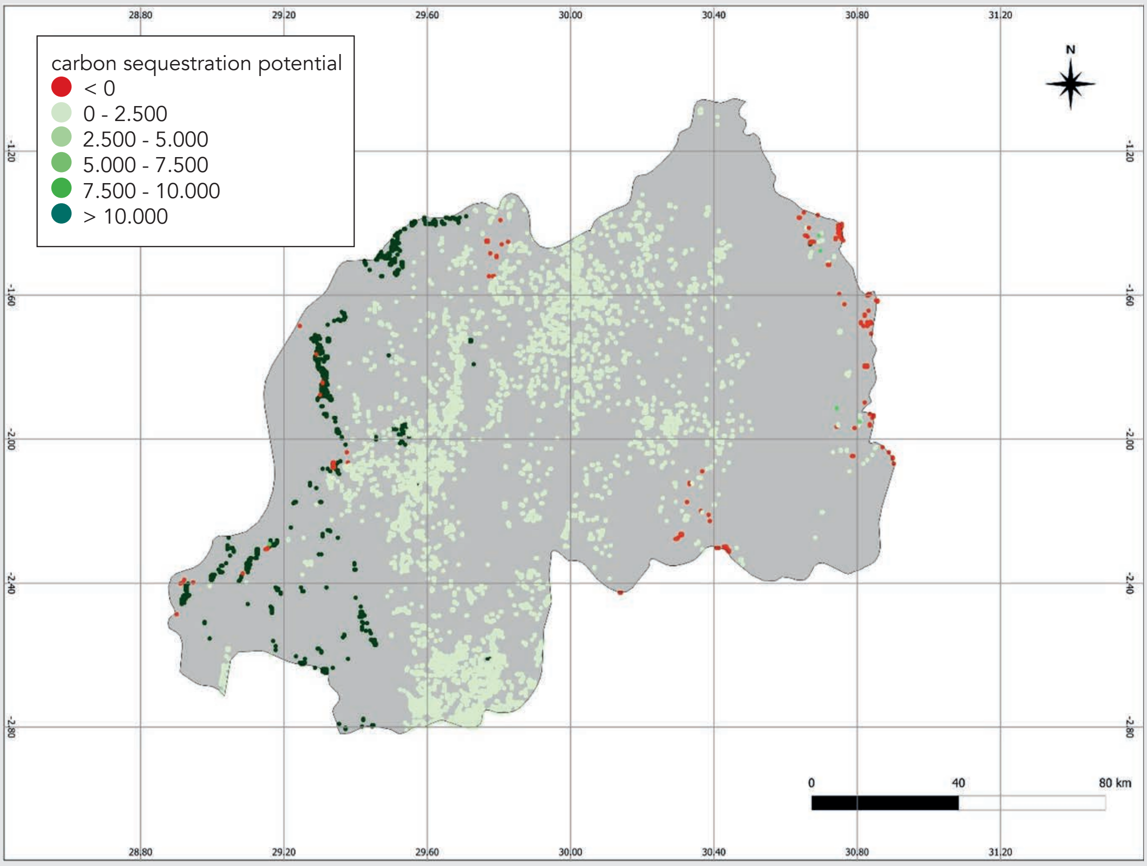


TABLE 14

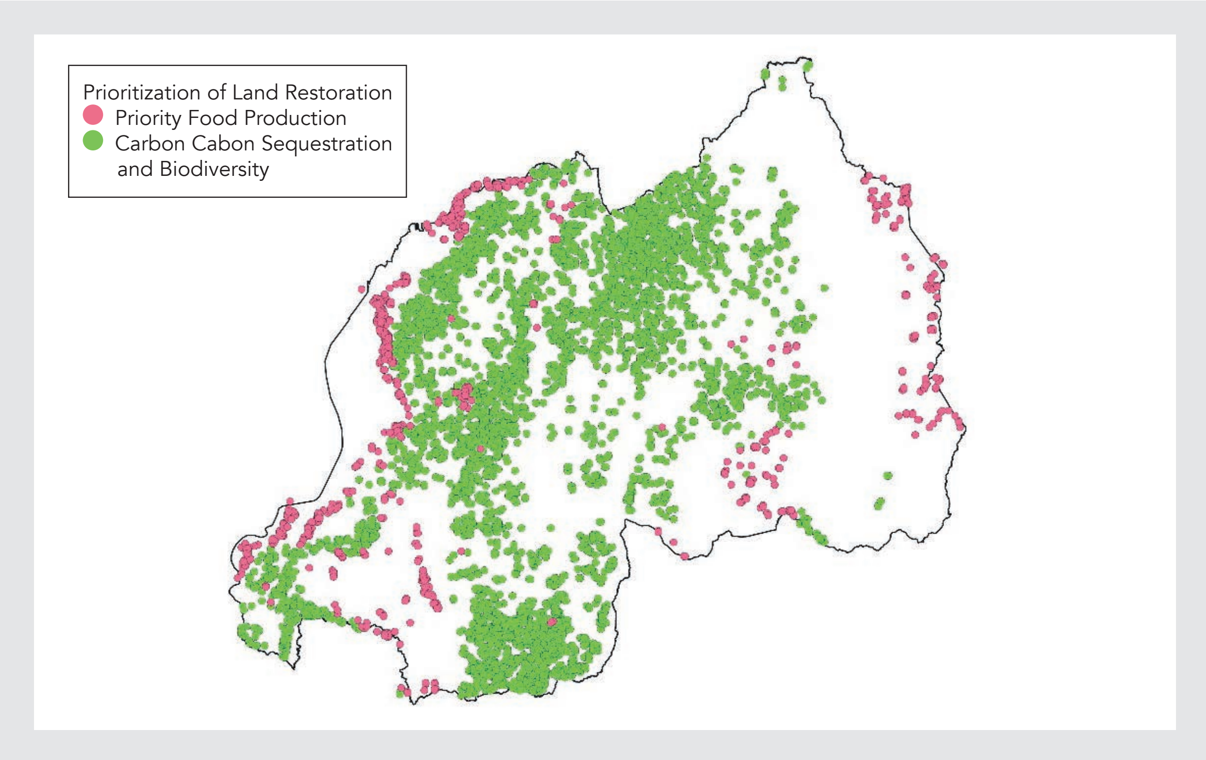
Carbon sequestration potential from land restoration in Rwanda

Source: authors.

Ecosystem to be restored	Gain in above ground biomass carbon after restoration (millions of tons)	Gain in below ground biomass carbon after restoration (millions of tons)	Total carbon gain (millions of tons)
Evergreen broadleaf forest	6.4	1.2	7.6
Wetlands	-0.02	0.03	0.01
Agroforestry systems	4.8	1.1	5.9
Total	11.1	2.4	13.5

FIGURE 14

Prioritization of land restoration
Source: authors.



tems, due to their extensive area coverage, agroforestry systems can provide with almost half of all additional carbon sequestration potential through land restoration in Rwanda. Restoring lost wetlands makes sense from a broader economic and biodiversity angle, but from the carbon sequestration perspective in above and below ground biomass, this appears to have only a very marginal effect. It is important to highlight that these calculations, when done only in terms of carbon value, represent only a small part of the overall benefits from land restoration.

Figure 14 provides another angle on the prioritization of land restoration activities by highlighting those areas where land restoration will, first and foremost, contribute to food production (491 thousand hectares of shifted agroforestry systems), and those areas where land restoration will primarily contribute to carbon sequestration and biodiversity values (20 thousand hectares broadleaf forests and permanent wetlands). However, it is important to note that land restoration prioritizing food production would primarily involve restoring the agroforestry systems, hence, these will also contribute to carbon sequestration, even if in smaller per hectare amounts.

The above calculations of the costs and benefits of land restoration focus on reversing land degrading land use changes. However, an important share of land restoration costs is incurred in Rwanda without land use change, but through soil erosion in croplands and pasture lands. For identifying investment needs for land conservation, SLM, and restoration, those areas also need to be considered. Indeed, RWB and IUCN (2022) estimate that the total cost incurred due to soil erosion reach about 921 million US dollars annually.

In Table 15, we combine RWB and IUCN (2022) estimates of costs of soil erosion with our estimates of costs of land degradation through land use change to show a more comprehensive accounting

TABLE 15

Costs and benefits of land restoration
Source: authors.

Costs of land degradation (Million US dollars)		Costs of land restoration (Million US dollars)		Benefit cost ratios	Source
Land use change	1280	Restore ecosystems	923	1.38	Our analysis
Soil erosion	921	Address soil erosion	513	1.79	RWB, IUCN (2022)
Total	2201		1436	1.53	

of the costs of land and soil degradation in Rwanda. These combined estimates show that total costs of land degradation in Rwanda reach an equivalent of about 2.2 billion US dollars per year. Investments of about 1.4 billion US dollars are needed to address land and soil degradation in the country. This also means that each dollar invested into land restoration and addressing soil erosion in the country brings back about 1.53 US dollars of return.

5.3. Financing needs and opportunities for land restoration

Table 16 summarizes the financing needs for land restoration in Rwanda based on the results of this study as well as earlier work by RWB and IUCN in 2022 on estimating economic aspects of addressing soil erosion. The results show that a total of about 2.1 billion US dollars are needed for restoring degraded ecosystems, repairing eroded soils, and maintaining croplands in good condition in Rwanda until 2030. This means that between now in 2023 till 2030, annual investments of about 300 million US dollars are needed to avoid, reduce and reverse land and soil degradation in Rwanda. As a benchmark comparison, observed investments on land restoration projects between 2011 and 2018 made up about 75 million US dollars per year.

Land restoration is a critical component of global efforts to address climate change, biodiversity loss, and food security. Despite its importance, restoration finance remains limited due positive externalities of land restoration, funding constraints, long-term nature of restoration benefits, and many other reasons.

Land restoration projects often generate positive externalities or benefits that extend beyond the direct beneficiaries. The benefits, such as improved air and water quality, carbon sequestration, and biodiversity conservation, are not always captured by the market and may not be reflected in the financial returns of restoration projects. Consequently, there is a need for public funding to ensure that these externalities are accounted for and that restoration projects are adequately financed.

Moreover, many developing countries face significant budget constraints and must prioritize competing needs, such as health, education, and infrastructure. As a result, governments may struggle to allocate sufficient resources to land restoration projects, even when they acknowledge the long-term benefits of such investments.

Land restoration projects often require substantial investments upfront, while the benefits and financial returns may take years or even decades to materialize. This long-term nature of restoration benefits can be a deterrent for private investors, who typically seek short-term profitability. Many

TABLE 16

Overall financing needs for land restoration in Rwanda till 2030

Land restoration and SLM categories	Millions of USD	Source
Restoring degraded ecosystems	923	Our analysis (Table 11)
Repairing eroded soils	513	RWB and IUCN (2022)
Good maintenance of croplands	637	Our analysis (Table 12)
Total	2073	
Annual investment needs (2023-2030)	300	

land restoration projects are small in scale and geographically dispersed, making them less attractive to large investors who prefer more substantial, centralized investments with lower transaction costs. This challenge is particularly pronounced in the context of rural and community-based restoration efforts, where high transaction costs can undermine the financial viability of projects.

Governments play a crucial role in financing land restoration projects through budget allocations, subsidies, and incentives. Public funding is particularly important for projects with significant positive externalities, as it can help internalize these benefits and ensure that restoration efforts are adequately financed. Bilateral cooperation programs between countries can provide significant financial resources for land restoration projects, especially in developing countries. These programs can take various forms, such as grants, concessional loans, or technical assistance, and can help leverage additional funds from domestic and international sources. Multilateral development banks (MDBs) and international funding organizations, such as the World Bank, the Global Environment Facility (GEF), and the Green Climate Fund (GCF), can provide significant financial and technical support for land restoration projects. MDBs can offer concessional loans and grants, while GEF and GCF can provide targeted funding for projects that address climate change mitigation and adaptation or biodiversity conservation.

Payment for Ecosystem Services (PES) schemes allow for payments to landowners or resource managers for maintaining or enhancing ecosystem services, such as carbon sequestration, watershed protection, or biodiversity conservation. By creating a financial incentive for land restoration, PES can attract private investments and help bridge the financing gap in restoration projects.

Carbon credits or offsets can be generated through land restoration projects that sequester carbon or reduce greenhouse gas emissions. These credits can be sold in the carbon market, providing an additional revenue stream for restoration projects and making them more financially attractive to investors. Sustainability certification schemes, such as the Forest Stewardship Council (FSC) or the Roundtable on Sustainable Palm Oil (RSPO), can help attract investment in land restoration projects by ensuring that products derived from restored lands meet specific environmental, social, and governance criteria. By adhering to these standards, producers can access premium markets and obtain higher prices for their products, making restoration projects more financially viable.

Public-private partnerships (PPPs) and blended finance mechanisms can help attract private investments in land restoration projects by leveraging public funds and de-risking investments. Governments can offer financial incentives, such as tax breaks or guarantees, to encourage private sector involvement in restoration projects, while development finance institutions can provide concessional loans or equity investments to catalyse private capital.

A landscape approach is needed for integrating various land uses, stakeholders, and objectives within a defined geographic area to achieve multiple benefits, such as climate change mitigation, biodiversity conservation, and sustainable livelihoods. By pooling resources and investments across different sectors and actors, a landscape approach can help overcome the small scale and high transaction costs of individual land restoration projects, making them more attractive to investors.

Debt-for-nature swaps are agreements between debtor countries and their creditors, whereby a portion of the debtor country's external debt is forgiven in exchange for investments in environmental conservation or restoration projects. These swaps can help free up resources for land restoration while addressing the debt burden of developing countries.

06
Policy and financial environment for land restoration synergies

6.1. National Legal Framework relevant for Land Restoration

Rwanda has a significant number of policies and strategies that seek to strengthen the forestry, agricultural and environmental sectors in response to the various challenges. A total of 35 policies/strategies/plans/laws were identified that have relevance for land restoration (Table 17). Most are under the responsibility of MoE, MINILAF - now an affiliated agency of the MoE, MININFRA, and MINAGRI. As a result of this solid policy framework established in the country, various institutions developed a series of opportunity assessments during the last decade. Thus, according to IUCN, more than 80 restoration projects have been implemented throughout the country with significant national budget funds allocated into landscape restoration (IUCN and Government of Rwanda, 2021).

TABLE 17

National Regulatory Framework relevant for land restoration in Rwanda
Adapted from Dave et al. (2019) and IUCN (2020).

N°	Type	Name	Year enacted	Implementing institution	Other institutions related	Time period
1	Strategy	Green Growth and Climate Resilience Strategy (GGCRS) for Climate Change and Low Carbon Development	2011	MoE	MIDIMAR, MINAGRI, MINICOM, MINECOFIN, MINEDUC, MININFRA, MINIRENA, MINALOC, and MOH.	Long-term
2	Policy	Rwanda Biodiversity Policy	2011	MoE	REMA, PM, RDB, MINECOFIN, District councils, private sector, NGOs, and civil society.	Long-term
3	Policy	National Policy for Water Resources Management	2011	MoE	REMA, MINAGRI, MININFRA, MINECOFIN, MINICOM, MINALOC, MINISANTE, MINIJUST, MIDIMAR, MINEAC, MINEDUC, MINAFFET, MIGEPGROF, MINADEF, RDB; RAB, among others.	Medium and long-term
4	Policy	National Disaster Management Policy	2012	MDMRA	All ministries and affiliated agencies.	Long-term
5	Strategy	Rwanda Vision 2020 (revised)	2012	MINECOFIN	All ministries and affiliated agencies.	Long-term

N°	Type	Name	Year enacted	Imple-menting institution	Other institutions related	Time period
6	Strategy	National Urbanisation and Rural Settlement Sector	2012	MININFRA	MoE, CoK, districts, MINECOFIN, MINALOC, MoH, MINEDUC, RHA.	Short-term
7	Policy	Rwanda Wildlife Policy	2013	MINICOM	RBD, MININFRA; MoE, districts.	Long-term
8	Strategy	National Strategic Plan for the Environment and Natural Resources Sector 2014–2018	2013	MoE	RWFA, RLMUA, Meteo Rwanda, REMA, RMPGB, MINAGRI, and affiliated agencies: RAB and NAEB; MININFRA and affiliated agencies: WASAC, REG; MINICOM; RDB; MINALOC, MoH, MINEDUC, MINAFFET, MIDIMAR, MINECOFIN, RURA, RBS, private sector, and civil society.	Short-term
9	Policy	Rwanda Protected Area Concessions Management Policy	2013	MINICOM	MINIRENA, MINICOM, MININFRA, REMA; RNRA and PSF, among others.	Long-term
10	Strategy	Economic Development and Poverty Reduction Strategy (EDPRS II) 2013–2018	2013	MINECOFIN		
11	Law	Law Forest management N° 47bis/2013 of 28/06/2013	2013		All ministries and affiliated agencies.	
12	Policy	National Horticulture Policy	2014	MINAGRI		
13	Policy	National Energy Policy	2015	MININFRA	MINICOM, MINECOFIN, REMA, MINEDUC, among others.	Long-term
14	Strategy	Energy Sector Strategic Plan 2013/14–2017/18	2015	MININFRA		
15	Law	The Constitution of the Republic of Rwanda of 2003, revised in 2015	2015	Government of Rwanda	All ministries and affiliated agencies.	-
16	Policy	National Urbanisation Policy	2015	MININFRA	MINICOM, MINECOFIN, MINALOC MIFOTRA, RDB, CoK, Districts.	Long-term
17	Strategy	NBSAP	2016	MoE	REMA, MINAGRI, RDB, RAB, private sector, NGOs, and civil society.	Long-term
18	Strategy	7 years Government Programme: National Strategy for Transformation (NST 1)	2017	Office of the Prime Minister		

N°	Type	Name	Year enacted	Imple-menting institution	Other institutions related	Time period
19	Strategy	Strategic Programme for Climate Resilience (SPCR)	2017	MoE	All ministries and affiliated agencies, private sector, NGOs, and civil society.	Long-term
20	Policy	Rwanda National Forestry Policy	2018	MINILAF		
21	Strategy	Forest Sector Strategic Plan (FSSP) 2018-2024	2018	MINILAF		Short-term
22	Strategy	Agroforestry Strategy and Action Plan 2018-2027 (draft 2018)	2018	MINILAF		Medium-term
23	Strategy	National Tree Re-productive Materials Strategy 2018–2024	2018	MINILAF		Short-term
24	Strategy	Strategic Plan for the Transformation of Agriculture 4 (PSTA 4) 2018–2024	2018	MINAGRI	RAB, NAEB, MINALOC, private sector, NGOs, and civil society.	Short-term
25	Policy	National Environment and Climate Change Policy (draft 2018)	2018	MoE		
26	Strategy	National Biomass Energy Strategy (BEST)	2018	MININFRA		
27	Policy	National Agriculture Policy	2018	MINAGRI	MINAGRI, MINECOFIN, MYICT, MINICOM, RDB, MITEC, PSF, MINALOC, MINILAF, MIGEPROF, MINEDUC, MoE, private sector, and civil society.	
28	Policy	National Land Policy (under revision 2018)	2018	MINILAF	MINECOFIN, MoE, MININFRA, MINALOC, MINAGRI, MINIJUST, MIGEPROF, RAB, RHA, RTDA, REMA, University of Rwanda (UR-GIS), INES, private sector and civil society.	
29	Strategy	Environment and Natural Resources (ENR) Gender Assessment and ENR Gender Mainstreaming Strategy and its Implementation Plan (2018/2019-2023/2024)	2019	MoE and MINILAF	RWFA, RLMUA, Meteo Rwanda, REMA, RMPGB, MINAGRI, and affiliated agencies: RAB and NAEB; MININFRA and affiliated agencies: WASAC, REG; MINICOM; RDB; MINALOC, MoH, MINEDUC, MINAFFET, MIDIMAR, MINECOFIN, RURA, RBS, private sector, and civil society.	

N°	Type	Name	Year enacted	Imple-menting institution	Other institutions related	Time period
30	Policy	National Environment and Climate Change Policy	2019	MoE		
31	Strategy	Rwanda National Cooling Strategy	2019	MoE	MoE, MININFRA, RSB RURA, MINICOM, RDB, REG, REMA, MINECOFIN, MINEDUC, RRA, MINISANTE, BRD, BDF, FONERWA, RHA, MINAGRI, and private sector.	
32	Strategy	National Land Use and Development Master Plan (NLUDMP) 2020-2050	2020	MoE	RLMUA, MINECOFIN, MININFRA, OTP, Office of PM, MoE, MINAGRI, MINALOC, MINICOM, RDB, RHA, RTDA, REMA, CoK, RFA, RAB, NISR, private sector, and civil society.	
33	Law	Law governing land N° 27/2021 of 10/06/2021	2021		All ministries and affiliated agencies.	
34	Law	Law governing biological diversity N° 64/2021 of 14/10/2021	2021		All ministries and affiliated agencies.	
35	Strategy	Vision 2050	2020	MINECOFIN	All ministries and affiliated agencies, the private sector, and civil society.	

Rwanda's legal framework spans a broad spectrum from strategies to policies and laws. For instance, the Green Growth and Climate Resilience Strategy for Climate Change and Low Carbon Development (GGCRS) was enacted in 2011 and seeks to interweave the principles of green growth and low carbon development. Similarly, the National Urbanisation and Rural Settlement Sector Strategy of 2012 offers a blueprint for rural development while maintaining ecological balance. Key laws such as the Forest Management Law and the Law governing biological diversity further reinforce Rwanda's commitment to managing its natural resources sustainably.

Moreover, some strategic documents, such as Vision 2050 and NLUDMP (2020-2050) provide an overarching policy environment for land restoration. For example, according to the NLUDMP (2020-2050), agricultural lands are mandated to be between 1.2-1.5 million ha by 2030. The Master plan also requires that current 0.53 million ha of natural and planted forests are maintained, and about 0.92 million ha are put under conservation.

An important element of all these laws, policies and strategies is that they require a high level of cross-sectoral collaboration for their successful implementation. The MoE plays a central role in the implementation of most strategies, together with other ministries and agencies, including MINAGRI, Ministry of Infrastructure (MININFRA), Ministry of Finance and Economic Planning (MINECOFIN), and the Rwanda Development Board

(RDB), among others. All ministries and affiliated agencies are also implicated in the implementation of overarching laws.

Many of Rwanda's policies and strategies directly address key areas of concern, such as biodiversity, forestry, and climate change resilience. They showcase the nation's efforts to balance the need for economic growth with the preservation of its ecosystems. Yet, such balancing acts invariably involve tradeoffs. For instance, food production is usually prioritized over carbon sequestration and biodiversity, leading to shifts in land use and cover.

Given these challenges, it is vital for Rwanda to continuously review and update its policies to align them with the prevailing circumstances and challenges. This includes revising financial strategies to increase funding for land restoration, strengthening institutional capacities, fostering stakeholder collaboration, and promoting sustainable land use practices at the grassroots level. Through adaptive policymaking and a robust, dynamic implementation strategy, Rwanda can effectively navigate these challenges and ensure the successful implementation of its land restoration objectives.

6.2 Institutional Setting of Land Restoration in Rwanda

A greater understanding of national restoration governance in Rwanda requires introspection into the connectivity among its constituent actors as well as its flows and dynamics. The governance system of restoration in Rwanda is composed of a vast network of actors (McLain et al., 2019). According to their functioning, the actors can be differentiated, on the one hand, into regulatory, supervisory, financing, and local community bodies. Moreover, one can also recognize them by their type of constitution, including public, private, and civil society actors. Furthermore, finally, their management varies according to their scale: multisectoral (national), sectoral (district), and local or targeted (cells). Figure 15 schematizes the flows (implementation, monitoring, funding, and raw materials) between the various actors in the broad network.

Implementing Actors

According to the PM's Order No. 108/03 of 10/15/2020, the MoE is the highest body in charge of ensuring the protection and conservation of the environment, as well as guaranteeing the optimal and rational use of water resources, land, and forests for sustainable national development. This ministry frames the central regulatory norms and laws for optimal restoration governance at the national level. It also seeks to disseminate environmental and climate change policies, strategies, and programs. Of the five affiliated agencies, at least four play an essential role: REMA, Rwanda Forestry Authority (RFA), NLA, and FONERWA.

Supervising Actors

The central supervisory bodies in the framework of restoration governance are REMA and the NLA. Through REMA, the government supervises and evaluates development programs to ensure compliance with environmental laws (both during preparation and implementation). The government oversees all land management and land use control matters through the NLA. Although REMA and NLA are involved in monitoring tasks at the national level, the fact is that at the local level, there is a gap in the absence of public mechanisms to ensure compliance with the standards and the expected benefits for farmers (Buckingham et al., 2021).

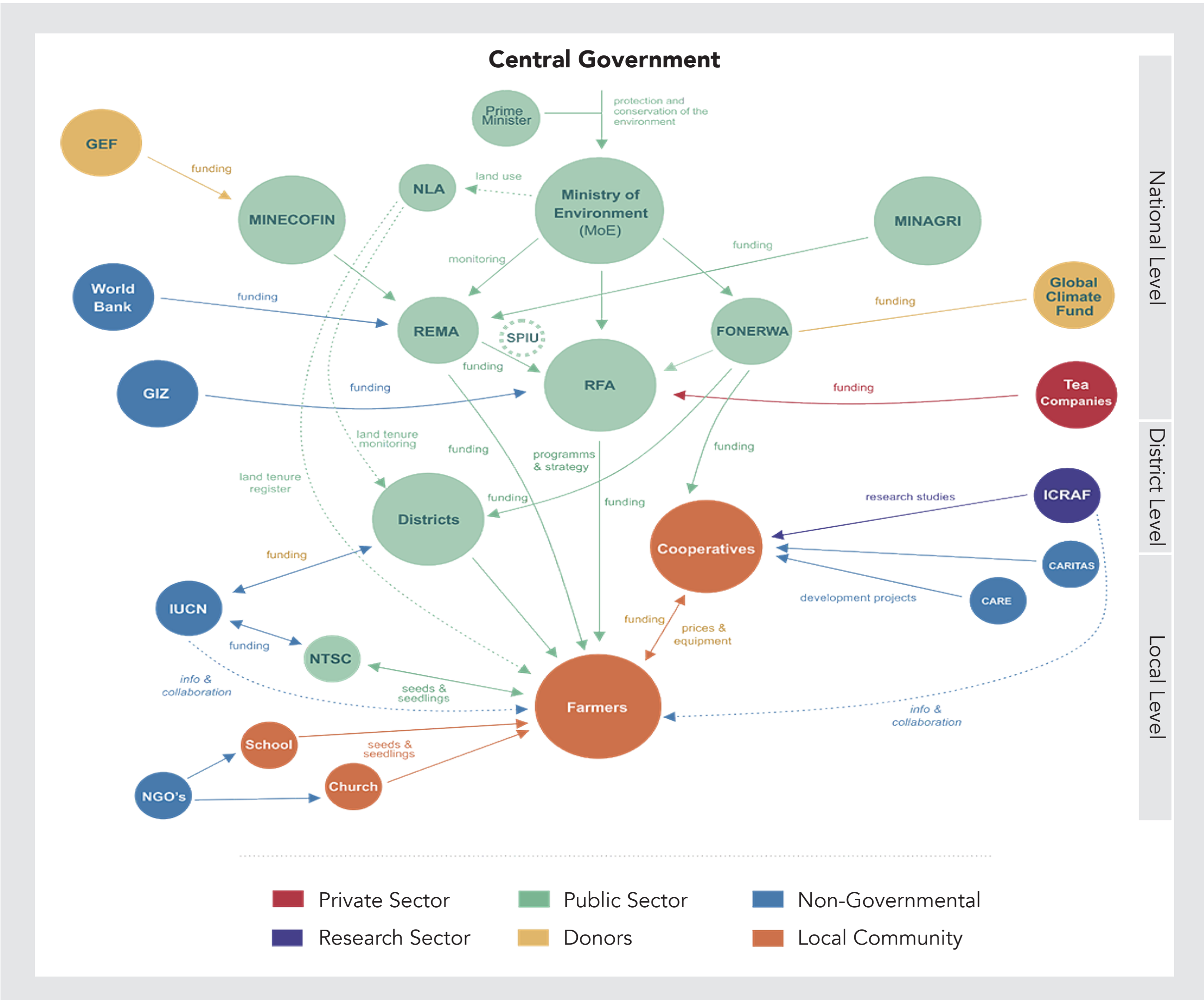
Financing actors

In financing, although there is a wide variety of actors, financial flows remain limited and, in some cases, are developed through closed groups. At the national level, the RFA, in practice, functions as a financial centre, receiving funds from other governmental actors, private actors (mainly tea companies), and non-profit organizations (such as GIZ) and then sending them to other organizations that are more involved at the district level (and then passing them on to the farmers). REMA, whose flow (although on a smaller scale) also connects directly with farmers, mainly directs funds through the management of the RFA. Furthermore, REMA has two primary sources for directing funds: in the governmental sphere, it has a close relationship with MINECOFIN, which also receives funds from donors such as GEF. REMA's second source is the World Bank since multiple projects related to restoration governance are managed through this affiliated agency of the MoE. REMA also has a constant flow with MINAGRI, which has multiple joint projects. Internally, REMA manages the Project Implementation Unit (PIU), which is equipped with human and financial resources to develop bankable projects and collaborate with different stakeholders, including international climate finance institutions, to attract more resources for the implementation of the GGCRS and the NDC. In addition, at the national level, there is also FONERWA, another agency affiliated with the MoE, through which multiple external donors, such as the GCF, come together. FONERWA provides technical and financial support to public and private projects that improve the environment, combat climate change, and promote green growth (McLain et al., 2019; Buckingham et al., 2021). At the district level, three actors stand out for their connectivity: district governments (governmental), IUCN (non-profit organization), and farmers' cooperatives (private). The latter has, at this scale, direct coordination with FONERWA, which in many cases channels its funds through them due to their extensive field knowledge. The cooperatives also play a role at the local and community level as farmers seek to secure higher prices and better technical equipment through them. Through them, many non-profit organizations such as CARITAS or CARE channel sources of funding, and even institutions such as ICRAF channel various research studies.

FIGURE 15

Governance system of restoration in Rwanda

Source: MINIRENA et al. (2014) and Buckingham et al. (2021). .



Local community actors

Farmers are, in essence, the main actors in the framework of restoration governance. With the support of various private institutions such as IUCN and through the National Tree Seed Centre - NTSC (managed until 2014 by RAB), farmers have improved their access to raw material systems (seeds and seedlings). Although the official supplier, the NTSC is not the only one, as multiple NGOs (mainly through churches, and schools, among others) offer seeds and seedlings at low prices or even free of charge to farmers. In terms of financing, as mentioned above, farmers have a high level of connectivity, mainly through funds managed by district governments and cooperatives. However, hierarchically multiple shortcomings weaken their role in the structure, including the lack of access to information on regulations, new technologies, and monitoring systems. In this aspect, ICRAF and IUCN play an essential role in the dissemination of information and collaboration.

In addition to bilateral interactions and collaborations, many of these organisations also seek to coordinate their activities through various land management focused Task Forces, sectoral and other Working Groups. However, our analysis shows that although land conservation, SLM, land restoration activities, including more specific interventions such as agroforestry, need to be undertaken and coordinated together, many of these Task Forces and Working groups have a more focused mandate on specific dimensions of this continuum. Hence, bringing these existing coordination mechanisms together in a more systematic way could help increase the synergies for land management in Rwanda. This is especially true since in most cases the same actors are engaged in different working groups.

Despite the existence of these collaborative linkages across various actors in land conservation, SLM, and land restoration in Rwanda, stakeholder consultations in Rwanda during the workshop in March 2020, highlighted several gaps and potential entry points for increasing the effectiveness and efficiency of land conservation, SLM, and land restoration activities in Rwanda. These are discussed in the detail in Chapter 7.

07
Mechanisms for Synergies from coordinated Land Restoration

Enhanced effectiveness and efficiency in land restoration can be achieved through synergistic collaborations among the three Rio Conventions, as opposed to pursuing separate, uncoordinated efforts. Effectiveness implies that the Conventions, through cooperation, accomplish land restoration objectives that would be unattainable individually. Efficiency means that collaborative efforts reduce the cost of restoring each hectare of land. Synergy-enabling mechanisms should be adaptable, viable, and cost-effective, with overly intricate approaches avoided in favour of simplicity and ease of implementation. Ideally, these mechanisms should repurpose existing structures and entry points, rather than introducing disruptive changes. The transaction cost theory, as detailed in Chapter 2, offers a suitable analytical framework for devising potential synergy mechanisms.

There are five primary categories of land restoration expenses: acquisition, establishment, maintenance, opportunity, and transaction costs (Table 18). Acquisition costs refer to the expenses involved in obtaining land, usually from private owners, for conservation or restoration purposes. Establishment costs encompass the initial expenses of implementing ecosystem restoration techniques and practices, such as site preparation, seeding, and planting. For instance, the initial costs of planting trees in a reforestation program are considered establishment costs, while the ongoing care for these trees falls under maintenance costs. Both establishment and maintenance costs can vary significantly depending on the location and the specific restoration technology or practice.

Opportunity costs account for the lost benefits associated with the land's previous use before restoration. For example, if a reforestation program replaces cropland, the lost benefits from prior crop production must be considered as opportunity costs in the analysis. Transaction costs include expenses related to identifying suitable restoration sites, planning, negotiating, organizing restoration initiatives, and monitoring and evaluating the results.

TABLE 18

Costs of land restoration in Rwanda
Source: author calculations based on various sources.

Types of restoration costs	Examples	Costs (US dollars per ha)
Establishment costs	Planting of saplings, construction of terraces, etc.	221-1573
Maintenance costs	Annual recurring costs	28-137
Opportunity costs	Values of the biome being replaced after restoration	80-3350
Transaction costs	Research and information, design and implementation, funding mobilization, support and administration, contracting, monitoring and evaluation, awareness raising and education, enforcement	62-430

TABLE 19

Transaction costs of land restoration in Rwanda

Sources: REMA (2022) and our estimations-based REMA (2022) and costs of land restoration activities in Rwanda.

Types of transaction costs	Share in total costs
Monitoring and enforcement	14%
Research and capacity building	5%
Awareness raising	3%
Coordination and administration	2%
Funding mobilization	< 1%
Total share in land restoration costs	**25%**

Transaction costs can constitute up to 50% of the total land restoration program expenses (Coggan et al. 2010), so it is crucial to include them in the economic analysis of land restoration projects. Table 18 shows the range of establishment, maintenance, opportunity, and transaction costs for Rwanda. Acquisition costs are not very relevant for the Rwandan context of land restoration, so they are not presented in Table 18 and our analysis. From Table 18, we see that depending on restoration type and technology, establishment costs in Rwanda range from 221-1573 US dollars, maintenance costs range between 28-137 US dollars, and transaction costs represent range between 62-430 US dollars.

The key synergies come through reducing these transaction costs through collaboration. The transaction costs of about 25% under the REMA projects in Rwanda (Table 18) implies that land restoration activities are already carried out with a high level of effectiveness and efficiency. Globally, 25% represent a lower end in the shares of transaction costs in the overall land restoration and nature conservation programs, which can make up more than 50% of all costs in some cases (Annex 1). This implies that in other settings where prevailing transaction costs of land restoration are higher, the payoff from collaborations would be even bigger.

The following five potential scenarios for synergistic collaboration for land restoration under the Rio Conventions' processes were evaluated. These synergy mechanisms were elaborated based on the review of literature, various project and policy documents, as well as, importantly, through a stakeholder dialogue workshop conducted on March 28-29 2023 in Kigali. The rich discussions on strengths and weaknesses of each of these collaboration mechanisms when applied to the Rwandan context, form the basis of qualitative assessment of the challenges and opportunities associated by these collaboration mechanisms presented below.

Scenario 1. A joint inter-agency working group for land restoration. The advantages include the opportunity to share experiences and skills, avoid duplication of efforts, and use resources more efficiently. Enablers for this scenario include coordination, joint planning, resource sharing, and better division of labor. Key hindrances include the risk of adding another administrative layer, which could lead to inefficiency, difficulty in reaching compromises, and the time-consuming nature of the process. Ensuring commitment, funding availability, high-level political will, and an overall coordinating body would help facilitate the working group's success. However, challenges may arise due to institutions seeking visibility, conflicts of interest among agencies, and a lack of financial resources. To overcome these obstacles, a clear Terms of Reference and the inclusion of additional stakeholders, such as the private sector, may be beneficial.

Scenario 2. An information exchange platform and website for land restoration. Advantages include easy flow of information, improved communication, and easy access to data for research, policymaking, and investment. Key enablers are information sharing, common understanding, resource mobilization, and capacity development for all stakeholders. Disadvantages include potential exposure to data breaches, digital divides for certain groups, and loss of exclusive data ownership. Hindrances may come from limited infrastructure, costs of cloud services, and outdated data. Other challenges include scattered information, complex applications, and high information costs. To address these concerns, implementing secure IT infrastructure, affordable cloud services, and skilled personnel is crucial. The government's efforts for digital inclusion and advanced IT technology can also contribute to success. Ensuring a dedicated institution is responsible for updating and monitoring the website, along with data protection measures, will further support the effective functioning of the information exchange platform.

Scenario 3. A joint monitoring and evaluation (M&E) system for land restoration. Advantages include timely and updated information, institutions sharing similar information, fair recognition of contributions, and improved learning systems. Key enablers are cost reduction, reliable information, avoiding duplication, shared human resources, and centralized information. Disadvantages include the resources and time required for harmonizing the system. Hindrances may arise from limited skills, systems, and financial resources. Other challenges include unsuccessful government efforts in joint planning and different sectoral plans. To address these concerns, having a robust M&E system, expertise, and financial resources is essential. MINECOFIN could potentially include cross-sectoral planning in Imihigo[1]. Capacity building, valorising data in planning and implementation, and joint planning and harmonization are other considerations to ensure the effective functioning of the joint M&E system.

Scenario 4. Joint planning and fund mobilization for land restoration. At both national and the Rio Conventions' levels, the development of a single framework for joint planning of programs and projects on land restoration could be considered. In Rwanda this could be a part of the National Plan for land restoration, and for the Rio Conventions, this could be part of the enhanced mandate of the JLG, both discussed above. This collaborative programming approach for land restoration can help streamline efforts and help mobilize resources to expand land restoration activities in a harmonized way. This joint planning is also a necessary condition for the functional joint M&E system, mentioned in the previous Scenario. Also, advantages of joint fund mobilization include the risk of conflicts due to unfair contributions, difficulties in reporting due to different systems and capacities, and complex financial reporting. Hindrances may arise from the complexity of joint responsibilities, varying levels of professionalism and capacities, and competition for resources among individual institutions. To address these concerns, government support through donor's basket funds, capacity-building for proposal writing and financial management, and commitment from MINECOFIN are crucial. Other considerations include the roles of MINECOFIN, donor support for joint funding, and the Single Project Implementation Unit at REMA. Proper distribution of roles and responsibilities, as well as joint planning and budgeting, will contribute to the effective functioning of joint funding mobilization.

Scenario 5. Joint research for land restoration. Advantages include skills sharing, data sharing, increased resources from partners' contributions, quality research results, and efficient use of financial resources. Key enablers are a combination of technical expertise, stronger human capacity, ex-

[1] Imihigo is a traditional Rwandan cultural practice and performance management tool for goal setting and accountability that has been adapted and integrated into the Rwandan public administration and governance structure. The term "Imihigo" translates to "pledges" or "commitments" in the Kinyarwanda language. Imihigo has been recognized for its effectiveness in driving development, enhancing public service delivery, and promoting accountability and transparency in governance. The Rwandan government has revitalized the Imihigo concept as a performance management tool to fast-track the country's development and achieve its national development goals, such as those outlined in its Vision 2020 and Vision 2050 strategies.

panding research networks, experience sharing, and rapid publications in journals. Disadvantages include longer times to generate research findings due to bureaucracy, conflicting research agenda items, and challenges in resource management. Hindrances may arise from time-consuming processes, difficulty in matching partners, and limited coordination. Other challenges include limited use of research findings for planning. To address these concerns, ensuring human resources, financial resources, and the existence of dedicated research institutions is essential. An institutional setup for research organization, laws governing research, and planning process consultation can also contribute to success. Considering local knowledge in research initiatives is another important factor to consider for effective joint research efforts.

Using the theory of transaction costs and outlined methodology for assessing the benefits from harmonized and well-coordinated implementation of land restoration activities under the Rio Conventions in Rwanda (Annex 2), Table 20 presents quantitative assessment of benefits from collaborative approaches under each of these synergy scenarios. Based on different scenarios for synergy collaboration, it is evident that the combined implementation of land conservation, SLM, and land restoration activities under the NBSAP, NDC, and LDN processes can substantially reduce transaction costs and enhance the overall effectiveness of land restoration activities.

The estimations show that harmonized implementation of land restoration activities under NBSAP, NDC, and LDN processes in Rwanda using all these synergy scenarios may reduce the transaction costs of land restoration by almost 56%. Specifically, coordinated implementation is estimated to save about 45.6 million US dollars per year compared to when the activities under the three Rio Conventions are carried out separately. Thus, well-coordinated and harmonized implementation can provide with significant efficiency gains in land restoration activities.

The values represented in Table 20 show average values. The confidence interval of gains from the coordinated approach ranges from 12.09 million USD - 90.98 million USD annually. Coordinated approach is economically preferable to separate implementation in 99.98% of the simulations. These numbers are calculated for annual investments of 300 million US dollars in land conservation, SLM, and land restoration activities. These results clearly support our earlier conclusion on the importance of coordinated approach from the financial efficiency dimension as well.

08
Policy Recommendations

The following recommendations for collaborative synergies are suggested based on the findings of this study for the consideration by concerned ministries and other organizations in Rwanda engaged in land management and, at the international level, by the secretariats of the three Rio Conventions.

Synergy mechanism 1.
A joint inter-agency working group for land.

Strengthening inter-ministerial coordination on land conservation, SLM, and land restoration in Rwanda. National dialogues and coordination mechanisms are essential for implementing international conventions and agreements effectively. Establishing such mechanisms can help streamline communication and cooperation among different stakeholders, including government ministries, agencies, sub-national administrations, private sector, civil society organizations, and local communities.

Establishing a national focal point for coordinating land-based activities (including the entire spectrum from conservation, SLM, to restoration) within the government, such as dedicated inter-ministerial committee headed by a high-level official, can help coordinate actions among different ministries and stakeholders engaged in land management from diverse angles. The focal point could also bring together currently existing working groups which are operating in parallel despite being usually made up of the same organizations and individuals.

Enhancing the mandate of the Joint Liaison Group among the Rio Conventions. At the Rio Conventions' level, the JLG was established to enhance coordination and cooperation among the Rio Conventions. Strengthening the JLG's capacity and providing it with a more explicit mandate to facilitate collaboration on land restoration could help enhance synergies among the Rio Conventions.

Synergy mechanism 2.
Joint research and planning of land target implementation.

Joint spatial mapping of lands for conservation, SLM, and restoration across the Rio Conventions. Full harmonization of Conventions' specific indicators on land can be highly costly and long process without clear and certain benefits and may be for some indicators infeasible. It may be a more optimal approach to accept these individual targets and differences as such and bring them together in one map capturing the national commitments of land conservation, SLM, and land restoration under the three Rio Conventions in a spatially explicit manner. It is clear from this study's findings that the predominant share of land conservation, SLM, and land restoration activities in Rwanda will occur on agricultural lands. Therefore, a coherent and salient integration of food security and (agro)-biodiversity implications is necessary.

Harmonizing national action plans for land conservation, SLM, and land restoration with the joint support of the three Rio Conventions can help outline Rwanda's land-related commitments, targets, and strategies for implementing and serve as a joint roadmap for all stakeholders. Rwanda has a very rich basis to initiate such process, for example, Restoration opportunity assessment methodology (ROAM) could provide the starting elements for this national coordination.

Synergy mechanism 3.
Joint funding mobilization

Mobilizing resources for joint work on land conservation, SLM, and land restoration: Rwandan national organizations and the three Rio Conventions can work together to secure financial resources to support collaborative efforts on land, including from GEF, GCF, and other funding sources. An urgently needed and very specific topic for such finding could be joint spatially explicit mapping of NBSAP, NDC, and LDN commitments and on joint monitoring and evaluation.

Elaborating joint work programs and projects. At both national level and at the Rio Conventions' level, the development of joint work programs and projects could be considered. In Rwanda this could be part of the National Plan for land conservation, SLM, and land restoration, and for the Rio Conventions, this could be part of the enhanced mandate of the JLG, both discussed above. This collaborative programming approach can help streamline efforts and help mobilize resources to expand implementation activities in a harmonized way.

Synergy mechanism 4.
An information exchange platform and joint research

Facilitating knowledge and information generation and sharing: Creating a platform for the exchange of knowledge, information, and best practices related to land conservation, SLM, and land restoration between the national organizations in Rwanda can help bring together land related information into one place and help provide open access to it. Having such publicly available source of rich information on all aspects of land conservation, SLM, and land restoration will help unleash various research activities supporting evidence-based design of land management policies, but also help attract more investments to land conservation, SLM, and land restoration by reducing information uncertainties and risks faced by both private and public investors. Maintaining and updating this platform could be part of the functions of the national focal point for land conservation, SLM, and land restoration in Rwanda.

Fostering capacity-building efforts. The secretariats of the Rio Conventions can collaborate on providing support for capacity building and strengthening on integrated approaches that address land objectives across the Conventions. This could include training, technical assistance, and the development of tools and guidelines for application of best practices of land conservation, SLM, and land restoration.

Increasing awareness and political will. Raising awareness of the benefits of collaboration and synergies among the conventions at the political level, including through high-level dialogues and meetings, to generate the necessary political will to support collaboration on land conservation, SLM, and land restoration.

Synergy mechanism 5.
A joint monitoring and evaluation (M&E) system

Monitoring of progress of land conservation, SLM, and land restoration and evaluating its outcomes. Establishing a joint mechanism for monitoring progress and evaluating the effectiveness of collaborative efforts in land conservation, SLM, and land restoration is the highest payoff synergy area for collaboration. FERM under the UN Decade on Ecosystem restoration is currently intending to provide an overarching mechanism for monitoring of broader impacts of land restoration on all dimensions of sustainable development. In addition to this, however, there is a need for more targeted and the Rio Conventions' specific monitoring framework that is also well applicable to diverse country settings, with a clear focus on monitoring and measuring the progress of the land conservation, SLM, and land restoration targets under the LDN, NBSAP, and NDC processes, both at national and international levels. A periodic publication on the state of land restoration in the world that documents the outcomes of such monitoring could be considered.

References

Bagstad, K. J., Ingram, J. C., Lange, G.-M., Masozera, M., Ancona, Z. H., Bana, M., Kagabo, D., Musana, B., Nabahungu, N. L., Rukundo, E., Rutebuka, E., Polasky, S., Rugege, D., & Uwera, C. (2020). Towards ecosystem accounts for Rwanda: Tracking 25 years of change in flows and potential supply of ecosystem services. People and Nature, 2(1), 163-188.

Benham, A., Benham, L., Gunia, B., Jaramillo, M., Shirley, M., & Zylbersztajn, D. (2004).

Questionnaire on Costs of Exchange: Registering a New Firm Officially. Ronald Coase Institute Working Papers, (3).

Berry, L. and Olson, J. (2003). Land Degradation in Rwanda: Its Extent and Impact, in Assessing the Extent, Cost and Impact of Land Degradation at the National Level: Findings and Lessons Learned from Seven Pilot Case Studies, p. 204.

Buckingham, K., Arakwiye, B., Ray, S., Maneerattana, O., & Anderson, W. (2021). Cultivating networks and mapping social landscapes: How to understand restoration governance in Rwanda. Land Use Policy, 104, 104546.

Coase, R. (1937). 'The Nature of the Firm', Economica 4 (16): 386-405.

Coggan, A., Whitten, S. M., & Bennett, J. (2010). Influences of transaction costs in environmental policy. Ecological economics, 69(9), 1777-1784.

Cuypers, I. R., Hennart, J. F., Silverman, B. S., & Ertug, G. (2021). Transaction cost theory: Past progress, current challenges, and suggestions for the future. Academy of Management Annals, 15(1), 111-150.

Dave, R., Saint-Laurent, C., Murray, L., Antunes Daldegan, G., Brouwer, R., de Mattos Scaramuzza, C. A., Raes, L., Simonit, S., Catapan, M., García Contreras, G., Ndoli, A., Karangwa, C., Perera, N., Hingorani, S., & Pearson, T. (2019). Second Bonn Challenge progress report: Application of the Barometer in 2018. IUCN, International Union for Conservation of Nature.

Falconer, K., Dupraz, P., & Whitby, M. (2001). An investigation of policy administrative costs using panel data for the English environmentally sensitive areas. Journal of agricultural economics, 52(1), 83-103.

Falconer, K., & Saunders, C. (2002). Transaction costs for SSSIs and policy design. Land use policy, 19(2), 157-166.

Fang, F., Easter, K. W., & Brezonik, P. L. (2005). Point-nonpoint source water quality trading: a case study in the Minnesota river basin 1. JAWRA Journal of the American Water Resources Association, 41(3), 645-657.

Friedl, M., and D. Sulla-Menashe. (2019). "MCD12Q1 MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid V006 [Data Set]. NASA EOSDIS Land Processes DAAC." 2019.

Government of Rwanda (2018). Rwanda Natural Capital Accounts Land. Final Report. Kigali, Rwanda: The National Institute of Statistics of Rwanda (NISR) and the Ministry of Environment with assistance from the World Bank and the WAVES Global Partnership.

High Level Forum on Harmonization (2003). Rome Declaration on Harmonization (25February). Paris: OECD.

International Union for Conservation of Nature [IUCN] (2020). Restore our future - The Bonn

Challenge: Impact and potential of forest landscape restoration.

International Union for Conservation of Nature [IUCN] (2022). Restore our Future: The Bonn Challenge.

International Union for Conservation of Nature [IUCN] and Government of Rwanda (2021). A Thousand Hills Turn Green. A Thousand Hills Turn Green.

Janishevski L. (2020). Synergies in implementing the CBD and other MEAs. (Presentation)

Kabirigi, M., Mugambi, S., Musana, B., Ngoga, T. G., Muhutu, J. C., Rutebuka, J., Ruganzu, V., Nzeyimana, I., & Nabahungu, N. (2017). Estimation of soil erosion risk, its valuation and economic implications for agricultural production in western part of Rwanda, Journal of Experimental Biology and Agricultural Sciences, 5, pp. 525–536.

Lawson, A. (2009). Evaluating the transaction costs of implementing the Paris Declaration. Concept Paper submitted by Fiscus Public Finance Consultants to the Secretariat for the Evaluation of the Paris Declaration, November.

McCann, L., & Easter, K. W. (2000). Estimates of public sector transaction costs in NRCS programs. Journal of agricultural and applied economics, 32(3), 555-563.

McCann, L., Colby, B., Easter, K. W., Kasterine, A., & Kuperan, K. V. (2005). Transaction cost measurement for evaluating environmental policies. Ecological economics, 52(4), 527-542.

McLain, R., Lawry, S., Guariguata, M. R., & Reed, J. (2019). Integrating tenure and governance into assessments of forest landscape restoration opportunities. (Vol, 241). Center for International Forestry Research (CIFOR).

Merkert, R., Smith, A. S., & Nash, C. A. (2012). The measurement of transaction costs—evidence from European railways. Journal of Transport Economics and Policy (JTEP), 46(3), 349-365.

Ministry of Disaster Management and Refugee Affairs [MIDIMAR] (2015). The National Risk Atlas of Rwanda. Kigali, Rwanda.

Ministry of Environment [MoE] (2016). National Biodiversity Strategy and Action Plan. Rwanda Environment Management Authority, Republic of Rwanda.

Ministry of Environment [MoE] (2017). Strategic Programme for Climate Resilience (SPCR). Final Report. Kigali, Rwanda, p. 271.

Ministry of Environment [MoE] (2018a). National Agroforestry Strategy (2018-2027). Kigali, Rwanda.

Ministry of Environment [MoE] (2018b). Third National Communication: Report to the United Nations Framework Convention on Climate Change. Rwanda Environment Management Authority, Republic of Rwanda, Kigali.

Ministry of Environment [MoE] (2018c). Final Country Report of the LDN Target Setting Programme in Rwanda. Rwanda Water and Forestry Authority, Republic of Rwanda, Kigali.

Ministry of Environment [MoE] (2020). Update Nationally Determined Contribution, Republic of Rwanda.

Ministry of Environment [MoE] and International Union for Conservation of Nature [IUCN] (2019). Rwanda Forest Cover Mapping. Final Report. Kigali, Rwanda, p. 235.

Ministry of Finance and Economic Planning [MINECOFIN] (2020). Rwanda Vision 2020. Government of Rwanda.

Ministry of Lands and Forestry [MINILAF] (2018). Forest Sector Strategic Plan 2018 – 2024. Kigali, Rwanda, p. 59.

Ministry of Natural Resources [MINIRENA], International Union for Conservation of Nature [IUCN] and World Resources Institute [WRI] (2014). Forest Landscape Restoration Opportunity Assessment for Rwanda. Nairobi, Kenya, p. 64.

Mirzabaev, A., & von Braun, J. (2022). True cost of food and land degradation. Russian Journal of Economics, 8(1), 7-15.

Mirzabaev, A., Sacande, M., Motlagh, F., Shyrokaya A., Martucci A. (2022). Economic efficiency and targeting of the African Great Green Wall. Nat Sustain 5, 17–25 (2022).

Mirzabaev A. and Wuepper D. (2023). Economics of ecosystem restoration. Annual Review of Resource Economics.

National Institute of Statistics Rwanda [NSIR] (2014). Fourth Population and Housing Census, Rwanda - ATLAS. Ministry of Finance and Economic Planning.

Nkonya, E., Anderson W., Kato E., Koo J, Mirzabaev A., von Braun J., and Meyer S. (2016). Global Cost of Land Degradation. In Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development, 117–165. Cham: Springer International Publishing.

Ofei-Mensah, A., & Bennett, J. (2013). Transaction costs of alternative greenhouse gas policies in the Australian transport energy sector. Ecological Economics, 88, 214-221.

Pannell, D. J., Roberts, A. M., Park, G., & Alexander, J. (2013). Improving environmental decisions: A transaction-costs story. Ecological Economics, 88, 244-252.

Paul, E., & Vandeninden, F. (2012). Foreign aid transaction costs: what are they and when are they minimised?. Development Policy Review, 30(3), 283-304.

Rwanda Environment Management Authority [REMA] (2011). Atlas of Rwanda's Changing Environment - Implications for Climate Change Resilience.

Rwanda Environment Management Authority [REMA] (2019). Compendium of Environment Statistics of Rwanda 2018. Final Report. Kigali, Rwanda, p. 158.

Rwanda Environment Management Authority [REMA] (2020). Rwanda 6th National Report to the Convention on Biological Diversity. Kigali, Rwanda, p. 153.

Rwanda Environment Management Authority [REMA] (2022). REMA Strategic Plan, Kigali, Rwanda, p. 35.

Rwanda Governance Board [RGB] (2017). Impact Assessment of Umuganda 2007-2016. Kigali, Rwanda, p. 48.

Rwanda Water Resources Board [RWB] and International Union for Conservation of Nature [IUCN] (2022). The State of Soil Erosion Control in Rwanda. Kigali, Rwanda, p. 331.

Rubinstein, R. Y., & Kroese, D. P. (2016). Simulation and the Monte Carlo method. John Wiley & Sons.

Singh, A., Barr, J., Lund, H., Tovivo, K., Gelaye, M., Ochieng, E. Giese, K., & Nyamihana, C. (2015). Rwanda - State of Environment and Outlook Report 2015. Environmental Pulse Institute.

Spawn, S.A., and H.K. Gibbs. 2020. Global Aboveground and Belowground Biomass Carbon Density Maps for the Year 2010. ORNL DAAC, Oak Ridge, Tennessee, USA.

Stainback, G. A., Masozera, M., Mukuralinda, A., & Dwivedi, P. (2012). Smallholder Agroforestry in Rwanda: A SWOT-AHP Analysis, Small-scale Forestry, 11(3), pp. 285–300.

Stepman, F. (2020). Agroforestry Rwanda: Improving resilience of farmers' livelihoods to climate change through innovative, research proven climate-smart agroforestry and efficient use of tree resources in the Eastern Province and peri-urban areas of Kigali city | Capacity4dev. European Union.

The Economics of Land Degradation [ELD] Initiative (2020). Insights from capacity building on the economics of land degradation in Rwanda. Report for the Economics of Land Degradation Initiative in the framework of the "Reversing Land Degradation in Africa through Scaling-up Evergreen Agriculture" project.

United Nations Convention to Combat Desertification, 2022. The Global Land Outlook, second edition. UNCCD, Bonn.

van der Esch, S., Sewell, A., Bakkenes, M., Berkhout, E., Doelman, J. C., Stehfest, E., ... & Ten Brink, B. (2022). The global potential for land restoration: Scenarios for the Global Land Outlook 2. PBL Netherlands Environmental Assessment Agency: The Hague, The Netherlands.

Wiese-Rozanov, L. (2022). Soil organic carbon commitments under three Rio Conventions: Opportunities for integration. Soil Security, 100052.

Williamson, O. E. (1975). Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organization. University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship.

Williamson, O. E. (1985). The Economic Institutions of Capitalism: Firms, markets, relational Contracting. Free Press.

Williamson, O. E. (2010). Transaction cost economics: The natural progression. American Economic Review, 100(3), 673-690.

World Overview of Conservation Approaches and Technologies [WOCAT], The Economics of Land Degradation [ELD] and United Nations Convention to Combat Desertification [UNCCD] (2022). Costs and Benefits of Sustainable Land Management Technologies – a new open access ECON-WOCAT dataset to support project planning and design. 11 pages. Bonn, Germany.

World Bank [WB] (2017). Rwanda Admin Boundaries and Villages. WB Data Catalog. Washington D.C.

Technical Annexes

Annex 1. Conceptual framework

A1.1. Measurement of transaction costs

Land restoration programmes by the government raises several transaction cost dilemmas. The type of organisational structure, the control and command structures, number of actors, and how cost and benefits will be shared affect the transaction cost and the successful implementation of the project (Tables 21 and 22).

Aside the direct cost of restoring the land such as seed/seedling production, tree planting, soil and water management; the associated indirect cost (transaction cost) is likely to be high. Some of

TABLE 21

Type of transaction cost and production cost involved in a land restoration program

TC classification	Activity	Governance structure	Type of transaction cost	Type of production cost
Ex-ante	Establishment of organisation /institution/ platform	Hybrid (donors & government)	1. Research & information 2. Contracting & bureaucracy 3. Design and planning 4. Support and administrative support	
Ex-post	Implementation	Hybrid (donors & government)	1. Research & information on contractors/consultants 2. Administrative support (incl. procurement) 3. Monitoring & evaluation 4. Enforcement	
		Contrators (farmer groups, specialised firms; community engagement)	1. Time and cost of community engagement 2. Administrative support (incl. procurement staff) 3. Monitoring and evaluation	4. Input cost (seeds, seedlings, labour, machinery, etc) 5. Technology and innovation 6. Maintenance cost (watering, replacing dead trees, agronomic practices, etc)
	End of project	Hybrid (donors & government)	1. Monitoring and evaluation 2. Reporting system	

TABLE 22

Type of transaction cost and production cost involved in a land restoration program

Source: Adapted from McCann and Easter (2000); Falconer et al. (2001); Fang et al. (2005); McCann et al. (2005); Coggan et al. (2010); Ofei-Mensah and Bennett (2013); and Pannell et al. (2013).

Authors	TC (%) of total cost	Methodology	Comment
McCann and Easter (2000)	38	TC = share of total conservation cost Total conservation cost = (abatement + TC) Abatement cost = financial assistance + private cost TC = planning + application + support + other cost	The TC component of a natural resource conservation service programme is based on planning, application, support (maps, office equipment, and rent) costs and other agency costs, e.g., conservation districts
Falconer et al. (2001)	28.9		TC= public sector administrative costs of Agri-Environmental Schemes (AESs) implementation across England. i.e., running costs (information, contracting, policing) + environmental monitoring cost (evaluation)
Fang et al. (2005)	35	$TC=\sum(t_i * r_i * S_i)$ *t = time spent on administrative and contracting activities* *r = wage (%/hr)* *s = number of personnel* *i = number of transactions*	Total TC included TC from private entity and government agency to implement a water quality-trading scheme in the Minnesota River basin. TC included time spent on permit negotiation, searching for trading partners, administrative expenditures, mandated communications between the permittee and government agency. In addition, time spent by government agency staff on credit verification, post-project site inspection, and routine project management.
McCann et al. (2005)			TC comprises of research and information; enactment or litigation; design and implementation; support and administration; contracting/monitoring/detection/conflict resolution; prosecution/enforcement
Coggan et al. (2010)	21-50		TC as a percentage of total cost of policy
Ofei-Mensah and Bennett (2013)	18-19[a] 3-4[b]	$TC = \sum \beta_t (R_{ijt}+K_{ijt}+I_{ijt}+A_{ijt}+C_{ijt}+M_{ijt}+F_{ijt})$ *ß = discount factor* *i = policy; j = paying entity* *t = time period* *R-F = transaction cost elements* TC elements (dollars) = salary (dollars per day) x staff (numbers) x time (days/hours)	• Use of surveys and official records from institutions implementing the policy programme • TC=research and information (R) + enactment (K) + implementation (I) + administrative (A) + contracting (C) + monitoring (M) + enforcement cost (F) [a] TC relative to compliance cost of the Fuel Label Programme (FLP) in Australia [b] TC relative to total cost of the Fuel Efficiency Programme (FEP) in Australia
Pannell et al. (2013)	68	Summation of share of allocation to programme funds. $TC = \sum_{(i=1)}^{n}$ *share of budget*	• Use of official records from institutions implementing the programme • Under the National Action Plan for Salinity and Water Quality by the Australian government, • TC= central administration of the programme + administration and capacity building of regional environmental bodies + planning + monitoring and evaluation at regional level + data, analysis and research + extension, information provision, persuasion, networks

the immediate ex-ante transaction costs include formation of implementing agencies (inter-ministerial committee), drafting of contracts, engagement of consultants, community engagement and education, alternative opportunities for affected communities (opportunity cost), and bargaining cost with affected actors. Ex-post transaction costs include monitoring and enforcement, environmental assessment, maintenance and the long-term commitment (probity) to protect restored lands.

The broad definition of TC makes its measurement difficult. Therefore, the use of specific typologies can help streamline its measurement (McCann et al., 2005). So far, the literature shows two approaches to measure TC. Both the direct and indirect approaches can be used to measure transaction cost (Merkert et al., 2012; Benham et al., 2004). The direct approach encompasses two methods. Method 1 estimates TC based on the size of "transaction sector" within firms of non-transaction industries. For instance, the wage payment to employees in legal, finance and human resource departments. Method 2 estimates TC based on the cost of specific transactions. For instance, salary cost of time spent collecting information, or waiting in a queue (Merkert et al., 2012). Most authors (A1.3) applied method 2 to the computation of TC in the environmental sector. Benham (2004) and Merkert et al. (2012) applied method 2 to the railway sector. The magnitude of TC is dependent on the components of TC measured.

Annex 2. Methodological Framework

A2.1. Methods

Economic assessment of land restoration

The calculation of the costs of land degradation includes the total economic values (TEV) of direct use and indirect use ecosystem services obtained from land ecosystems in Rwanda. The costs and benefits of land restoration activities are calculated by their net present value (NPV) in year t for Rwanda's planning horizon T. The costs of land restoration activities are comprised of establishment costs for restoring the degraded biomes, maintenance costs, the opportunity costs of the lower value biome, which is being replaced by the higher value biome, as well as the transaction costs used for implementing land restoration programs.

$$\pi_t^c = \frac{1}{\rho^t} \sum_{t=0}^{T} (PY_t^c + IV_t - lm_t^c) \qquad (1)$$

where, π_t^c = net present value (NPV) of land restoration in year t for Rwanda's planning horizon T; ρ^t = 1+r, r = discount rate (10%); Y_t^c= production of direct use provisioning services after land restoration (food, fodder, timber, non-timber products, etc.); P = unit price of Y_t^c; IV_t = value of indirect use ecosystem services (e.g. carbon sequestration); lm_t^c = cost of land restoration, including establishment, maintenance, opportunity, asnd transaction costs. The planning horizon (T) in this study is determined to be 30 years, i.e., between 2020 and 2050.

If Rwanda does not undertake land restoration, the NPV is given by:

$$\pi_t^d = \frac{1}{\rho^t} \sum_{t=0}^{T} (PY_t^d + IV_t) \qquad (2)$$

where π_d^d = NPV of the ecosystem services still derived from the degraded biome. Superscript d indicates a degraded biome.

The benefit of land restoration is given by:

$$BA = \pi_t^c - \pi_t^d \qquad (3)$$

The difference $\pi_t^c - \pi_t^d$ is essential in decision making. If the returns to land restoration, after including land restoration costs, are smaller than the corresponding returns from the degraded biome, it would not make economic sense to conduct land restoration activities.

As the first step, our cost-benefit analysis of land restoration focuses on land dynamics, as measured by the MODIS Land Cover Type Product (MCD12Q1) global maps of land use and cover at 500-m spatial resolution (Friedl and Sulla-Menashe 2019), that have occurred each year between 2001 and 2020, for the evaluation of land dynamics, and their associated costs and benefits Rwanda. The underlying assumptions about the trajectories of ecosystem recovery after restoration are given in Table 23.

Analytically, this would mean calculating (4) below. For example, when a forest is cut down and turned into a cropland, this would mean lower values of ecosystem services because forests usually provide higher TEV of ecosystem services than croplands.

$$C_{LULC} = \sum_i^K (\Delta a_1 * p_1 - \Delta a_1 * p_2) \qquad (4)$$

where C_{LULC} = cost of land degradation due to land dynamics; a_1 = land area of biome 1 being replaced by biome 2; P_1 and P_2 are TEV biome 1 & 2, respectively, per unit of area.

Hence, by the definition of land degradation, $P_1 > P_2$.

This means, land dynamics that lead to higher TEV, i.e., when $P_1 < P_2$, is not regarded as land degradation but rather as land improvement.

The analysis of land dynamics is based on International Geosphere-Biosphere Programme (IGBP) definitions and comprises the following biomes present in Rwanda: Evergreen Broadleaf Forest, Evergreen Needleaf forests, Mixed Forest, Closed shrubland, Woody savannas, Savannas, Grassland, Permanent wetlands, Cropland, Urban areas, Cropland/Natural Vegetation Mosaics which correspond to agroforestry systems, and barren areas, and Water bodies.

TABLE 23

Trajectory of ecosystem recovery

Costs of action	Forest	Shrublands, woody savannas and savannas	Agroforestry systems	Wetland	Cropland	Grassland
Establishment period	30	10	10	10	1	1
Staggered entrance into full potential	First 5 years (20% of the full potential), 2nd 5 years (33% of potential), next 10 years (50 of potential), next 5 years (80% of potential)	First 5 years (50% of the full potential), 2nd 5 years (80% of potential)	First 5 years (50% of the full potential), 2nd 5 years (80% of potential)	First 5 years (50% of the full potential), 2nd 5 years (80% of potential)	Full potential is reached one year after restoration	Full potential is reached one year after restoration
Survival rates	60%	60%	60%	100%	100%	60%

TABLE 24

International Geosphere-Biosphere Programme (IGBP) definitions of land uses and covers

Land use and cover	Description
Evergreen Broadleaf/ Needleaf Forests	Lands dominated by broadleaf/needleaf 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.
Woody Savannas	Lands with herbaceous and other understory systems, and with forest canopy cover between 30% and 60%. The forest cover height exceeds 2 m.
Savannas	Lands with herbaceous and other understory systems, and with forest canopy cover between 10% and 30%. 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. Tree and shrub cover is less than 10%.

Economics of coordinated vs uncoordinated land restoration under the Rio Conventions

This analysis investigates the costs and benefits of coordinated vs uncoordinated land restoration activities under the three Rio Conventions following the theory of transaction costs. Based on the literature review, we identified that transaction costs make up about 25% in land restoration project costs in Rwanda (Table 15). This corresponds to a very efficient organization of land restoration activities. The transaction costs across all participants of the land restoration activities under the three Conventions are likely to vary substantially. Hence, it is important to account for variations in these transaction costs. Coordination allows for reducing these transaction costs. How much transaction costs are reduced would also vary depending on both the extent of collaboration and the nature of these transaction costs. The following steps are taken as part of this methodology:

Step 1. Account for the variation in the shares of the transaction costs

This is done through using average transaction costs of 35% and including a standard deviation of these transaction costs of 10% around this mean value. To account for this variability in transaction costs, Monte Carlo simulations were performed. The simulations are used to estimate the potential outcomes of a stochastic process by running 10,000 iterations with changing shares of the transaction costs within the total land restoration costs. In each iteration, transaction costs are generated by sampling from a normal distribution. Specifically, the transaction cost share is constrained between 0 and 1 using the max and min functions, and it follows a normal distribution with a mean of 0.35 and a standard deviation of 0.10. This sampling allows for variability in the transaction costs, reflecting the uncertainty and potential fluctuations in these parameters.

Step 2. Account for benefits of coordination

Coordination allows for reducing these transaction costs. How much transaction costs are reduced would also vary depending on both the extent of collaboration and the nature of these transaction costs. Reductions in transaction costs are modelled to vary between 0% (no benefit from coordination) to 75% for different cost types. The coordination reductions are sampled from a normal distribution with a mean of 0.45 and a standard deviation of 0.3. Here as well, 10,000 Monte Carlo simulations are run to identify the distribution of potential outcomes.

Step 3. Model the variations in each type of transaction costs

By multiplying the transaction costs by the corresponding proportions of each specific transaction cost type (ME-Monitoring and Enforcement, RCB - Research and capacity building, AR-Awareness raising, CA-Coordination and administration, FM-Funding mobilization), the baseline costs without coordination for each cost type are determined. This allows for the evaluation of the cost distribution across different transaction cost types in the baseline No coordination scenario.

Step 4. Identifying reductions in each transaction cost through coordination

Coordination efforts lead to the reduction in transaction costs. It varies for each cost type and follows a normal distribution with a mean of 0.45 and a standard deviation of 0.3, ensuring that the reduction factor falls within the range of 0% to 75% reductions in the overall transaction costs. This reflects the cost reduction achieved through coordination activities in the coordination scenario.

Step 5. Compare Coordination vs No Coordination scenarios.

Steps above result in calculation of the expected values of transaction costs under coordination and no coordination considering potentially high variability of these costs and benefits of collaboration across different actors in Rwanda.

A2.2. Data

Land Use and Land Cover (LULC)
The MODIS Land Cover Type Product (MCD12Q1, here referred to as Modis500 land dynamics) global maps of land use and cover at 500-m spatial resolution (Friedl and Sulla-Menashe, 2019) are used as the source for the land dynamics data. Modis500 land dynamics provides global land cover types at annual intervals (2001-2018). Modis500 land dynamics is derived using supervised classifications of MODIS Terra and Aqua reflectance data. The supervised classifications then undergo additional post-processing that incorporate prior knowledge and ancillary information to further refine specific classes (Figure 16).

Economic values of ecosystem services
We conducted a thorough review of all available data from literature published on the values of ecosystem services specifically from Rwanda and neighbouring countries. We complemented this through interviews with experts and various other stakeholders. Since it is not possible to derive individual ecosystem values for each pixel of the analysis, we used the benefit-transfer approach to assign economic values to ecosystem services in those settings in Rwanda with missing data by using ecosystem values from other locations Rwanda and from their neighbouring countries (Tables 25-26).

Costs of land restoration actions
The data on the costs of land restoration actions is similarly collected from existing databases and publications, particularly: the World Overview of Conservation Approaches and Technologies (WOCAT), Economics of Land Degradation (ELD) database (Nkonya et al., 2016), as well as through focus group discussions and expert interviews in Rwanda. The data that we compiled on the establishment and maintenance costs of ecosystems restoration indicate that ecosystem re-establishment costs range from 304 US dollars per ha for grassland to 3726 US dollars per ha for wetland (Table 24).

Costs and benefits of separate vs integrated planning and implementation of land restoration
The data on transaction costs of implementing land restoration activities is obtained through review-

ing REMA (2022), as well as the focus group discussions with the participants of the stakeholder workshop on 28-29 March 2023 in Kigali, Rwanda. The key outcome of these focus group discussions was to identify the key constraints from segregated decision-making mechanisms and implementation and potential benefits from coordinated planning and implementation of these action agendas in their land related components under various collaboration scenarios. We also conducted a thorough review of related literature and policy documents and identified key features, potential areas of synergies and tradeoffs between LDN, NDC, and NBSAP processes and their implementation in Rwanda, including the associated investment flows for the implementation of these plans. Finally, quantified scenarios for collaboration synergies that emerged during the workshop are modelled based on this data comparing when land restoration activities are conducted through separate processes vs. when they are implemented through coordinated and well-integrated processes.

Data on carbon sequestration potentials from ecosystem restoration

The data on carbon sequestration potentials from ecosystem restoration comes from the database of above ground and below ground biomass carbon database by the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC) for Biogeochemical Dynamics of NASA. (Spawn et al. 2020).

TABLE 25

Economic values of ecosystems and costs of ecosystem restoration

Source: various datasets and publications on ecosystem benefits and costs of land restoration (e.g., ESVD, ECON-WOCAT, Mirzabaev et al. (2022), ZEF Agroforestry dataset). n/a – not applicable.

Ecosystems in 2001, hectares	Value of ecosystems, USD per ha	Establishment costs per ha	Maintenance costs per ha
Evergreen Needleleaf Forest	2,146	1133	239
Evergreen Broadleaf Forest	3,350	1133	239
Mixed Forest	2,146	1133	239
Closed shrubland	629	646	150
Woody savannas	629	646	150
Savannas	629	646	150
Grassland	370	304	34
Permanent wetlands	3,187	3726	186
Cropland	466	566	165
Urban areas	n/a	n/a	n/a
Agroforestry systems	1,069	737	119
Barren	80	0	0
Water bodies	n/a	n/a	n/a

TABLE 26

Economic values of ecosystem services by different land uses and land covers in Rwanda.

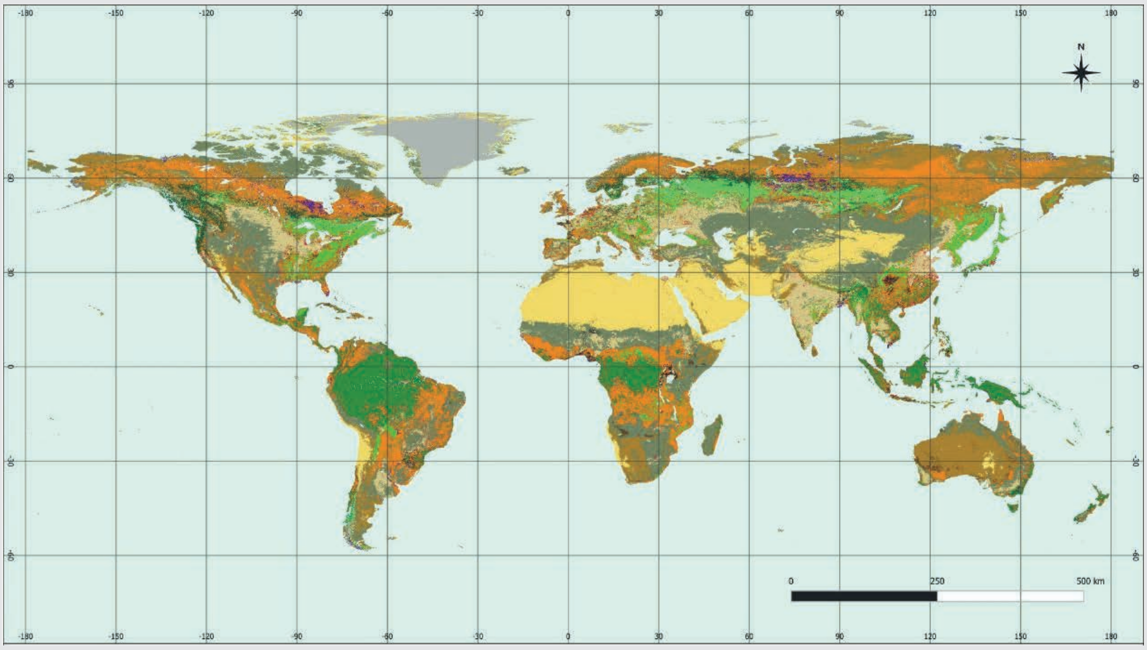
Source: various datasets and publications on ecosystem benefits and costs of land restoration (e.g., ESVD, ECON-WOCAT, Mirzabaev et al. (2022), ZEF Agroforestry dataset).

Ecosystem services	Forests	Agroforestry on pastoral systems	Shrublands, woody savannas and savannas	Grassland	Wetlands	Cropland	Agroforestry on cropping systems	Barren land
Provisioning services	**284**	**192**	**192**	**49**	**427**	**427**	**632**	**80**
Food	132	33	33	36				
Water	33							
Raw materials	76	42	42	12				
Genetic resources	38	25	25					
Medicinal resources	5	2	2	1				
Ornamental resources		90	90					
Regulating services	**1,838**	**216**	**216**	**316**	**2,664**	**38**	**216**	**0**
Air quality regulation	14			23	67			
Climate regulation	1,343	49	49	75	109	2	49	
Disturbance regulation								
Regulation of water flows	55	33	33			19	33	
Waste treatment	153				2,206	4		
Erosion prevention	221	104	104	140	179	2	104	
Nutrient cycling	19	10	10	78	103		10	
Pollination	19	19	19			9	19	
Biological control	14	1	1			2	1	
Habitat services	**24**	**215**	**215**	**0**	**45**	**0**	**215**	**0**
Nursery service	8				29			
Genetic diversity	16	215	215		16		215	
Cultural services	**1,204**	**6**	**6**	**5**	**55**	**1**	**6**	**0**
Esthetic information								
Recreation	1,204	6	6	5	12	1	6	
Inspiration								
Spiritual experience					41			
Cognitive development					2			
Total	**3,350**	**629**	**629**	**370**	**3,187**	**466**	**1,069**	**80**

FIGURE 16

Global land use and cover in 2020

Source: based on data from Friedl and Sulla-Menashe (2019).



Global extent of land use and cover in 2020

- Evergreen Needleleaf Forests
- Evergreen Broadleaf Forests
- Deciduous Needleleaf Forests
- Deciduous Broadleaf Forests
- Mixed Forests
- Closed Shrublands
- Open Shrublands
- Woody Savannas
- Savannas
- Grasslands
- Permanent Wetlands
- Croplands
- Urban and Built-up Lands
- Cropland/Natural Vegetation Mosaics
- Permanent Snow and Ice
- Barren
- Water Bodies

Annex 3. Visualizations of Coordination and Baseline Scenarios

FIGURE 17

Cumulative distribution plot of total costs under Baseline and Coordination Scenarios

Note: Coordination scenario has a first order stochastic dominance over the baseline scenario.

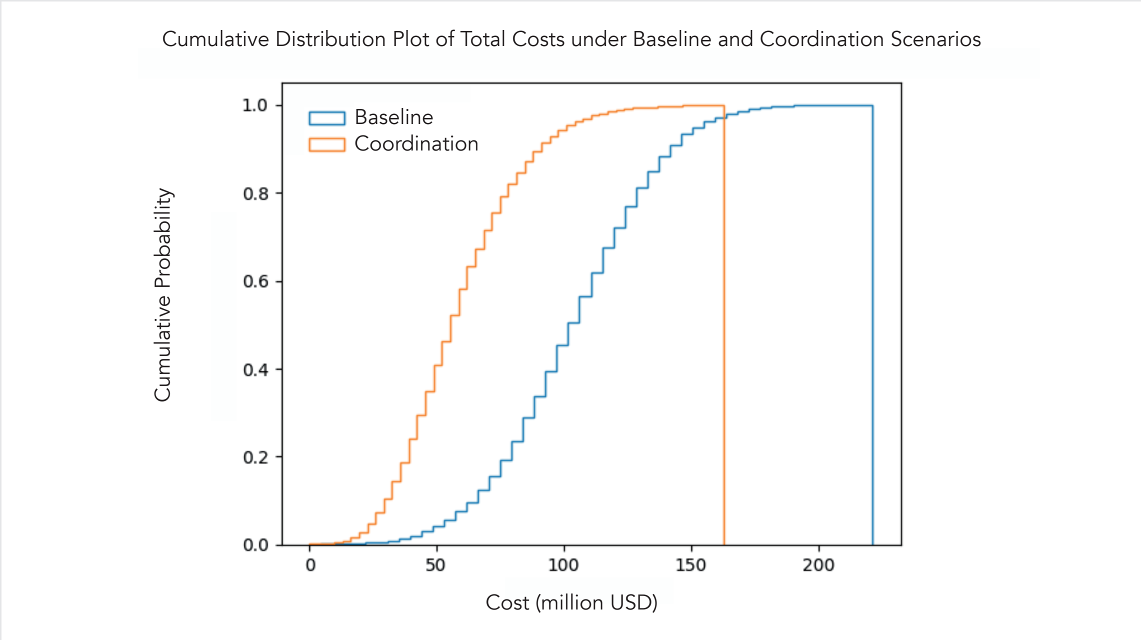


FIGURE 18

Density plot of total costs under Baseline and Coordination Scenarios

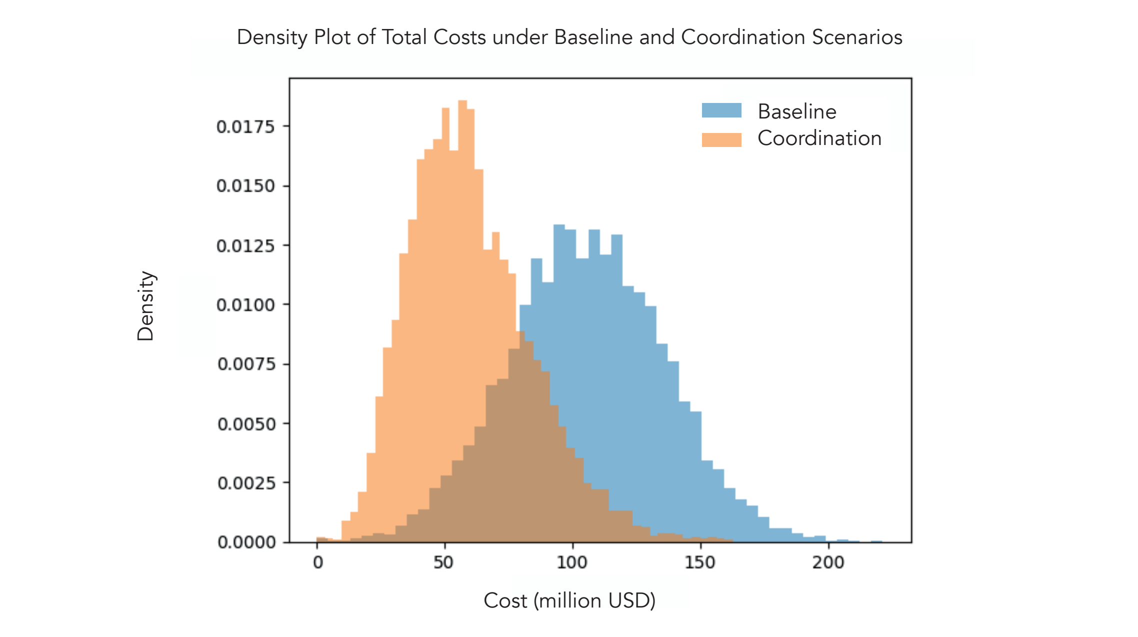
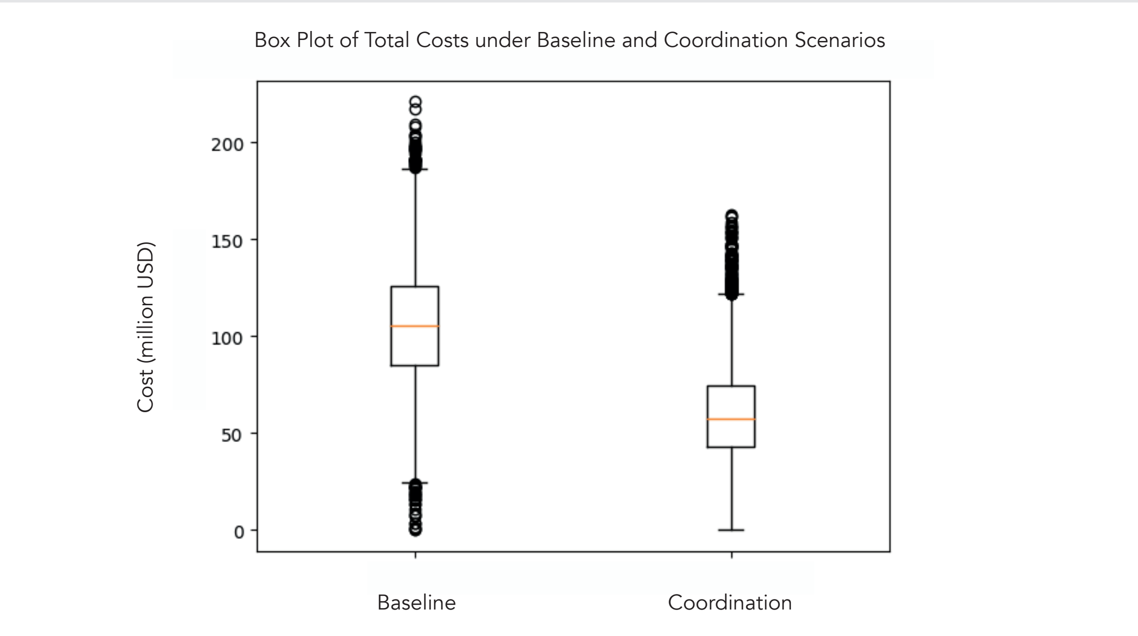


FIGURE 19

Box plot of total costs under Baseline and Coordination Scenarios.



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