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MINISTRY OF NATURAL RESOURCES

Forest Landscape Restoration Opportunity Assessment for Rwanda

September, 2014



Forest Landscape Restoration Opportunity Assessment for Rwanda

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Foreword, Government of Rwanda

I am privileged to introduce a report on Forest Landscape Restoration Opportunity Assessment. Rwanda recognizes the importance of forest landscapes for its socio-economic transformation goals. The Economic Development and Poverty Reduction Strategy - EDPRS2 and the Vision 2020 provide a roadmap for forest cover increase up to 30% of the total country. To date, Rwanda has about 28.8% forest cover (of which 37 percent are humid natural forests and Savannahs). In 2004, forest cover was 19.6% meaning we have registered a growth of 1% per year for the last decade. Despite this positive trend we continue to grapple with a number of challenges in an effort to achieve the 2020 vision of forest resources. These include:



- Changes from natural forest to agricultural land use: primarily to satisfy the needs of a growing population;
- The over-cutting of small woodlots, Fuel wood is the main source of energy and it is expected remain so for years to come, the over-cutting of woodlots is a major cause of forest degradation, improved sustainable fuel wood production is needed;
- The low productivity of forest land: More than 50 percent of forest plantations are at the end of their productive life. Due to short rotations stumps are exhausted and in the last three decades, the annual wood increment dropped from 20m³ to 8m³ per hectare.
- Low species diversity: Tree cover in Rwanda has been dominated by a small number of Eucalyptus species. Eucalyptus has been so far irreplaceable given its multiple roles in Rwanda. Relying on it, however, constitutes a real threat to sustainability of our forestry sector, in case of outbreak of diseases or pests, while native species are at low numbers;
- Limited and poor genetic material: Seed are collected from the impressive arboretum established during the 1930's in Huye, Southern Province, but generally the quality of forest genetic material is poor. There are no dedicated seed orchards to provide a variety of quality seeds to forest growers. Biotechnology for multiplying high productive clones of Eucalyptus is now needed.

I am pleased that this report provides information needs to actually turn more than 80% our country land to productive landscapes for the national green economy. I have no doubt that restoration will not only result in enhanced ecological services but it will also create resilient economy and diversified livelihoods for many Rwandans.

I wish to take this opportunity therefore to affirm the Government of Rwanda's commitment to the implementation of this report through our national institutions. We are deeply grateful to the International Union for the Conservation of Nature (IUCN) and the World Resources Institute (WRI) for the expertise provided to our professionals from Rwanda Natural Resources Authority (RNRA) which resulted to this accurate report. We look forward to continued partnerships towards the implementation of this report and realization of our countrywide restoration commitment.

A handwritten signature in black ink, appearing to read 'Vincent Biruta'.

Vincent Biruta,
Minister of Natural Resources, Rwanda

Foreword, International Union for Conservation of Nature

As a practitioner of Forest Landscape Restoration (FLR) for the last two decades I have worked with several countries to identify and restore landscapes through an FLR approach. This experience has been brought together by IUCN and WRI in the Restoration Opportunity Assessment Methodology (ROAM) Handbook, which provides a flexible framework for countries to rapidly assess FLR potential and locate specific areas of opportunity at a national or sub-national level.

In 2011, Rwanda made an ambitious pledge to the Bonn Challenge to restore 2 million hectares of forest and agricultural land, establishing itself as a global leader in the restoration movement. Rwanda's pledge represents a significant commitment to both its people and environment by recognizing the value of the goods and services provided by landscapes and also providing a platform for Rwanda to achieve many of the goals outlined in EDPRS 2 and Vision 2020.



This report details the findings from the ROAM analyses for Rwanda and provides a number of concrete actions that can be taken to achieve Rwanda's potential for restoration. Professionals from the Department of Forestry and Nature Conservation in RNRA worked in partnership with IUCN and WRI experts and alongside relevant governmental and non-governmental stakeholders to conduct the ROAM in Rwanda. This report identifies priority areas for restoration as well as a short list of feasible interventions that would restore degraded and deforested land, and would help to meet many of the goals set out in Rwanda's Vision 2020.

The results of the ROAM analyses strengthen the analytical base for restoration and can provide a framework for increased collaboration across key sectors and stakeholders in Rwanda. It is my hope that this report represents another step forward in the march towards a Rwanda where restored landscapes support livelihoods and ecosystem functionality for the benefit of all.

A handwritten signature in black ink, appearing to read 'Stewart Maginnis', with a stylized flourish at the end.

Stewart Maginnis,
Global Director of the Nature-based Solutions Group

Acknowledgements

The Ministry of Natural Resources would like to acknowledge the multitude of institutions and individual involved in the development of Rwanda's Restoration Opportunities Assessment. In particular we would like to recognise the commitment of our senior management to this important task. This assessment was very much a joint product with our key partners the International Union for Conservation of Nature – IUCN and the World Resources Institute – WRI and we extend a debt of gratitude to them for their support. We would like to thank all the participants of the many meetings held both in the regions and also in Kigali, especially institutions from government, civil society and the private sector. We would like particularly to acknowledge our development partners the German Ministry of Nature Conservation and Nuclear Safety – BMUB who took a lead role in the support of the Assessment and also UK AID who also supported the assessment process and is providing on-going support to restoration activities. Without the backing of these institutions the vision of landscape restoration in Rwanda would just be an inspiring idea.

Just as the assessment required the cooperation of a wide group of Rwandan, regional and international stakeholders, so too will the implementation of its recommendations. We look forward to working jointly with many collaborators on the national vision for restoration as envisaged by the Bonn Challenge, and we extend an open invitation to all parts of society to join hands with us on this important endeavour.

Supported by:



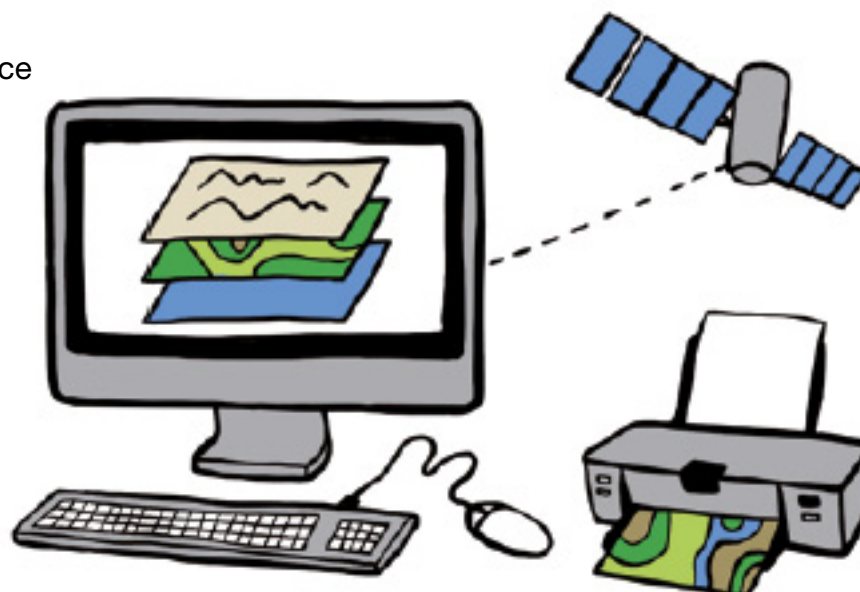
Federal Ministry
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based on a decision of the German Bundestag



Combining best knowledge and best science

best science



best knowledge



ROAM uses a powerful combination of stakeholder engagement ("best knowledge") and analysis of documented data ("best science") to identify and investigate FLR opportunities.

1. Introduction

1.1. Forest Landscape Restoration

Forest landscape restoration (FLR) is the long-term process of regaining ecological functionality and enhancing human well-being across deforested or degraded forest landscapes. It is about “forests” because it involves increasing the number and/ or health of trees in an area. It is about “landscapes” because it involves entire watersheds, jurisdictions, or even countries in which many land uses interact. It is about “restoration” because it involves bringing back the biological productivity of an area in order to achieve any number of benefits for people and the planet. It is long-term because it requires a multi-year vision of the ecological functions and benefits to human wellbeing that restoration will produce although tangible deliverables such as jobs, income and carbon sequestration begin to flow right away. It can indeed be achieved more quickly than many people think.

Over the last centuries, vast forest areas worldwide have been cleared to meet the needs of a growing population. In fact, about 30% of global forest cover has been cleared and a further 20 % has been degraded. This has led to significant reduction in biomass, biodiversity and ecosystem services from forests. FLR provides the opportunity for breaking the spiral of loss and degradation while generating multiple benefits. For example, restored landscapes support livelihoods and biodiversity through provision of clean water, reducing soil erosion, providing wildlife habitat, biofuels and other forest products. In addition, restoration of forest landscapes plays a critical role in mitigating climate change by sequestering carbon. Restoration of trees in agricultural landscapes can boost food productivity through enhanced soil fertility and moisture conservation. It is important to note that forest landscape restoration activities must complement and not displace existing land uses to result in a mosaic of different land uses, including for example agriculture, agroforestry systems and improved fallow systems, ecological corridors, discrete areas of forests and woodlands, and river or lakeside plantings to protect waterways.

FLR Guiding Principles

1. Restore entire landscapes rather than sites to balance a mosaic of interdependent land uses.
2. A forward looking approach to restore the functionality of the landscape.
3. Aim to generate a suite of ecosystem goods and services from a range of restoration activities.
4. Actively engage local stakeholders in decisions regarding restoration goals, implementation methods and trade-offs
5. Consider a wide range of eligible technical strategies for restoring trees on the landscape
6. Adapt restoration strategies to fit local social, economic and ecological contexts.
7. Adapt restoration strategies to changes in human knowledge and societal values.
8. Address ongoing loss and conversion of primary and secondary natural forest.

In 2011, the Global Partnership on Forest Landscape Restoration made a commitment “The Bonn Challenge” to restore 150 million hectares of deforested and degraded land by 2020. At this event, Rwanda demonstrated global leadership as the first African country, committing to achieve a countrywide reversal of natural resource degradation. Through this pledge, Rwanda aims to restore forest landscapes to improve ecosystem quality and resilience, provide new opportunities for rural livelihoods, while securing adequate water and energy supplies and supporting low carbon economic development. Following this pledge, the Ministry of Natural Resources, in particular the Department of Forestry and Nature Conservation in Rwanda Natural Resources Authority has conducted a countrywide restoration opportunity assessment with support from international experts at IUCN and WRI. The findings and recommendations for scaling-up FLR in Rwanda are presented in this report.

1.2 Objective

The objective of this report is to discuss and present opportunities for scaling up pilot projects that will support the government of Rwanda to achieve “border to border” forest and landscape restoration that contributes to multiple sustainable development objectives. Such objectives include increased agricultural productivity, food security, and rural incomes; increased resilience to climate change; improved water supplies; and reduced vulnerability to landslides and other disasters. The report presents the results of a process of national analysis and dialogue conducted to identify degraded lands and restoration opportunities in Rwanda, map their physical extent, measure their economic performance, and identify the key success factors that already exist, as well as those that are currently missing and need to be in place to facilitate progress on restoration. The results presented in this report are intended to guide the scaling up of Rwanda’s restoration efforts and can also be used to influence international forest financing mechanisms for both forest restoration activities and avoided deforestation, through mechanisms such as the Forest Investment Program (FIP), Forest Carbon Partnership Facility (FCPF), and Reducing Emissions from Deforestation and forest Degradation (REDD+). The results may also be used to support national restoration projects.

1.3 Background on Rwanda

The Republic of Rwanda is a densely populated, developing country of 10.5 million people with an average annual growth rate of 2.6%¹ and the GDP of 1,302 billion Rwandan Francs.² Rwanda is a small country, encompassing 2.4 million hectares, of which approximately 2 million hectares are under cultivation or permanent pasture.³ Most of the country is at an altitude above 1,000m, which creates a moderate climate despite being 2 degrees south of the Equator. The country has two rainy seasons, the first of which occurs from February to June and the second of which occurs from September to December. Rainfall is distributed unevenly across the country with the West and North receiving more rainfall than the South and East.

Despite Rwanda’s land-locked geography, it still possesses adequate water resources from lakes and rivers, although in general Rwanda has few exploitable land resources compared to other

countries in the region.⁴ Land, water, flora, and fauna are the main natural resources Rwanda’s population relies on for their livelihoods, which are largely based on subsistence agriculture and energy production. Indeed, an estimated 90% of the population and 70% of the country’s land area are devoted to subsistence agricultural production, while a further 16% of land area is allocated to fuel wood and timber production to meet the country’s energy needs.⁵ With the population’s high dependence on the country’s limited land resources, degradation, deforestation, soil erosion, and loss of biodiversity pose potential threats to the country’s rural population.⁶ The primary challenge faced in Rwanda is the management of existing resources to meet the needs of an increasing populace who depend on natural resources for every aspect of their livelihoods.⁷

1.3.1 Agriculture in Rwanda

The agricultural sector in Rwanda is primarily focused on the non-mechanized cultivation of food crops for home consumption.⁸ Approximately 98% of cultivated land is rain-fed, exposing farmers to significant climate-related food security risk. Only 4% of cultivated land is devoted to cash crops, such as coffee or tea, while 67% of cultivated land is dedicated to the production of food crops.⁹

The agricultural sector faces many ongoing challenges, one of which is that agriculture is a low-input activity that uses no mechanization and relies on very few inputs because most farmers cannot afford the investment necessary to intensify production.¹⁰ In 2008 only 16% of households purchased inorganic fertilizers and only 10% of households purchased improved seeds, while 75% purchased traditional seeds.¹¹ Labor and farm equipment, like hoes and shovels, are the most

1 NISR (2012). *Population and Housing Census, 2012*. National Institute of Statistics of Rwanda. Kigali.

2 NISR (2014). *Gross Domestic Product (GDP); First Quarter, 2014*. National Institute of Statistics of Rwanda. Kigali

3 Habiya mbere, T., Mahundaza, J., Mpambara, A., Mulisa, A., Nyakurama, R., Ochola, W. O., et al. (2009). *Rwanda State of Environment and Outlook*. Kigali: REMA.

4 Habiya mbere, T., Mahundaza, J., Mpambara, A., Mulisa, A., Nyakurama, R., Ochola, W. O., et al. (2009). *Rwanda State of Environment and Outlook*. Kigali: REMA.

5 Habiya mbere, T., Mahundaza, J., Mpambara, A., Mulisa, A., Nyakurama, R., Ochola, W. O., et al. (2009). *Rwanda State of Environment and Outlook*. Kigali: REMA.

6 Republic of Rwanda Ministry of Lands, Environment, Forestry, Water and Mines. (2003). *National Environmental Policy 2003*. Kigali: Ministry of Lands, Environment, Forestry, Water and Mines.

7 Habiya mbere, T., Mahundaza, J., Mpambara, A., Mulisa, A., Nyakurama, R., Ochola, W. O., et al. (2009). *Rwanda State of Environment and Outlook*. Kigali: REMA.

8 NIS. (2008). *National Agricultural Survey 2008*. National Institute of Statistics Rwanda. Kigali: National Institute of Statistics Rwanda.

9 NIS. (2008). *National Agricultural Survey 2008*. National Institute of Statistics Rwanda. Kigali: National Institute of Statistics Rwanda.

10 Habiya mbere, T., Mahundaza, J., Mpambara, A., Mulisa, A., Nyakurama, R., Ochola, W. O., et al. (2009). *Rwanda State of Environment and Outlook*. Kigali: REMA.

11 NIS. (2008). *National Agricultural Survey 2008*. National Institute of Statistics Rwanda. Kigali: National Institute of Statistics Rwanda.

costly farming inputs besides land.¹² As Figure 1 shows, these issues are especially problematic as population pressures continue to increase demand for land while reducing the average plot size at the same time.

The subsistence nature of agricultural production also drives farmers to cultivate continuously, which depletes soil nutrients and reduces future crops yields. Cultivating steep slopes with inadequate ground cover to prevent erosion exacerbates the problem. The FAO estimated that as much as 40% of cultivated land in Rwanda is at risk of severe erosion and requires anti-erosion investments before cultivation begins. Some reports have estimated that as much as 10 tons of soil is lost per hectare each year, flowing directly into rivers and streams that are not adequately protected.¹³ Like intensification, farmers lack the resources to invest in erosion prevention measures.

Rwanda's efforts to reduce poverty are affected by high dependence on agriculture, especially when combined with climate change, declining plot sizes, and limited investment in intensification and erosion prevention.¹⁵ In fact poor or eroded soils and drought are cited as the primary causes of on-farm poverty in Rwanda after lack of land.¹⁶

1.3.2 Forest resources in Rwanda

The total area of Rwanda's forest cover is about 686,636 ha, representing 28.8% of the total country land.¹⁷ This includes about 258,067 ha of natural forest cover (37.6%) and 428,569 (62.4%) of forest plantations.¹⁸ The forest cover of Rwanda has been shaped by the country's food and energy needs in recent years. The area of natural forests inside of national parks and forest reserves has declined since 1990, largely as a result of increased demand for agricultural land and fuel wood plantations.¹⁹ The government has protected the remaining areas of intact natural forest and has even led efforts to increase their size through afforestation activities.

12 NIS. (2008). *National Agricultural Survey 2008*. National Institute of Statistics Rwanda. Kigali: National Institute of Statistics Rwanda

13 Habiyaambere, T., Mahundaza, J., Mpambara, A., Mulisa, A., Nyakurama, R., Ochola, W. O., et al. (2009). *Rwanda State of Environment and Outlook*. Kigali: REMA.

14 The Integrated Household Living Conditions Survey (EICV) was a living standards survey conducted by the National Institute of Statistics of Rwanda in 2000 (EICV1), 2005 (EICV2), and 2010 (EICV3), to monitor poverty and living conditions. The survey methodology has changed little over its 10 years, making it ideal for monitoring changes in the country.

15 Institute of Policy Analysis and Research - Rwanda. (2009). *Rwandan Agricultural Sector Situational Analysis*. Kigali: Institute of Policy Analysis and Research - Rwanda.

16 Habiyaambere, T., Mahundaza, J., Mpambara, A., Mulisa, A., Nyakurama, R., Ochola, W. O., et al. (2009). *Rwanda State of Environment and Outlook*. Kigali: REMA.

17 MINERENA (2014). *Annual report*. Kigali

18 MINERENA (2014). *Annual report*. Kigali

19 Food and Agricultural Organization of the United Nations. (2006). *Global Forest Resources Assessment 2005*. Food and Agricultural Organization of the United Nations. Rome: Food and Agricultural Organization of the United Nations.

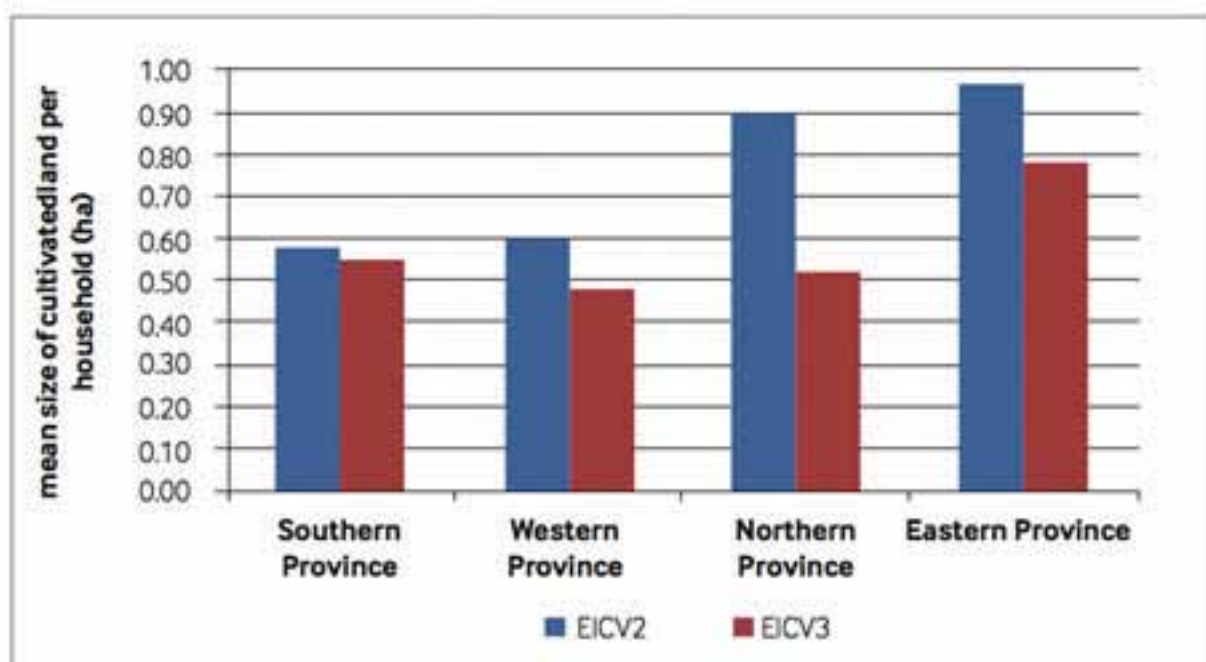


Figure 1: Average size of cultivated land per household (Ha) for 2005 (EICV2) and 2010 (EICV3)¹⁴

While the expansion of plantations has been necessary to meet demand for energy and timber, it is believed that most plantations are inefficient and the same yield could be achieved with less land through improved management practices.²⁰

1.4 Vision 2020

Rwanda's Vision 2020 document provides an outline of how the country plans to address its environmental, social, and economic challenges and become a middle-income country by 2020. Vision 2020 is the result of a national consultative process started in 1998 to clearly define the future goals of Rwanda.²¹ Vision 2020 is based on six pillars that are designed to overcome barriers to growth:

1. Good governance and a capable state
2. Human resource development and a knowledge based economy
3. A private sector-led economy
4. Infrastructure development
5. Productive and Market Oriented Agriculture
6. Regional and International Economic integration

Each pillar is evaluated against a list of indicators measuring the country's progress towards overcoming the challenges Vision 2020 is designed to address.

The midterm strategy EDPRS²² has been designed to pave the way towards the vision 2020. Now it is in its second phase, the Rwanda's EDPRS2 2013-2018 retains forestry as a main concern in recognition of its prime contribution to the GDP. This will be achieved through increased job creation in forestry from 0.3% to 0.5% by 2017, and reduction in the use of biomass energy through the use of improved stoves and improved kilns to produce 75% of charcoal by year 2017. EDPRS2 2013-2018 supports the previous target of increasing forest cover to 23.5% by 2012 in EPRS1 and reset a new indicator to reach 30% by 2018. In addition, EDPRS2 2013-2018 recommends for sustainable management of forest biodiversity and natural ecosystems through protection and maintenance of 10% of the existing country land covered by Natural Forests and Savannah forests, and reduction of wood energy consumption from 86.3 % to 50% by 2020 as reflected in the 2020 Vision targets²³.

The Government of Rwanda has been working with national and international partners to implement forestry programs that contribute towards meeting the EDPRS2 and Vision 2020 goals. For example, the Belgian Development Agency is working with the Rwandan Natural Resource Authority (RNRA) to reduce deforestation and poverty by improving the management of existing woodlots and reforestation

20 Belgian Development Agency . (2012). Support Program to the reforestation in 9 districts of the northern and western provinces of Rwanda. Belgian Development Agency . Belgian Development Agency .

21 Republic of Rwanda Ministry of Lands, Environment, Forestry, Water and Mines . (2003). *National Environmental Policy 2003*. Kigali: Ministry of Lands, Environment, Forestry, Water and Mines.

22 GOVERNMENT OF RWANDA (2013). Economic development and poverty reduction strategy 2013 – 2018. Shaping our future. Kigali

23 MINIRENA (2013). *Five year strategic plan for the environment and natural resources sector - 2014 – 2018*. Kigali

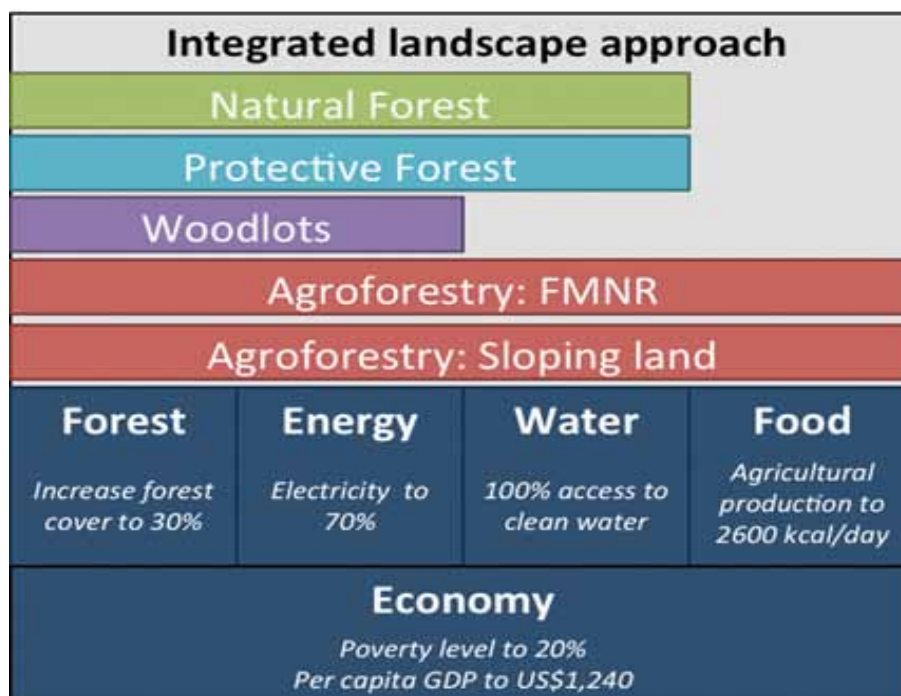


Figure 2: FLR interventions and corresponding Vision 2020 indicators

degraded and sensitive land.²⁴ The World Bank is working with the Rwanda Environment Management Authority (REMA) as part of the Landscape Approach to Forest Restoration and Conservation (LAFREC) project to develop sustainable forest management objectives for the Gishwati Forest landscape. NGOs such as World Vision are also working with partners inside of the country to address environmental, social, and economic challenges in the eastern part of Rwanda by selectively raising naturally occurring trees that have economic value.

These and many of the projects in the forest sector are taking steps in the right direction to enable Rwanda achieve its development goals. To strengthen these efforts, more integrated approaches are needed because the challenges facing forest resources in Rwanda cut across multiple pillars and institutions and also impact diverse groups of stakeholders. Forest landscape restoration (FLR) is an integrated approach for addressing environmental, social, and economic challenges that involve multiple institutions and stakeholders. By taking a landscape perspective, FLR brings stakeholders and institutions together to overcome challenges by designing more efficient land-use plans. This approach is particularly relevant in Rwanda where landscapes are used for many different purposes, are governed by many different institutions, and have many different stakeholder groups.

Unlike single intervention projects, which target one land use, the interventions of the Forest Landscape Restoration approach target multiple land uses and contribute to several pillars of Vision 2020 as measured through the indicators represented in Figure 2.

- Restoring degraded land using a combination of natural forests and protective forests would contribute directly towards meeting the country's goals of increasing forest cover to 30% and providing 100% access to clean water by reducing erosion and increasing the water filtration services of forests.
- Improving the management of existing woodlots in conjunction with restoring forests would reduce pressure to collect fuel wood from natural and protective forests and improve energy security.
- Using agroforestry on existing agricultural land would improve crop production, reduce erosion (thereby increasing access to clean water), and reduce pressure on natural forests to supply fuel wood.

By taking a landscape approach to restoration, the productivity of degraded landscapes can be recovered in the fullest possible way.

²⁴ Belgian Development Agency . (2012). Support Program to the reforestation in 9 districts of the northern and western provinces of Rwanda. Belgian Development Agency . Belgian Development Agency .

2. Restoration Opportunities Assessment Methodology

Implementation of Rwanda's "border to border" restoration commitment requires a systematic and rigorous assessment and quantification of restoration opportunities available. IUCN and WRI have developed such a methodology "Restoration Opportunities Assessment Methodology" (ROAM). Figure 3 shows the process through which ROAM is used as a tool for national and subnational restoration opportunities assessment. For example, after the environmental challenges, national priorities, and landscape intervention options have been identified, ROAM uses geospatial, economic,

and Rapid Restoration Diagnostic analyses to map, quantify, and assess the institutional readiness of areas with opportunities for restoration.

In Rwanda, the Department of Forestry and Nature Conservation professionals of RNRA in partnership with IUCN and WRI experts worked as a team. This team used ROAM as a tool to identify and map areas and landscapes with the most urgent restoration need, where benefits are most immediate and where success is more likely. Relevant governmental and non-governmental stakeholders currently involved

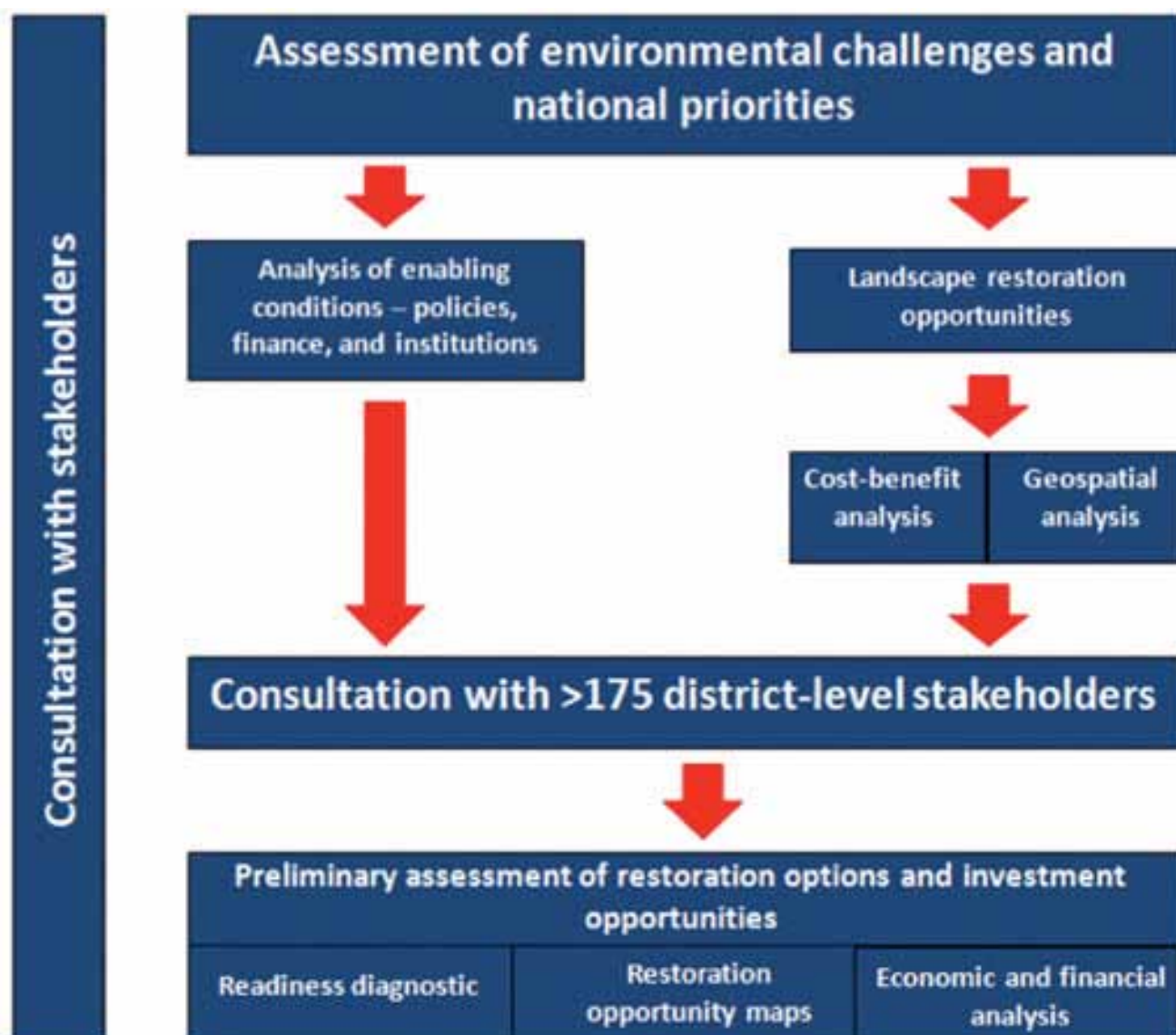


Figure 3: Restoration Opportunities Assessment Methodology

in restoration activities in Rwanda were invited to contribute and critique ROAM analyses during a number of consultative workshops held across each of the five provinces. More than one hundred District Officials and other key stakeholders from civil society attended these workshops. The details of ROAM analyses for Rwanda are provided in the following sections.

2.1 Geospatial analysis

To quantify the areas of degraded land use that are opportunity areas for forest and landscape restoration, a geospatial analysis was performed incorporating more than a dozen national datasets representing the geographic and topographic features of Rwanda. Datasets including elevation, slope, land cover, forest cover, water bodies, parks and reserves, and administrative areas, were consolidated into a geographic information system (GIS), where criteria associated with each type of potential restoration intervention were applied. These criteria represent the means to identify the areas best suited for implementing the intervention and are discussed in Appendix 1. The datasets representing these criteria were overlaid and combined with each other, and areas where they intersected were identified as opportunity areas. This process was replicated for each of the restoration interventions to create maps of opportunity areas. Areas were summarized at various administrative levels (e.g., province and district) to convey the level of opportunity within an applicable context.

2.2 Economic and financial analysis

The economic analysis modeled the costs and benefits of degraded and restored land uses using a return-on-investment (ROI)²⁵ and a policy framework²⁶. The analysis identified restoration transitions for each degraded land use and calculated the expected rate of return for each transition from the perspective of private landowners. The analysis modelled crop and timber yields, erosion, and carbon sequestration for each degraded land use and restoration intervention at one-hectare resolution using nationally representative data. In order to estimate the costs and benefits of restoring degraded land, a model of each land use and restoration intervention was created for representative parcels by combining the results from the ecological modeling with market prices and an enterprise budget that accounted for the direct and indirect financial costs

of restoring the land.²⁷ The benefits of the transitions were defined as private or public goods depending on whether private landowners or the public at large received them. The results of this classification were used to identify policies that can encourage private landowners to adopt restorative land uses. Repeated random sampling was used to account for ecological uncertainty by creating data representing a range of ecological outcomes for each land use and mimicking the likely range of outcomes that would be observed. The financial and non-financial value of each restoration transition was calculated by modeling the ecosystem services associated with each degraded land use and restoration transition using simulated mean-annual-increments, carbon sequestration, precipitation values, and crop yields.²⁸

2.3 Rapid restoration diagnostic

There are a number of factors that when present increase the likelihood that forest landscape restoration will successfully occur. In order to assess the state of these “key success factors” a “Rapid Restoration Diagnostic” developed by WRI and IUCN was used to identify which success factors already exist and which are currently missing (or partially missing) within landscapes being considered for restoration. The assessment team conducted desk research, key informant interviews and workshop sessions to better understand the situation related to the key success factors for forest landscape restoration in Rwanda. First, an assessment was conducted to identify the relevant governmental and non-governmental institutional stakeholders that are currently involved in restoration activities. Stakeholders were consulted to produce preliminary results of the assessment of key success factors for forest landscape restoration in Rwanda.

2.4 Limitations

While the data incorporated into this opportunity assessment are relatively robust, the analysis is inherently limited by the quality and accuracy of the available data, as well as the criteria applied to define potential restoration interventions, which are by necessity broadly defined and may not apply to the variety of unique on-the-ground situations. Therefore, it is important to note that the results of the national-level opportunity assessment are meant to convey a sense of the scale of the opportunity, while a more detailed local-level analysis is a vital next step for identifying the appropriate restoration interventions for a particular location.

25 Goldstein *et al.* (2008) ‘Using return-on-investment to guide restoration: a case study from Hawaii’ *Conservation letters*.

26 Pannell (2008) ‘Public Benefits, Private Benefits, and Policy Mechanism Choice for Land-Use Change for Environmental Benefits’ *Land Economics*.

27 An enterprise budget is a written objective statement for a crop or livestock production activity that lists the production goals, management activities, resource requirements, and economic returns of a farm enterprise.

28 Financial values reflect the revenue earned through the sale of primary production, such as crops, fuel wood, or timber. Non-financial values reflect benefits received

3. Current land uses, restoration interventions, and restoration transitions

3.1 Current land uses

The assessment team identified three degraded land uses that could benefit from restoration through the strategic introduction of trees and management practices. Relevant governmental and non-governmental institutional stakeholders that are currently involved in restoration activities in Rwanda were consulted in producing the preliminary list of degraded land uses. Through the consultative workshops, the following land uses were identified as benefiting most from restoration:

1. Traditional agriculture,
2. Poorly managed woodlots and timber plantations, and
3. Deforested land.

The workshop participants also identified the restoration interventions and transitions best suited to restoring these degraded lands, as described in more detail in the following sections.

3.2 Restoration interventions

Five broad restoration interventions that could be used to improve the ecological and economic productivity of degraded land uses are:

- Agroforestry on steep sloping land in conjunction with other soil conservation measures such as radical and progressive terracing
- Agroforestry on flat or gently sloping land, including those areas principally managed as pasture and rangelands
- Improved silviculture and rehabilitation of existing, sub-optimally managed woodlots and plantations, including very small (<0.5 hectare) areas
- Protection and restoration of existing areas of natural forests, mainly in or around protected areas but also extending to small isolated fragments
- Establishment or improvement of protective forests on important and sensitive sites such as ridge tops with steep (20-55%) and very steep sloping land (>55%), riparian zones and wetland buffer zones and margins

3.3 Restoration transitions

Based on the current land uses and proposed restoration interventions, the following restoration transitions were identified:

1. Traditional agriculture ➡ Agroforestry on steep sloping land and flat or gently sloping land
2. Poorly managed eucalyptus woodlots and plantations ➡ Improved silviculture and rehabilitation of existing, sub-optimally managed woodlots, spacing only
3. Poorly managed eucalyptus woodlots and plantations ➡ Improved silviculture and rehabilitation of existing, sub-optimally managed woodlots with spacing and erosion and fire-prevention best practices
4. Deforested land ➡ Protection and restoration of existing areas of natural forests
5. Deforested land ➡ Establishment or improvement of protective forests on important and sensitive sites

The financial and non-financial value of each restoration transition was calculated by modeling the ecosystem services associated with each degraded land use and restoration transition using simulated mean-annual-increments, carbon sequestration, precipitation values, and crop yields.²⁹

²⁹ Financial values reflect the revenue earned through the sale of primary production, such as crops, fuel wood, or timber. Non-financial values reflect benefits received

4. Findings

4.1 Geospatial Analysis

4.1.1 Agroforestry

The agroforestry interventions focus on incorporating trees into agricultural landscapes, including lands being used for cultivating crops and pastures for raising livestock. Two types of agroforestry interventions were assessed as part of the geospatial analysis and included identifying areas for new agroforestry on: 1) steeply sloping land; and 2) flat or gently sloping land, including those principally managed as pasture or rangelands. The agroforestry intervention is divided into two categories because the objectives and implementation are different for each type of agricultural landscape. Agroforestry on steeply sloping land is aimed at reducing erosion on lands that are highly susceptible to soil loss, and is implemented mainly by establishing terraces on

hillsides to stabilize the soil and fertility. On flat or gently sloping cultivated land, the goal of agroforestry is mainly to integrate trees with crops to improve soil fertility and water quality. In the case of pasture and rangeland, agroforestry is aimed at providing shade for livestock and increasing the availability of trees for fuel wood and other household uses, and is most readily achieved through farmer-managed natural regeneration of natural forests. Figure 4 illustrates the opportunity areas for agroforestry on steeply sloping land and Figure 5 illustrates opportunity areas for agroforestry on flat and gently sloping land. Table 1 summarizes the areas for both types of agroforestry interventions at the provincial level.

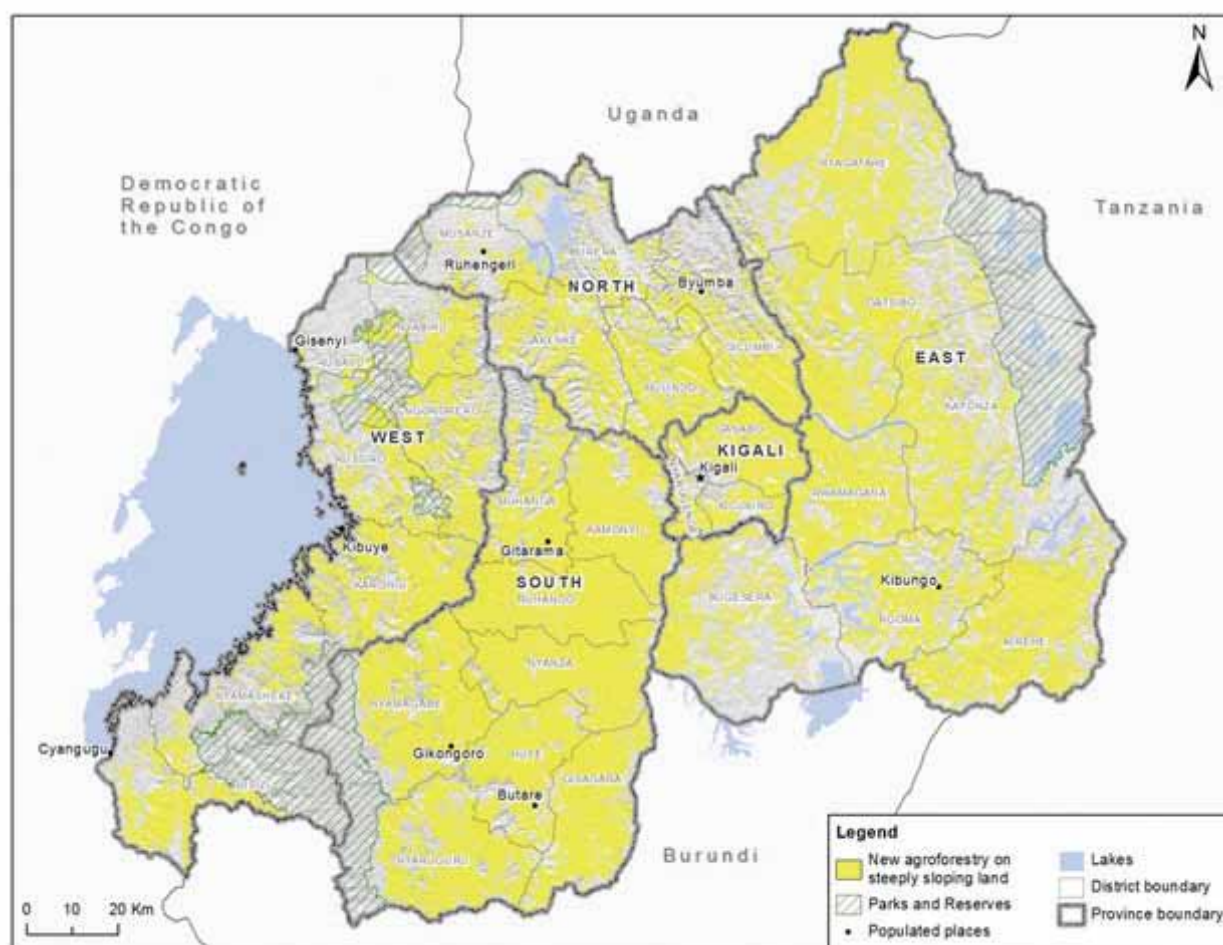


Figure 4: Opportunity areas for new agroforestry areas on steeply sloping lands (3-30 degrees/5-55% incline).

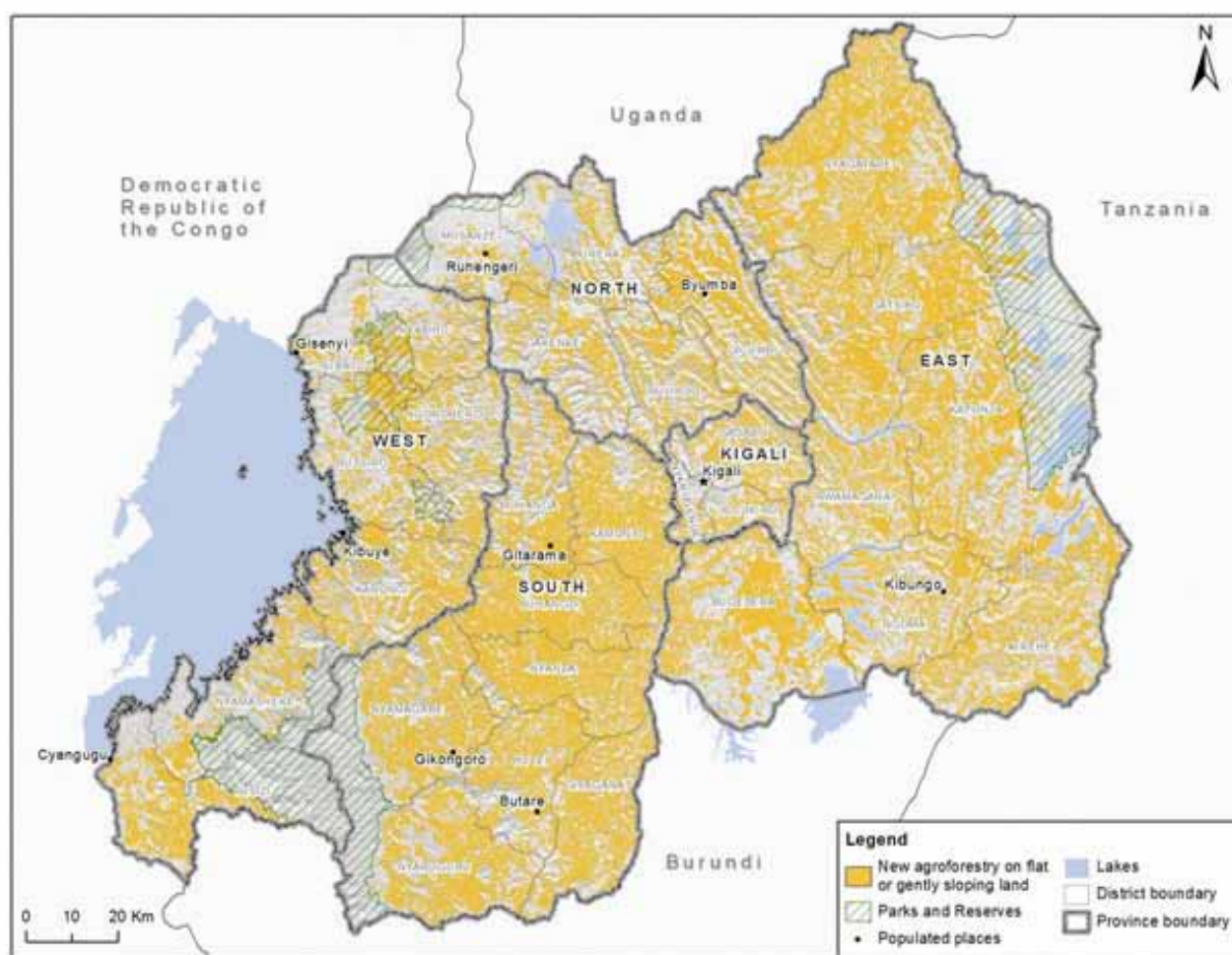


Figure 5: Opportunity areas for new agroforestry on flat and gently sloping lands.

Table 1. Opportunity areas for agroforestry interventions by province.

Intervention	Province						National Total
	Unit	East	West	North	South	Kigali	
New agroforestry on steeply sloping land	Area (ha)	272,723	87,183	63,683	250,504	31,069	705,162
New agroforestry on flat and gently sloping land	Area (ha)	231,855	45,732	40,209	78,410	9,108	405,314

In terms of scale, agroforestry represents the greatest opportunity for restoration across Rwanda. Of the 2.4 million hectares of land in the country, more than 45% (1.1 million hectares) is potentially suitable for one of the two types of agroforestry identified here. Implementing agroforestry on steeper sloping land offers the greatest opportunity of the two agroforestry interventions nationally, with approximately 30% of the country (705,000

hectares) potentially suitable. On a provincial level, the greatest opportunity for agroforestry exists in the East, South Provinces and Kigali City, where, respectively, approximately 505,000 hectares (56% of the total area of the East province), 104,000 hectares (55% of the South province), and 40,000 hectares (55% of the Kigali city) are potentially suitable for either of the agroforestry interventions.

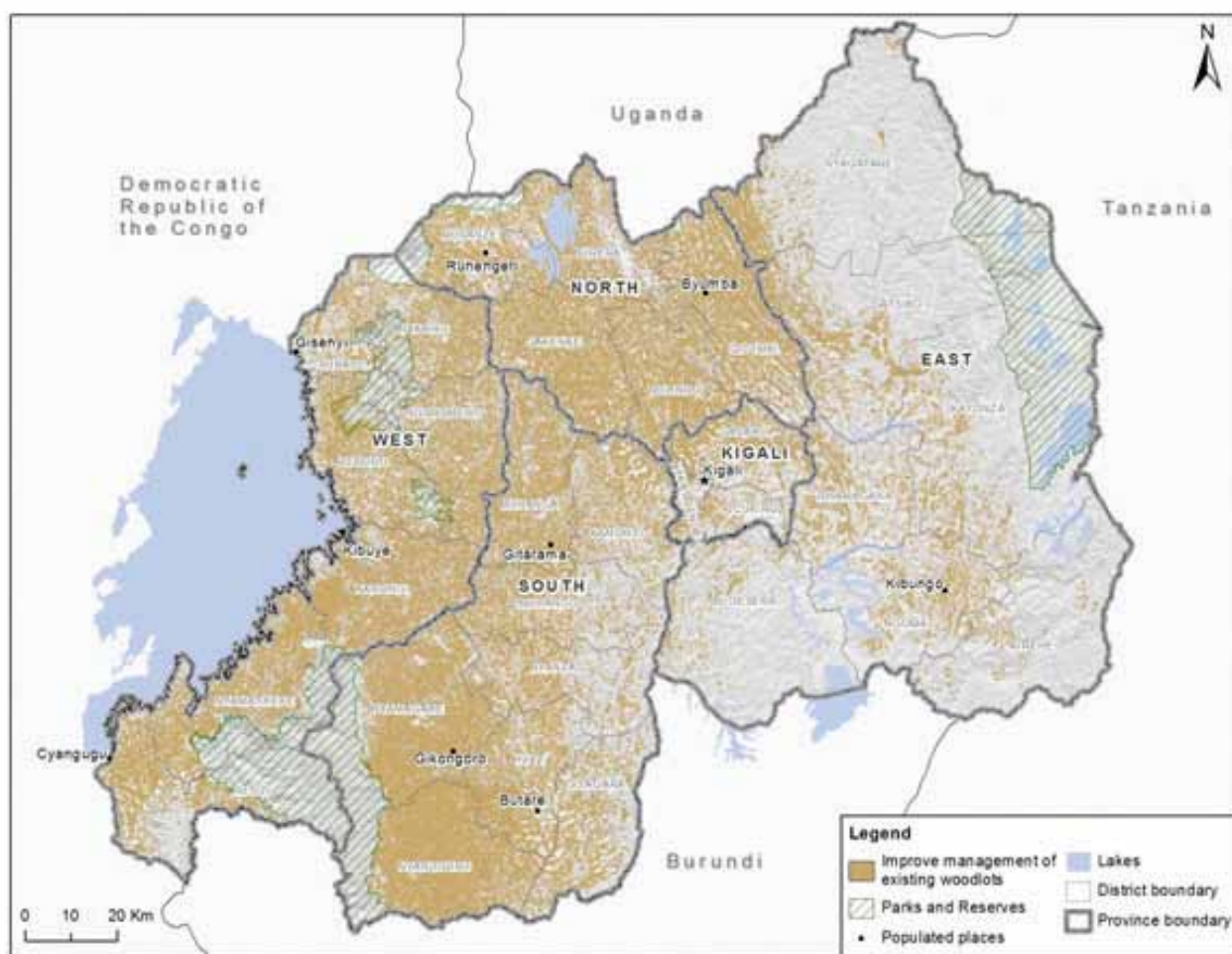


Figure 6: Opportunity areas for improving management of eucalyptus plots.

Table 2. Opportunity areas for eucalyptus interventions by province.

Intervention	Province						National Total
	Unit	East	West	North	South	Kigali	
Improve management of existing woodlots	Area (ha)	32,816	62,868	54,173	96,343	9,730	255,930

4.1.2 Improved woodlot and timber plantation management (eucalyptus and pine)

Improved management of woodlot and timber plantations interventions focuses on improving and intensifying fuel wood and timber production in Rwanda. While two categories of woodlot and plantation management interventions were considered as part of this study (i.e., improved management through spacing only and improved management through spacing + best practices) the geospatial analysis identifies the opportunity areas for both categories collectively. However, given

that eucalyptus and pine (*Pinus*) are the primary tree species harvested for fuel wood and timber in Rwanda we analyzed the planted area of each species separately.

Figure 6 illustrates the opportunity areas to improve the management of eucalyptus woodlots and plantations. Approximately 11% of the total land area of Rwanda (256,000 hectares) is potentially suitable for improved management of eucalyptus woodlots and plantations. The greatest opportunities are in the North and South provinces. Approximately 17% (54,000 hectares) of the North province and 16% (96,000 hectares) of the South province are potentially suitable.

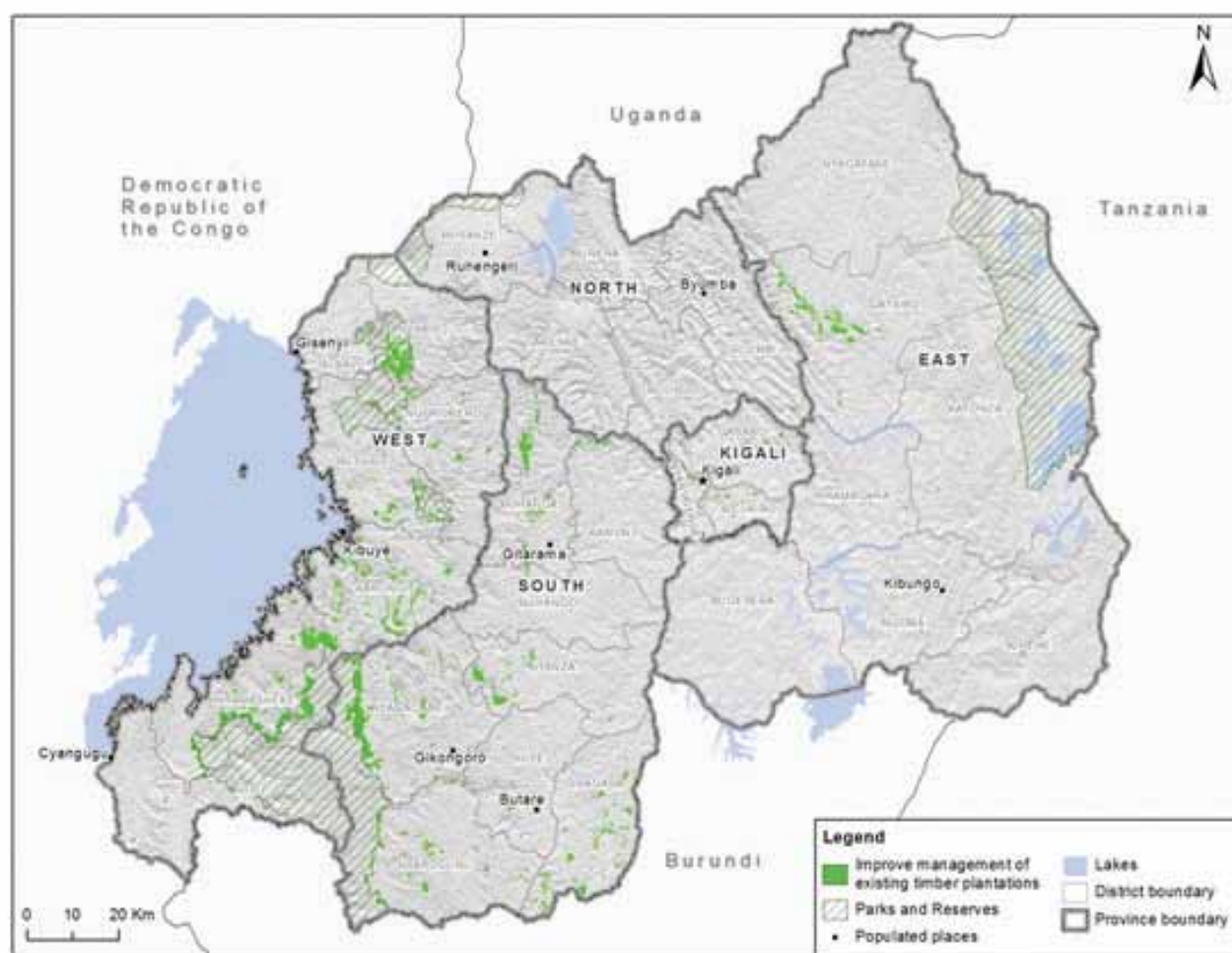


Figure 7: Opportunity areas for improved management of existing timber plantations (pine).

Table 3. Opportunity area for pine plantation intervention by province.

Intervention	Province						National Total
	Unit	East	West	North	South	Kigali	
Improve management of existing timber plantations	Area (ha)	1,214	8,373	189	7,881	193	17,849

To assess the area planted with pine we used the national dataset of forest cover by species and quantified the opportunity area for improved management of existing pine plantations as the total area of pine plots. Figure 7 illustrates the opportunity areas for the pine plantation intervention and Table 3 summarizes the area at the provincial level. The opportunity area for improved management of pine plantations is dispersed relatively widely across Rwanda, with the greatest concentration in the West and South provinces. Approximately 2% of the West province and 1% of the South province (8,000 hectares in each province) is potentially suitable for this type of restoration intervention.

4.1.3 Protection and restoration of natural forests

Natural regeneration interventions are designed to capitalize on Rwanda's areas of intact natural forest to both expand and restore these ecosystems that are particularly important for their cultural and tourism value. Improving and expanding the natural forests of Gishwati, Mukura, and Nyungwe would improve habitat for wildlife such as chimpanzees, which can attract greater tourism revenues. Two types of natural forest interventions were assessed as part of the geospatial analysis: 1) establishing a

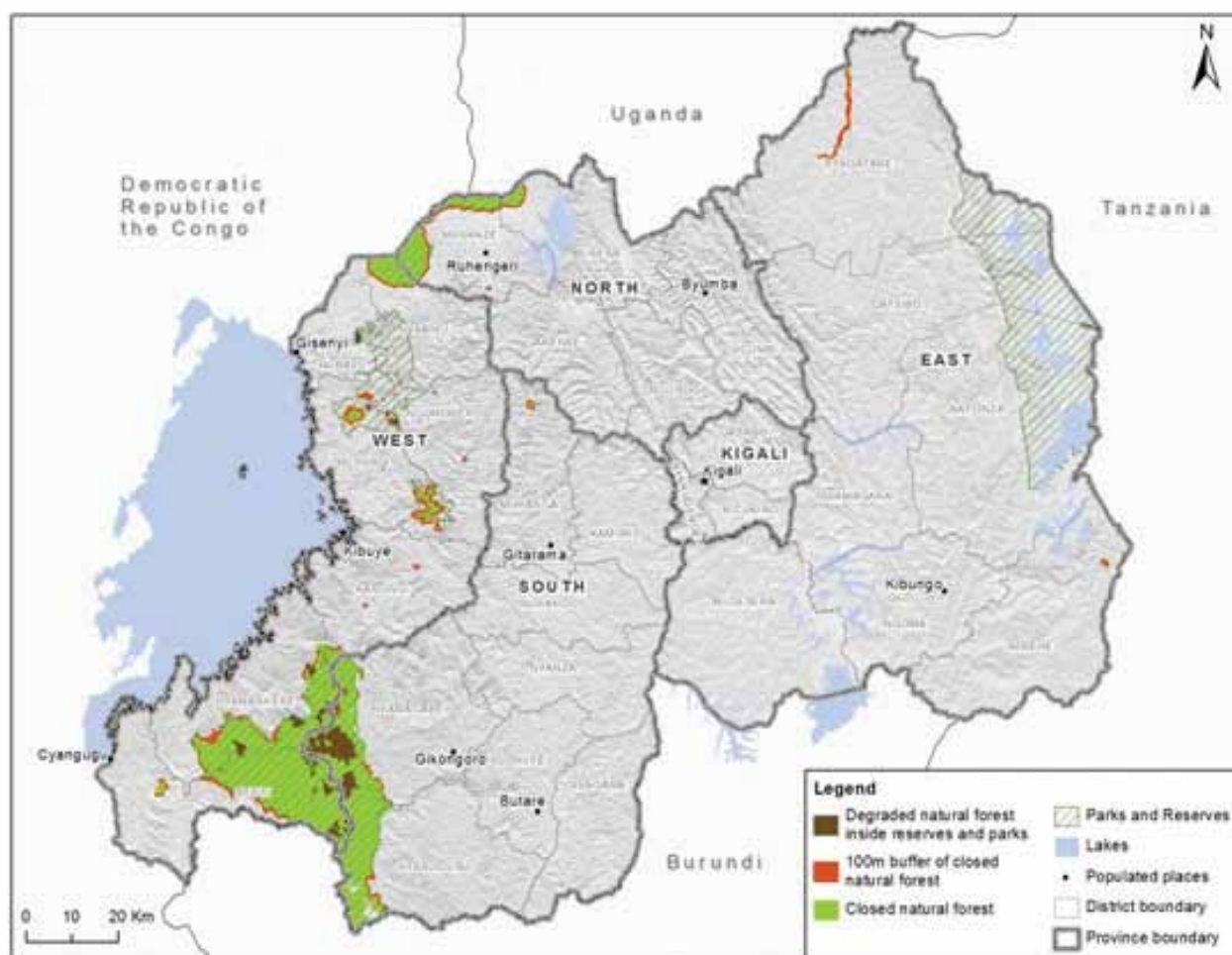


Figure 8: Opportunity areas for natural forest interventions, which includes 100m buffer of closed natural forest and restoring degraded forest inside reserves and national parks.

Table 4. Opportunity areas for natural forest restoration interventions by province.

Intervention	Province						National Total
	Unit	East	West	North	South	Kigali	
100m buffer of closed natural forest	Area (ha)	557	2,085	499	315	-	3,456
Restore degraded forest in parks/reserves	Area (ha)	-	3,629	-	6,848	-	10,477

100-m buffer of newly planted forest around existing closed natural forest; and 2) restoring degraded natural forest inside reserves and national parks. For the 'buffer of closed natural forest' intervention, a national dataset of forest cover was used to extract areas defined in the dataset as closed natural forest.

Figure 7 illustrates the opportunity areas for each type of natural forest intervention and summarizes these areas at the provincial level. Restoring natural forest through buffers and enrichment planting of degraded forests inside parks and

reserves represents a relatively small and localized opportunity in terms of scale, but is vitally important for maintaining these ecosystems and the services they provide. Approximately 1% of the total land area of the country is potentially suitable for the two natural forest interventions. The greatest opportunity for establishing buffers around closed natural forest exists in the West province where the Gishwati and Mukura forests and much of the Nyungwe forest are located. The greatest opportunity for restoring degraded natural forest exists in the West and South provinces inside the Nyungwe forest reserve.

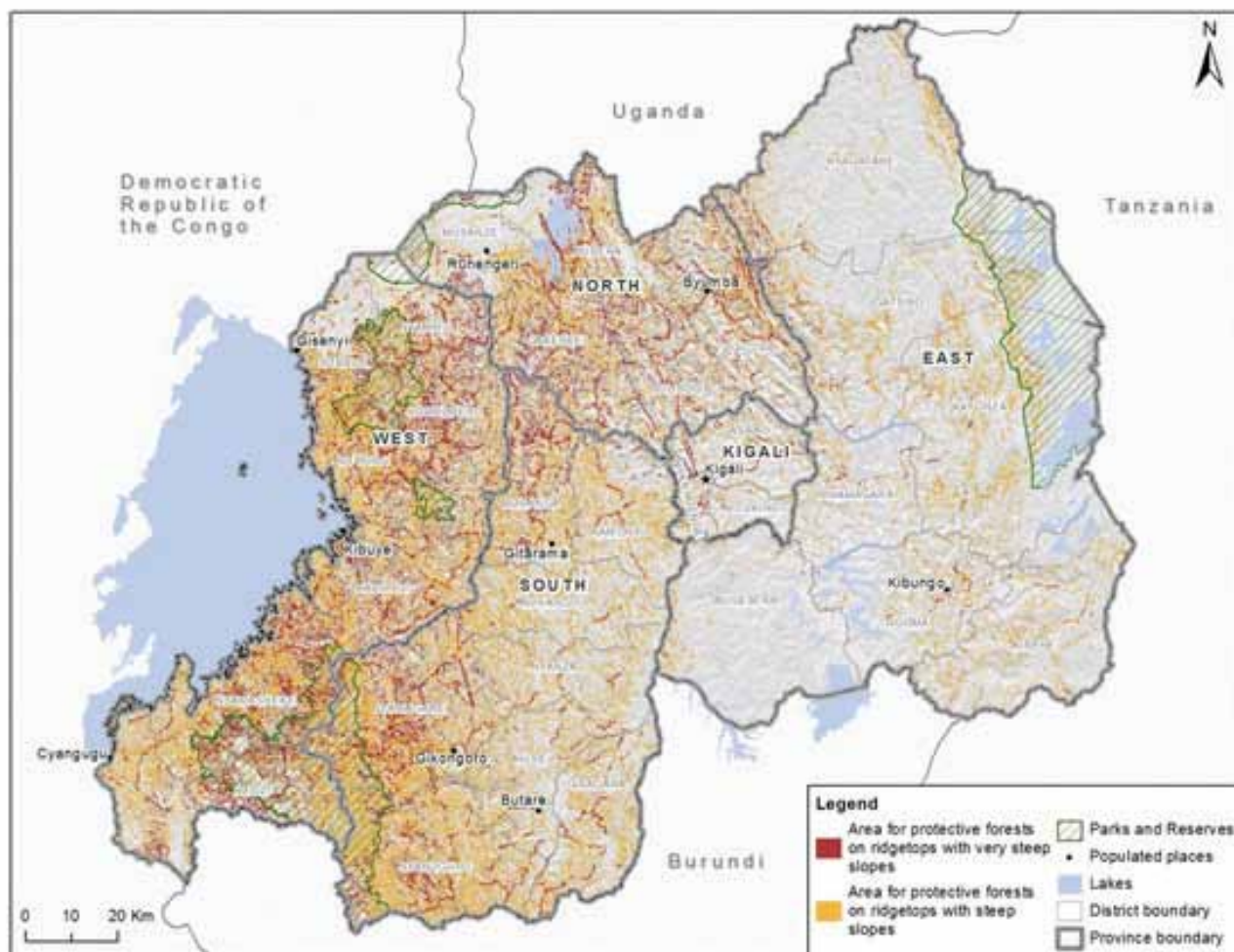


Figure 9: Opportunity areas for the following protective forest interventions: reforesting ridgetops with very steep (>30°/55% incline) and steep (12-30°/20-55% incline) slopes.

4.1.4 Protective Forests

The protective forest interventions aim to prevent erosion on the many steeply-sloped ridges and hillsides and to protect rivers and wetlands from the harmful effects of erosion by creating buffer zones of natural forest around these important water bodies. The protective forest interventions were divided into five categories: 1) protective forests on ridge tops with very steep slopes, defined as slopes greater than 30 degrees/55% incline; and 2) protective forests on ridge tops with steep slopes, defined as slopes between 12 and 30 degrees/20-55% incline; and 3) planting native tree species to create 20-m buffers of non-forested river courses; 4) replacing existing eucalyptus with native tree species within 20-m of river courses; and 5) planting native species as buffers within 50-m of wetlands. For the geospatial analysis of opportunity areas, data on elevation, slope, and forest cover was integrated in GIS.

Figures 9-10 illustrate the opportunity areas for the protective forest intervention and Table 5 summarizes these areas at the provincial level. Given the mountainous landscapes that dominate western

and central Rwanda, not surprisingly the opportunity area for protective forest interventions on ridge tops is concentrated in the North, South, and West provinces. In total, approximately 42,000 hectares (2% of Rwanda's total area) is potentially suitable for reforesting ridge tops to stabilize the soil and mitigate erosion. The greatest opportunity for reforestation on ridge tops with steep or very steep slopes exists in the West province, where nearly 15,000 hectares are potentially suitable (3% of the total province area). In the South province, more than 14,000 hectares are potentially suitable (2% of the province area) and in the North province, the opportunity area is nearly 7,000 hectares (2% of the province area).

While the total area for protective forest interventions associated with watershed management appears relatively small nationally, the extensive networks of rivers and streams as well as wetlands throughout the country represent an important opportunity for stabilizing the adjacent soil and mitigating the flow of sediment into these critical water bodies. Establishing 20-m buffers of native tree species along rivers and streams in non-forested areas or to replace existing eucalyptus stands represents a total

Table 5. Opportunity areas for protective forest interventions by province.

Intervention	Province						National Total
	Unit	East	West	North	South	Kigali	
Protective forests on ridgetops with very steep slopes (>30°/55%)	Area (ha)	462	4,968	2,374	2,762	180	10,745
Protective forests on ridgetops with steep slopes (12-30°/20-55%)	Area (ha)	5,702	9,842	4,385	11,266	501	31,695
20-m riparian buffer – replace eucalyptus with native species	Area (ha)	151	873	592	1,454	82	3,152
	Length (km)	35	207	146	378	22	788
20-m riparian buffer – reforest non-forested areas	Area (ha)	3,861	4,802	3,334	6,873	716	19,586
	Length (km)	997	1,141	834	1,731	159	4,863
50-m buffer of wetland perimeters	Area (ha)	23,337	3,522	5,052	22,844	2,606	57,362

opportunity area of about 23,000 hectares and 1% of the total area of Rwanda. The level of opportunity is dispersed relatively evenly across all five provinces, with a slightly higher concentration in the South province. Nationally, approximately 57,000 hectares and 2% of the total area of Rwanda is potentially suitable for establishing 50-m buffers of native tree species along the perimeters of wetlands. While opportunity for this type of intervention exists in all five provinces, the East and South provinces have the most potentially suitable land, with 3% and 4% of the total land area of each province and 23,000 hectares in each province, respectively.

4.2 Economic and financial analysis

4.2.1 Introduction

The objective of the economic and financial analysis is to calculate the costs and benefits of the restoration transitions identified in Rwanda and use them in return-on-investment (ROI)³⁰ and policy frameworks³¹ to addresses four questions: (1) What are the estimated returns on investment of restoration transitions from the perspective of private landowners? (2) Based on the distribution of private and public benefits produced by transitions that occur on private land, what policies can be used to encourage private landowners to restore degraded land? (3) Where are these opportunities to invest in the restoration value chain? (4) Which restoration transitions store the most carbon for the largest benefit/lowest cost?

30 Goldstein, J. H., Pejchar, L., & Daily, G. C. (2008). Using return-on-investment to guide restoration: a case study from Hawaii. *Conservation letters*, 236-243.

31 Pannell, D. (2008). Public Benefits, Private Benefits, and Policy Mechanism Choice for Land-Use Change for Environmental Benefits. *Land Economics*, 225-240.

The economic analysis models the costs and benefits of degraded and restored land uses. Restoration transitions are identified (e.g. agriculture to agroforestry) for each degraded land use and the net present value and expected rate of return for each transition are calculated. A project time horizons of 20 to 30 years was adopted, which reflect average rotation intervals, and estimate the costs and revenue that each degraded and restored land use would generate during that time. The cost estimates are based on an annual budget of the management activities and material inputs associated with each land use and restoration intervention for a representative one-hectare plot. The economic analysis estimates the costs and benefits of degraded and restored land uses in Rwanda in terms of four primary benefits:

1. Timber yields (private benefit)
2. Crop yields (private benefit)
3. Prevented erosion (public benefit)
4. Carbon sequestration (public benefit)

A benefit is defined as private if exclusively the landowner receives it while a benefit is considered to be public if people other than the land owner (i.e. society) receive the benefit.

The exact amount of benefits generated by each land use is uncertain and expected to vary because it depends on tree growth, precipitation, and tree-crop interactions. To account for this uncertainty, repeated random sampling was used to create data representing a range of ecological outcomes reflecting tree growth and tree-crop interaction for each land use and mimicking the likely range of outcomes that would be observed in Rwanda. The flow of costs and revenues was discounted using a 7% rate of discount, which is the current rate of return on Rwanda's sovereign debt. Sensitivity analysis was also carried out with discount rates between 3% and 25%.

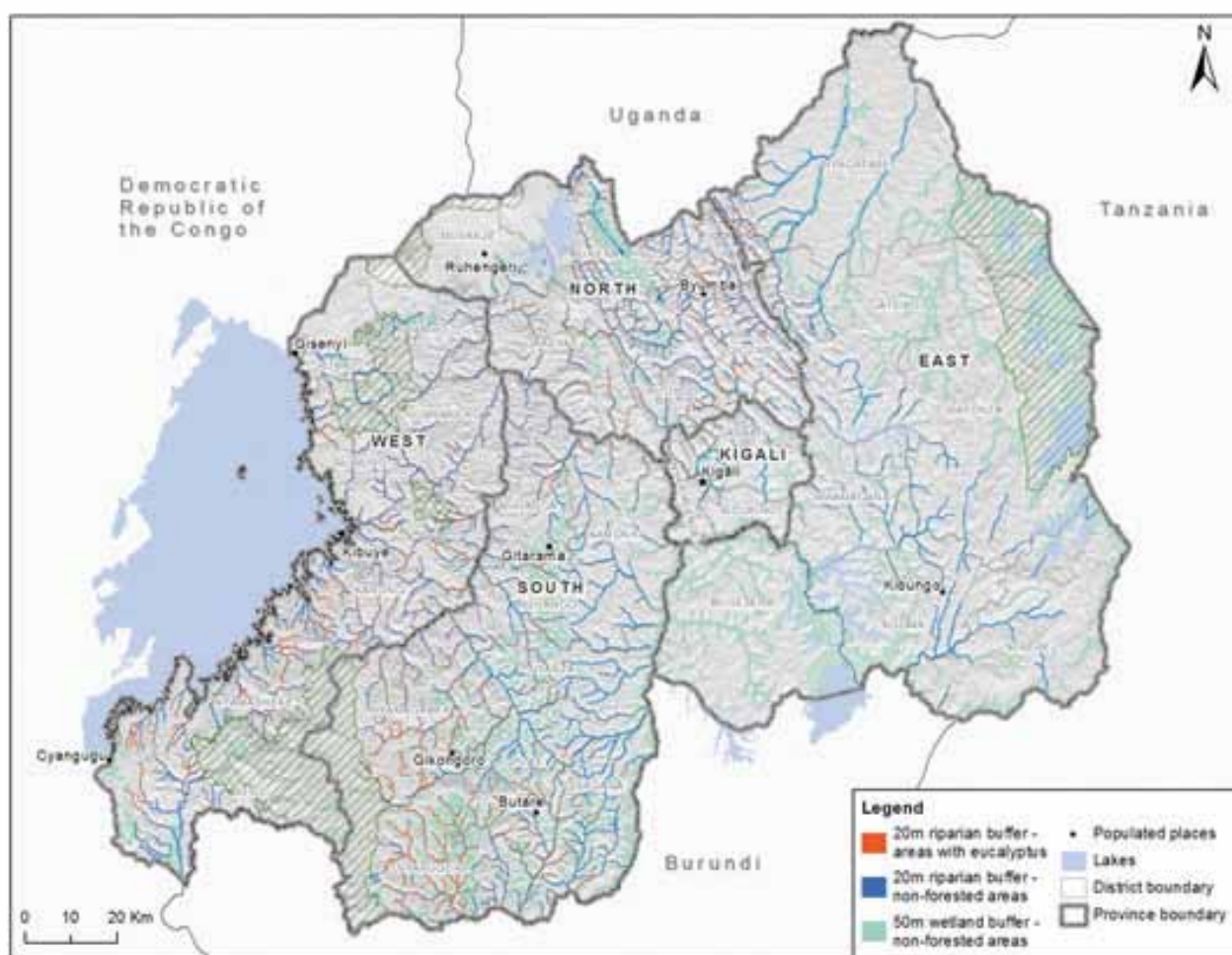


Figure 10: Opportunity areas for the following protective forest interventions: planting native tree species to create 20-m buffers of non-forested river courses; replacing existing eucalyptus with native tree species within 20-m of river courses; and planting native trees species as buffers within 50-m of wetlands.

4.2.2 Net Present Value from private landowner perspective

The net present value (NPV) concept allows various sums of money to be compared over time by discounting values that occur in the future so they are comparable with the current values. For example, RWf 10 received a year from now would have a NPV of RWf 9 assuming the future is discounted at a rate of 10%. The NPV concept simply reflects the fact that people prefer things that happen in the present to events that occur in the future.

The results of the economic model in Table 7 show that in nearly every case, the NPV of restoration transitions are positive from the perspective of private landowners. The restoration transition from agriculture to agroforestry with beans has the highest NPV of all of the restoration interventions, creating RWf 556,749/ha in additional revenue, on average, over a twenty-year period compared to traditional agriculture with beans, which produces an annual revenue of RWf -630,900/ha. Agroforestry with maize creates RWf 873,302/ha of revenue compared to RWf 396,394/ha created by traditional

maize agriculture and can potentially be much larger when growing conditions are favourable. In both cases, the NPV distributions of agroforestry overlap with the NPV distributions of traditional agriculture, suggesting that while the restoration transition will provide a net benefit on average, it may not provide a net benefit in each and every case.

Improving the management of existing eucalyptus woodlots for fuel wood and timber with erosion prevention measures and tighter spacing would create between RWf -85,295 to RWf 386,896 /ha in additional revenue over a twenty-eight-year rotation period, respectively, compared to poorly managed eucalyptus woodlots. The restoration transition with spacing only requires a small amount of additional labour that is easily repaid by the increased timber yield, although variation in timber yields will influence the NPV of the transition. The transition from poorly managed eucalyptus woodlots to improved management with best practices involves a much larger amount of additional labour to establish fire lines and erosion-prevention ditches, yet the increase in timber yield is not enough to compensate for the additional expenses. This transition will only create

Table 6: Net present value of land uses and restoration interventions in Rwanda.

Net Present Value (RWf)	Agroforestry with beans	Traditional agriculture with beans	Agroforestry with maize	Traditional agriculture with maize	Poorly managed woodlots	Improved management of woodlots with spacing only	Improved management of woodlots with best practices	Protective forests	Naturally regenerated forests
Minimum	-484,942	-869,246	-1,444,434	-1,623,191	228,573	298,518	-193,342	-645,202	-367,728
Mean	556,749	-630,900	873,302	396,394	286,077	386,896	-85,295	-627,127	-1,562
Maximum	945,291	111,467	6,582,152	5,788,093	336,996	464,790	9,761	-608,224	366,178

net benefits for landowners under very high growth scenarios and even then, the landowner would have been better off if they had simply improved spacing rather than adopting the full suite of best practices.

The transition from deforested land to natural forest would generate RWf -1,562/ha in NPV over a twenty-year period through the sale of carbon. The sale of carbon from protective forests on ridge tops and steep slopes could offset some of the transition's costs, but the NPV of is still RWf -627,127/ha. The distribution of NPV's for natural forests shows that when high levels of carbon dioxide are sequestered, the transition from deforested land to naturally regenerated forest has the potential to pay for itself through sale of carbon credits on the voluntary market. However, the distribution of NPV's for protective forests shows that even under the most optimistic ecological scenarios, the high costs are difficult to pay for when carbon is the only source of revenue.

4.2.3 Costs of restoration transitions

Figure 11 shows the results from the enterprise budget, which provides cost estimates for each restoration transition. The transition from traditional agriculture to agroforestry is the most costly intervention in the analysis. Over the twenty-year time horizon the transition would cost an estimated RWf 843,600/ha compared to leaving the land in agriculture. Allowing forests to naturally regenerate on deforested and degraded land would cost an estimated RWf 384,000/ha over the course of 30 years. The restoration transition from deforested land to protective forests would cost approximately RWf 762,586/ha. The price is significantly higher than the cost of natural regeneration due to the additional materials and labour that are required to re-establish a forest. Improving the management of poorly managed eucalyptus woodlots would cost between RWf 79,753 and 729,702/ha compared to continuing with existing poor management practices depending on whether restoration improves spacing or involves a suite of best management practices.

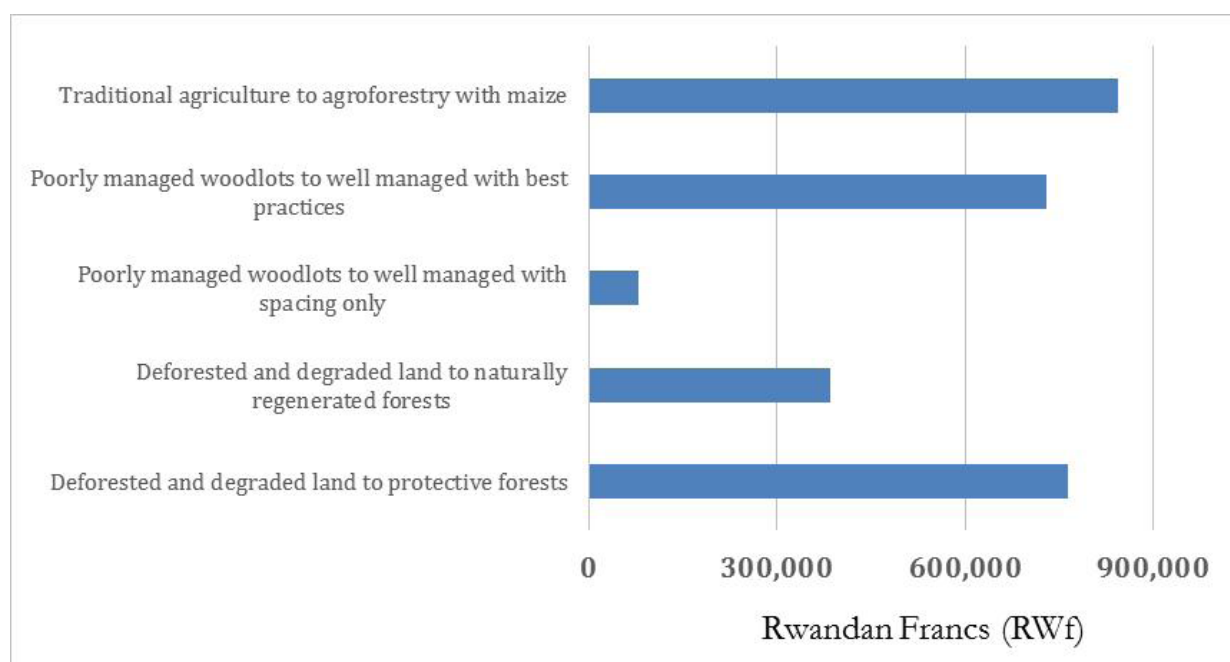


Figure 11: Restoration transitions costs (RWf/ha): Transition costs were calculated from the enterprise budgets by discounting costs occurring in the future at a 7% rate of discount.

Many of the costs are non-monetary and are borne by landowners and managers who must provide the labor to restore land. Landowners and managers must provide labor to prepare land for restoration, transport and plant seedlings (or sow seeds in the case of agroforestry), prune trees and manage weeds, and cut and harvest wood to use for fuel, construction, or farming materials. Non-labor costs include material inputs such as seedlings, fertilizer, and small agricultural equipment. However, the costs of learning new land management practice should also be taken into consideration as they can prevent landowners from adopting superior land management practices.

4.2.3 Return on Investment (ROI) from private landowner perspective

In order to achieve Rwanda's restoration potential with a limited budget there is a need to identify restoration transitions that maximize the benefits received from each Rwandan Franc spent on restoration. These alternative options have different cost and benefit profiles, which result in different returns-on-investment (ROIs), and as a result different management and policy opportunities with varying restoration outcomes.

The return-on-investment calculates the amount of value (measured in currency) that would be generated by every RWf invested in the restoration transition. For

example, if a transition had an ROI of 0.2 that would mean every RWf 1 invested in restoration would create RWf 1.20 worth of ecosystem goods and services.

The ROI of each restoration transition displayed in Figure 12 shows that ROIs vary from a low of -82% to as much as 126%. The transition from deforested land to protective forests on ridge tops and steep slopes has the lowest financial return amongst the restoration transitions because the costs of establishing the forests are relatively high compared to the discounted future carbon revenues that are used to offset the costs. The transition from deforested and degraded land to naturally restored forests has an average ROI of 0% as the carbon revenues are great enough to just offset the costs in most cases. The transition from poorly managed woodlots to well managed woodlots with spacing only and best practices will generate average returns between 17% and 24%, assuming some fire and erosion-prevention measures are already in place. If fire lines and erosion prevention ditches have to be established the average ROI becomes negative and varies between -52% to -55%. The transition from traditional agriculture to agroforestry generates an average ROI of 12% to 38% depending on which crop is being considered and whether carbon revenue is included. The large number of farmers and small plot sizes in Rwanda may create problems monetizing carbon at the farm level, however, so the ROI of 38% should be seen as an upper limit.

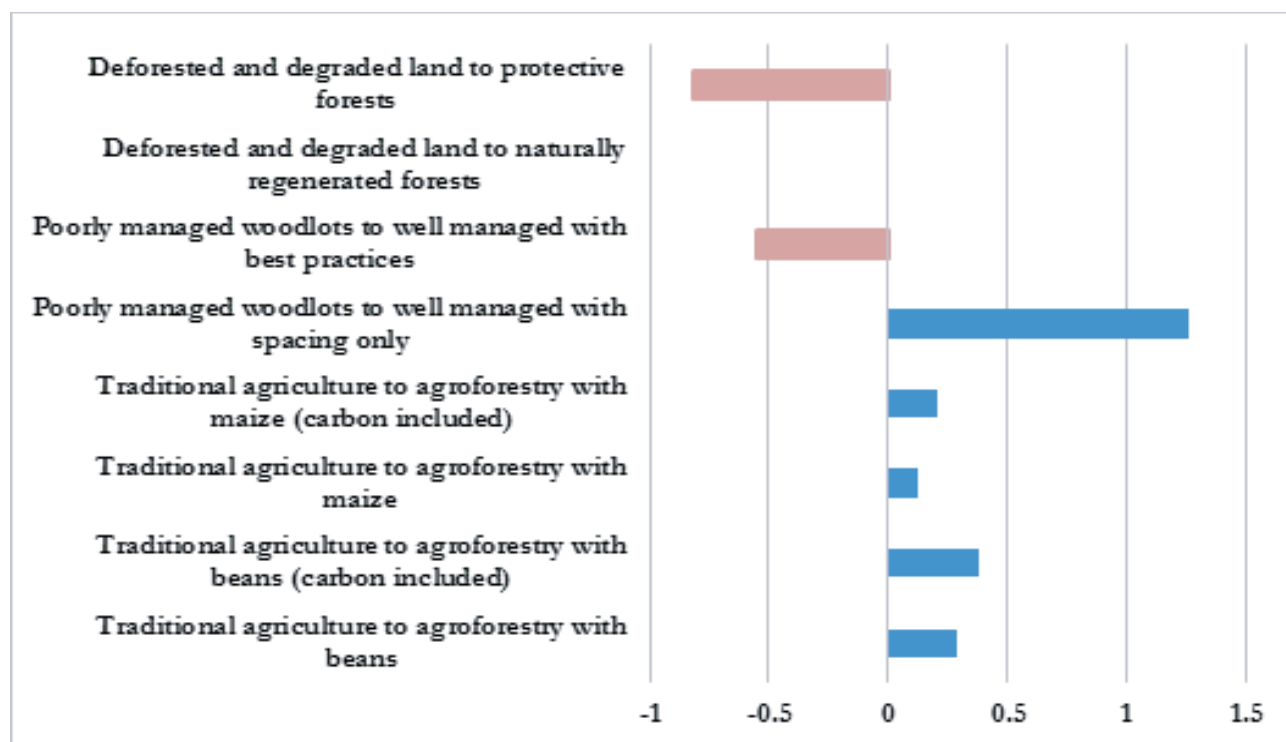


Figure 12: Return on investment for restoration transitions.

4.2.3.1 Agriculture to agroforestry and poorly managed woodlots to well managed woodlots

The results from the ROI analysis suggest that private landowners could benefit by improving the management of woodlots or adopting agroforestry practices. Each dollar invested by private landowners in either transition would be expected to create a return between 12 to 38% of the original investment. This suggests landowners may be willing to bear the labor and material costs of restoring woodlots and agricultural land because it is in their own self-interest.

These transitions could be supported through the second Financial Sector Development Program (FSDP II). The overarching goal of the program is to develop a reputable and stable financial sector that is sufficiently deep and broad, so that it is capable of efficiently mobilizing and allocating resources to address the development needs of the country. Private landowners could finance the material restoration costs through the savings and credit cooperatives (SACCOs), which are being expanded through the FSDP II. The program is also supporting the electronic land registration process, which will create a stronger incentive for private landowners to invest in their properties.

4.2.3.2 Deforested land to protective forests

The restoration transition from deforested land to protective forests was not found to generate positive returns on investment from the perspective of private landowners. Landowners must invest significant amounts of labor and material inputs into the transition from deforested land to protective forests and in return they receive few, if any, marketable benefits. The public benefits of the transition could be large in terms of protecting rivers, wetlands, and other vulnerable sites from the effects of erosion, but private landowners would not be likely to support the transition without a scheme that transfers some of the public benefits back to landowners.

4.2.3.3 Deforested land to naturally regenerated forests

The restoration transition from deforested land to naturally regenerated forests was not found to generate positive returns on investment from the perspective of private landowners. Potential for greater tourism revenue through the regeneration of habitat for chimpanzees, birds, and other wildlife has been identified in Gishwati, Mukura, Nyungwe, the conservation of which often comes at the expense of local communities that are unable to utilize or benefit from these natural resources. Under the analysis assumptions, private landowners

are unlikely to pursue natural regeneration unless some of the public benefits of the transition are transferred back to private landowners to offset their opportunity, labor, and material input costs.

4.2.4 Land use change policy analysis from private landowner perspective

Landscapes become degraded as a result of market failures that create incentives to degrade rather than maintain or restore land. Restoring degraded land requires policies to correct the market failures leading to degradation and preventing restoration. The choice of policy depends on which market failures are contributing to degradation and preventing restoration as well as who receives the benefits from restoration and who pays the costs.

The public and private benefits of each restoration transition are estimated and plotted onto a policy framework³² to identify context-specific policies to encourage private landowners to adopt restorative land uses in Rwanda. The framework can help choose between broad groups of policy tools to achieve restoration objectives on private lands for the highest benefit/least cost possible.

The goal of any policy is to improve the welfare of society, which requires choosing policies that leave everyone better off, or at least no worse off, than before. As a result, policies are selected based on who receives the benefits from restoration and who pays the cost. The Policy mechanisms are divided into four categories:

1. **Positive and negative incentives** - financial or regulatory instruments, including polluter-pays mechanisms (command and control, pollution tax, offsets) and beneficiary-pays mechanisms (subsidies, conservation auctions and tenders).
2. **Extension** - refers to influencing farmer's land use decisions by providing technical assistance and/or extension services to make certain land uses more attractive by supporting higher yields and/or incomes.
3. **Technological development** - refers to refining or identifying new land use practices that improve the productivity of the land through the use of different tree species or management practices.
4. **No action** - is taken when land uses create negative public and private benefits or when public benefits are slightly negative.

32 Pannell, D. (2008). Public Benefits, Private Benefits, and Policy Mechanism Choice for Land-Use Change for Environmental Benefits. *Land Economics*, 225-240.

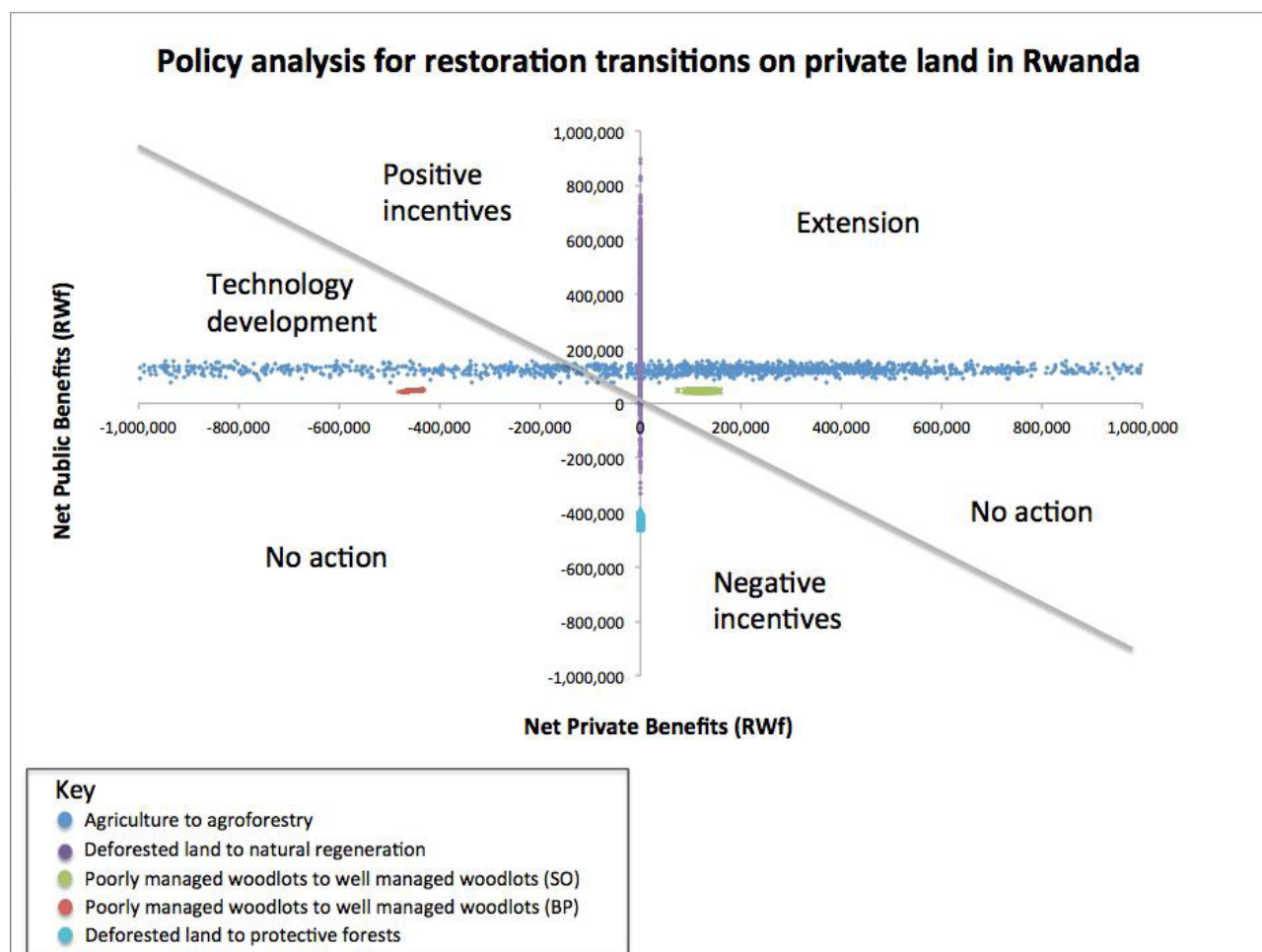


Figure 13: Policy analysis for restoration transitions on private land in Rwanda.

4.2.4.1 Agriculture to Agroforestry

The results from the policy analysis (Figure 13) show that the transition from agriculture to agroforestry produces a number of combinations of public and private benefits. Based on the assumptions made, the transition to agroforestry creates positive public benefits by increasing carbon storage and decreasing erosion. Yet, in some cases the transition reduces crop yields and creates a negative private benefit. Still, results suggest that landowners with land well adapted to specific agroforestry technologies can be encouraged to transition from traditional agriculture using extension services. On well-adapted sites, landowners may only need to be informed about the benefits of a specific agroforestry technology before they will adopt it.

Landowners who own land that is not well suited to specific agroforestry technologies will require technological development that creates agroforestry technologies that are suited for their land. In these cases, the public benefits of the transition are too small to make positive incentive programs, like payments for ecosystem services, worthwhile because the payments required by private landowners would

not be a cost effective way to provide the public benefits. (Bucago, Vanlauwe, Van Wijk, & Giller, 2012) have shown that Rwandan farmers are able to create new agroforestry technologies that meet their individual needs when they are able to choose from a number of native and non-native species. This type of technological development could be possible through targeted investments in the tree seed center to produce high-quality genetic stocks of native and non-native agroforestry species that can be made available to farmers.

4.2.4.2 Poorly managed woodlots to well managed woodlots (spacing only and best practices)

Improving the stocking density of poorly managed woodlots would store additional carbon and moderately reduce erosion. Yet, the primary benefit would be improved timber yields, which are captured by private landowners. Results suggest that the private benefit of improving management is great enough that landowners would consider the transition if extension services were provided to promote the benefits and practices of improved management.

4.2.4.3 Deforested land to protective forests

Restoring deforested land with protective forests can play an important role in maintaining ecosystem services, particularly as they relate to watersheds. Protective forests planted on ridge tops and sloping hillsides, help to prevent erosion by acting as a buffer and promoting soil health and stability, thereby safeguarding rivers and wetlands from the harmful effects of siltation³³ and sedimentation.³⁴ However, results suggest that protective forests are most effective when they are established in watersheds where erosion prevention services are highly valued. When the value of erosion prevention services is low, protective forests provide too few benefits relative to their cost. In areas with water dependent industries, such as tea or power production, the erosion prevention services of protective forests may justify the costs of the transition. Prior research has shown that the top three most valuable “uses” of watershed services are:

1. Tea production (\$804 USD/ha/year)
2. Small scale hydro power(SSHP) supply potential (\$164 USD/ha/year)
3. Flood prevention for tea estates and hydropower producers (\$137 USD/ha/year)³⁵

Establishing protective forests near these industries could be financed through payment for watershed service programs or other types of positive incentive schemes.

4.2.4.4 Deforested land to (assisted) natural regeneration

Restoring deforested land with natural regeneration provides a number of public benefits, including storing carbon and reducing erosion. Additionally, natural regeneration can increase species habitat and increase demand for eco-tourism in biologically rich areas. It was assumed that naturally regenerated forests are managed for the provision of public benefits and therefore produce no private benefits. The results show that private landowners could be encouraged to restore deforested land with natural regeneration through the use of positive incentive schemes such as payments for ecosystem services. As discussed below, the beneficiaries of restoration, such as power suppliers, tea producers, carbon emitters, eco-tourists and eco-tourism outfitters could finance the payments.

33 The increased concentration of suspended, fine particulates in the water column and increased accumulation of fine sediments on the bottom. In rural areas, climate change and poor land management practices commonly contribute to siltation of waterways.

34 The tendency for particles in suspension to settle out of the fluid in which they are contained and come to rest against a barrier. Sedimentation is particularly problematic in the context of hydroelectric plants.

35 Michael Masozera. 2008. *Valuing and Capturing the Benefits of Ecosystem Services of Nyungwe Watershed, SW Rwanda*.

4.2.5 Value chain investment opportunities

Rwanda has had success in attracting financing for agricultural value-chain opportunities, with most success in downstream investments in cash crop value chains such as coffee. But given the very nature of Rwanda's small land holdings increasing agricultural productivity can only be achieved through either; i) urbanization, where landholdings are consolidated into traditional-size agro-business operations, or ii) through promotion of efficient and effective aggregation programs that harness the power of smallholders to deliver investable opportunities that improve rural livelihoods.³⁶ The risks of the first agro-business approach include land displacement and the promotion of monoculture systems, and while there is a place for agribusiness approaches, integrated agroforestry systems are by their very nature better suited to small holders. However, a leading expert³⁷ in Brazil notes the difficulties in harmonizing these two approaches - public policies often support the smallholders, but most investments are made in the agribusiness sector.

The suggested value-chain investment opportunities identified here focus on achieving the goal of more trees on the landscape and center around the reality of smallholder land dynamics in the country. Thus, there is limited focus on downstream value chain investment opportunities, although there is recognition that functioning value chains are a critical component of increasing productivity and profitability for smallholders.

4.2.5.1 Agriculture to Agroforestry

Private sector investment in the producer-end of agroforestry will require identification of investments that provide an attractive return profile. One challenge with respect to investing in the transition from a non-tree landscape to a tree landscape is that trees take time to grow and thus, investors who are interested in receiving quick returns are less interested in this type of investment. This can be overcome by 1) bundling agro-systems with different return profiles such as fast growing value-added crops with trees crops, or 2) by identifying investment opportunities that have been operating for some time that can provide a better return profile. When looking at which agroforestry upstream value-chain that would be attractive to investors in Rwanda, the combinations are virtually endless, which is a challenge for prioritizing the interventions to attract investments.

36 EDPRS2

37 André Gonçalves, <http://www.fcni.org.uk/interviews/perspectives-agroforestry-model-sustainable-intensification-agriculture>

Table 7. Potential Value Chain Investments and Commercial Partners - Agroforestry.

Net Present Value (RWf)	
Apples, Apple Bananas, Bananas (with possible coffee intercropping ³⁸)	Floris, Shekina, Freshpak International Ltd, UrwibutsoEntreprise
Avocados ³⁹	Kigali Oil Company, Nakumatt Holdings, DD oil company, Ruremesha and Sons Fruits
Essential Oils – Geranium, Patchouli	Ikirezi Natural Products
Pyrethrum	SOPYRWA (Rwanda Pyrethrum Company)
Food crops that can grow in and around trees - Tree Tomatoes, Cassava, Taro, Chilles, and Passion Fruit	Shekina Enterprise, RChillex, Floris, Rwandaflora, Urwibutso, Nakumatt Holdings, multiple EU importers of passion fruit ⁴⁰
Shade trees for coffee or tea ⁴¹ , honey production – <i>Grevillea robusta</i> or indigenous species	Rwacof Exports SARL, Campos, Misozi Coffee Company Ltd, RWASHOSCCO

In this initial evaluation there were a number of agroforestry activities that could be promising for investment. These will need to be further evaluated based on what will need to be designed such that, when combined on the landscape, the activities can deliver the multiple benefits of restoration, food security, and income generation for smallholders and investors alike. In practice, these will be site and smallholder-specific, and should leverage the established organizations while scaling on existing practices.

Table 7 provides a listing of potential investment areas in agroforestry, and commercial partners in Rwanda, that can be leveraged to source and/or manage investments.

4.2.5.2 Poorly managed woodlots to well managed woodlots

Post-war financial and human resources for formally promoting woodlots have been limited, and Rwanda's first major forestry project did not even begin until 2002 with the \$11.5 million PAFOR project. Currently, the Government of Rwanda is reliant on its own budget for financing woodlot promotion, with some support received from NGOs and development partners in Belgium and the Netherlands. These donor-backed initiatives have provided direct investment toward reforestation activities and capacity building at the central and district levels within both public and private forests.

Despite the many advantages of promoting woodlots in a country where population pressures and land scarcity limit or prevent forest expansion, there appear to be very few organized efforts to promote woodlots currently or recently active in the country. Furthermore, most seeds used in Rwanda are supplied by the Tree Seed Centre (CGF) and there has been evidence of genetic degradation of germplasm particularly in the case of *Eucalyptus* (mainly due to inbreeding) and has greatly affected plantations' yields⁴². As such productivity is currently low (18 to 30% efficiency) and site quality is also low (mainly due to inappropriate management during planting, thinning and harvesting). As a matter of fact most high quality wood products is imported from Uganda, DRC or Dubai and China and the country needs to invest in technology and value chains (below) in order to be able to improve the quality of forest products (modern saw mills and wood based panel plants among others)⁴³ as at the moment the logging is done with axes and machetes.

Currently the majority of plantations in Rwanda are *Eucalyptus*, over 42% of all forests⁴⁴, which do not produce high quality timber. Improving the quality of timber products could potentially be a good income opportunity. Currently, good quality timber and finished wood products are imported from China, Dubai, Uganda or DRC. In order to improve the quality of timber it is necessary to i) support plantations that promote indigenous species, ii) improve the quality of seeds, iii) improve the processing facilities (currently wood is mainly sawn manually with pit saws, machetes and chainsaws leading to low quality and high wood waste) and stacking techniques.

38 It is not clear whether intercropping with banana-would qualify for certification as shaded.

39 http://growafrica.com/wp/wp-content/uploads/2012/04/Rwanda_Avocado-Packaging-and-Export-Investment-Case.pdf

40 <http://www.hcda.or.ke/downloads/REPORT%20ON%20RWANDA%20MARKET%20SURVEY.pdf>

41 Has limited application to full sun varieties, but could support valued-added shade grown systems

42 Forest Plantations and Woodlots in Rwanda, African Forest Forum, July 2011.

43 Forest Plantations and Woodlots in Rwanda, African Forest Forum, July 2011.

44 <http://www.aicomnet.org/index.php/country-profiles/country-profiles-rwanda>

Today seeds are only provided by the Tree Seed Centre (*Centrale des Graines Forestieres* funded by the government of Rwanda). As mentioned before, there have been issues in Rwanda with the decreasing genetic quality of germplasm. There is an important opportunity to source pure seeds and use stricter seed selection that would translate into increased timber yields on woodlots. This new and improved seed suppliers and nurseries could be managed by small business and enabled by loans using microfinance or equity schemes from impact investors or the government and providing the required technical assistance and capacity building.

Plantations in Rwanda are limited in size to be in the position or capacity to offer high quality timber or timber products and thus the potential for investment. This would require investment on modern sawmills, wood based panel plants, timber treating plants, training and introduction of certification systems. Investments can be enabled by loans, equity and loan to rent schemes which can be part of private impact investment initiatives in the case of cooperatives and/or small farmers. The CDM and Voluntary markets offer income opportunities especially on methodologies that use waste woodchips and sawdust for biomass (in Rwanda wood processing is very limited between -18 to 30% efficiency- and as a result big amounts of waste are produced); fuel wood efficient cook stoves; and reforestation as renewable source of wood supply for industrial use. The latter is much recommended as it generates carbon stocks and greenhouses gases (GHG) removals and replaces fossil fuel in industrial facilities for biomass. These projects should be enabled by more active capacity building and match making (developer – buyer) from the designated national authority (DNA).

4.2.5.3 Deforested land to protective forests

For purposes of this assessment, investable opportunities in protective forests and riparian zones will be approached as two sub-goals within the larger goal of achieving watershed protection, as Rwanda has prioritized an integrated water resources management (IWRM) approach in these areas, and topographic and hydrologic conditions found in Rwanda's riparian zones do not differ greatly from those of its hillsides and ridge tops.⁴⁵ In the quest for increased and improved watershed protection, there are a few key areas with investment potential in the rural energy value chain, as well as in the ecosystem services themselves, which are enabling and safeguarding the value chains of other sectors.

Watersheds are, in many ways, the limiting factor for many of Rwanda's industries. Without the services they provide, Rwanda's agricultural, energy, and export sectors would be severely jeopardized, and smallholders would face even more challenges in meeting subsistence and domestic needs in the face of an unpredictable climate and competitive water use scenario. The annual economic value of watershed protections services provided in Nyungwe National Park alone is nearly \$118 million USD.⁴⁶ Despite the huge cost savings to Rwandan industry, local communities tend to pay the price for the provision of these services, primarily in the form of opportunity costs related to conservation.

Tea producers and Independent Power Producers (IPPs) may represent two private sector interests to serve as investors in watershed services. Beyond benefits to industrial sectors, Investments in watershed management are capable of producing a 30% increase in household incomes from agriculture, and investors can expect a return of 7% per year. In fact, for every franc invested in watershed management in Rwanda now, three francs will be generated by 2020.⁴⁷

Watershed services benefit IPPs primarily in the form of avoided costs resulting from sedimentation leading to a loss of generation capacity; the associated costs due to a reduction of energy production, including the inability to meet obligations under PPAs with the Government of Rwanda, and; economic losses due to maintenance, which requires a temporary yet full halt in electricity generation from a plant. Case studies on watershed services in Rwanda, or lack thereof, have found staggering decreases in productivity. Masozera (2008) found that the annual cost associated with sedimentation of one hydropower plant in Gishwati is approximately \$1.15 million USD, equating to an energy loss of 38% of total production. It could be concluded that these costs are directly tied to sedimentation resulting from deforestation of the Gishwati Forest Reserve.

Tea estates are among the primary industrial users of water in Rwanda. Like other industries, the tea industry is largely self-supplied and is not connected to a distribution network. In addition to the water used for growing tea, water is used for processing leaves into black tea, which requires both adequate quantity and quality. The "free" water provided by the Nyungwe watershed to tea estates and the National Agriculture Export Board (NAEB), which amounts to 58,240,000 m3 per year, provides an avoided cost of \$81,536,000 USD annually.⁴⁸

⁴⁵ The lowest incline constituting a 'steep' slope in the context of forest landscape restoration on hillsides and ridge tops in watersheds is 20%. In many of Rwanda's wetlands, such as Rugezi, riparian zones exist with inclines in excess of 35%, making differentiating between these unnecessary for the purposes of protective forest restoration for watershed protection.

⁴⁶ Michael Masozera. 2008. *Valuing and Capturing the Benefits of Ecosystem Services of Nyungwe Watershed, SW Rwanda*.

⁴⁷ Rwanda Environment Management Authority. 2012. *Watershed management, a good investment able to increase 30% of agricultural productivity*.

⁴⁸ Michael Masozera. 2008. *Valuing and Capturing the Benefits of Ecosystem Services of Nyungwe Watershed, SW Rwanda*.

Flood prevention is also an important consideration for the tea industry. A 2007 flood affected 90 ha of tea estates, resulting in over \$500,000 in opportunity costs. However, avoided flood-related costs due to the presence of approximately 100,000 ha of forests in Nyungwe were nearly \$14,000,000 USD.⁴⁹

Two fundamental barriers exist to establishing payments for watershed services (PWS) in Africa: the financial health of institutions benefitting from watershed services, and a lack of “consumers” of ecosystem services with the ability to pay.⁵⁰ There are effectively three types of private sector interests that would not only benefit from promoting payments for watershed services (PWS), but which are not inhibited by these barriers in Rwanda. For these private sector actors, PWS will become an essential part of maintaining and expanding their operations, and sustaining revenue in the medium and long terms.

4.2.5.4 Deforested land to naturally regenerated forest

Investable opportunities for expanding and restoring Rwanda’s natural forests are limited, given the very small amount of natural forest left and the extent to which population and land pressure have almost entirely eliminated the availability of land for expansion of natural forests. This implies a need to interact closely with the communities living in the periphery of national parks and/or areas containing natural forest. The Rwanda Development Board (RDB) plans to diversify attractions in Volcanoes National Park (VNP) and create new attractions at Nyungwe National Park, and suitable landscape restoration interventions aimed at habitat restoration could potentially mesh with private sector interests in maintaining and expanding their offerings. Meanwhile, the creation of buffers can serve as an investable opportunity *vis a vis* the production of non-timber forest products (NTFPs).

Rwanda’s national Export and Tourism Policies both outline objectives related to the expansion of ecotourism in the country, particularly around Rwanda’s remaining natural forests and national parks and reserves. Tourism revenue is the primary source of funding for the Rwanda’s national parks and reserves, so a synergistic relationship between the parks and those who use them is essential for all parties involved.

Tree planting in Rwanda is an annual national activity. However, this collective reforestation effort does not have adequate inputs required to make native trees survive and thrive. The availability of nurseries establishes a quality base of naturally occurring and/

or other appropriate tree species required to overcome what has largely become a eucalyptus monoculture. The promotion of nurseries and tree planting is a commonly utilized strategy of ecotourism operators and could be considered the low-hanging fruit in Rwanda’s natural forest restoration value chain. Transporting primary seedlings to secondary growth areas is also an easy way to include guests in reforestation efforts around the parks they came to visit. Simple interventions and partnerships between local communities and the ecotourism sector could promote an expansion and maintenance of buffers and wildlife habitat that can also serve as a source of NTFPs.

NTFPs differ from traditional agricultural products due to the importance of wild harvesting in the production process, which inherently limits supply for individuals or households. The development of some type of organizing or oversight body is essential to ensuring a volume of supply substantial enough to make subsequent processing and distribution steps economical. In instances where NTFPs are harvested from common land, community organizations are typically well positioned to manage these activities. In instances where NTFPs are harvested primarily from smallholder plots, cooperatives are more likely to form to reduce costs and improve bargaining power. Purchase agreements between ecotourism operators and community groups engaged in the production of NTFPs could provide an income source for households; hotels in Rwanda have already begun sourcing furniture crafted from bamboo, the cultivation of which is being promoted in Rwanda.

4.2.5.5 Carbon (REDD+ and Afforestation/Reforestation)

It is worth highlighting the relevance of increasing carbon storage in Rwanda in terms of co-benefits. Countries who use restoration to offset emissions want to find the highest benefit / least cost way to do so. Carbon abatement curves use information on the costs and benefits of restoration to estimate the benefits of sequestering carbon under each restoration transition. The curves show how much carbon each transition could capture if all of the restoration opportunities were taken. Combining this information into a single graph helps decision makers offset emissions by restoring landscapes as efficiently as possible.

There are two dimensions to a carbon abatement curve:

- Benefit (cost) dimension: The height of each bar represents the additional benefits (costs) that are produced for each ton of carbon that is sequestered through the restoration transition.
- Volume dimension: The width of each bar represents the total amount of carbon that could be sequestered if all opportunity areas of each transition were restored.

49 Michael Masozera. 2008. *Valuing and Capturing the Benefits of Ecosystem Services of Nyungwe Watershed, SW Rwanda*.

50 Andres and Masozera. 2010. “Payments for Ecosystem Services and Poverty Reduction in Rwanda.” *Journal of Sustainable Development in Africa*.

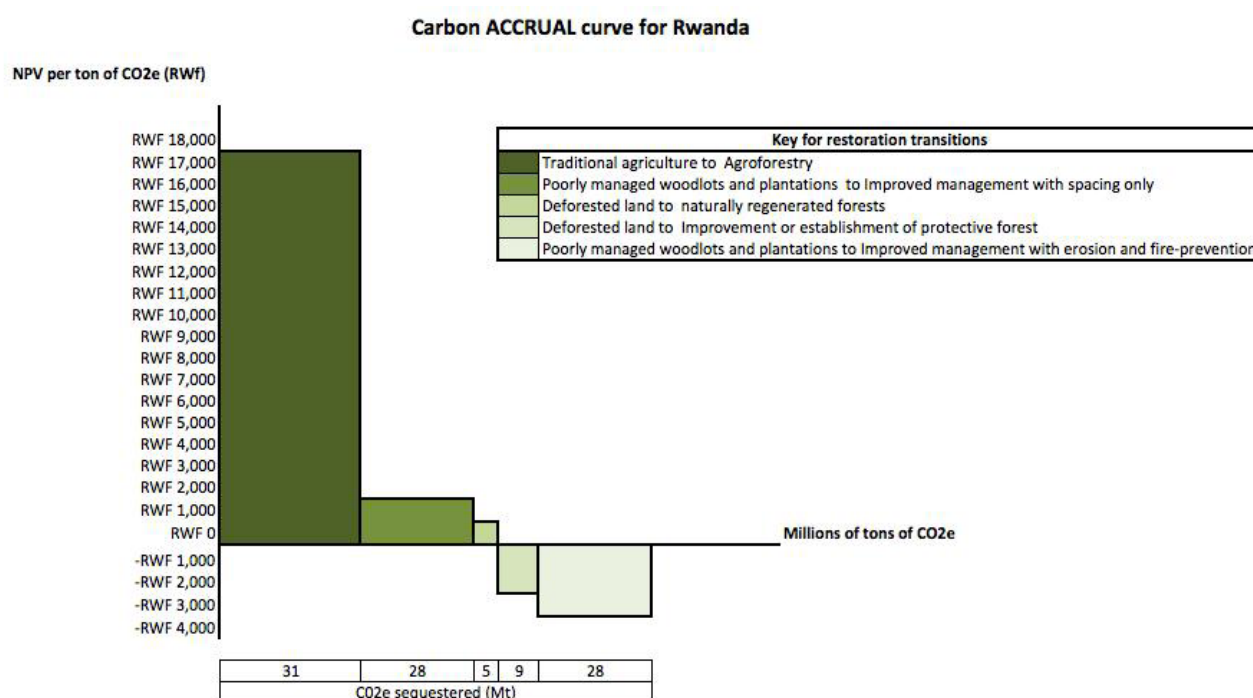


Figure 14: Carbon abatement curve for Rwanda.

As Figure 14 shows, the greatest potential to store carbon is by using transitions that provide the largest private (i.e. livelihood) benefits. Transitioning agricultural land to agroforestry could store an additional 31 Mt of CO₂e. For each ton of carbon stored through the transition RWF 17,000 would be produced through additional crop yields, reduced erosion, and wood production. Improving the management of woodlots would store 28 Mt of CO₂e and create approximately RWF 1,000 in additional private benefits for each ton of carbon stored. Transitions that produce more public benefits, such as naturally regenerating forest on deforested land, create fewer benefits for each ton of CO₂e that is stored and are less efficient means of storing carbon.

Rwanda's Vision 2020 seeks to increase forest cover from 17% to 30% by 2020. As such, great efforts need to be made in order to reach this goal. This represents an important opportunity to restore degraded and deforested landscapes with the additional benefit of reducing emissions. Figure 14 shows that Rwanda has the potential to reduce approximately 100 Mt of CO₂e emissions through restoration transitions. Even though the government has engaged in tree planting, there is room for improvement and financing is still an issue because the case for additionality of potential transitions must be made.

The potential for REDD+ in Rwanda is limited, as most of the country was deforested between 1960 and 1990 (36% forest loss) and carbon stocks are limited. Moreover, the country was initially excluded from pilot projects under UN-REDD and the Forest Investment Program, and deforestation has been significantly reduced in recent years. The main opportunity for

REDD+ is on the protection of parts of National Parks and protected areas that still face some deforestation and degradation threats such as the Volcano's National Park, Nyungwe and Gishwati Forest. Rwanda's Environment Management Authority (REMA) and the Designated Authority (DNA) consider this potential to be low as they describe these areas to be well protected already.⁵¹ However, there is some significant pressure on National Parks; as such, the total area of national parks has been reduced since 1960, largely due to conversion to agricultural land and settlements. The National Green Growth Strategy establishes, as one of the main priorities within its Finance Pillar, encouraging conservation through payments for ecosystem services schemes that go beyond existing pilot projects in Gishwati and Nyungwe Forests. This priority could include some REDD+ initiatives.

It is worth highlighting that the relevance of REDD+ in Rwanda in terms of co-benefits, mainly biodiversity co-benefits, could be significant, as Rwanda is located in the western arm of Africa's Rift Valley. This valley is considered to have "the highest species richness in Africa," with around 40% of the continent's mammal species. This includes 30% of the global population of mountain gorilla, listed by IUCN as an endangered species, more than 1,000 bird species, around 300 reptiles and amphibians, and almost 6,000 higher plants.⁵² Rwanda has seven identified Key Biodiversity Areas (KBAs) that cover almost 3,000 km², include about 56 Mt of carbon

⁵¹ Carbon Market and Forestry in Rwanda, Rwanda Environment Management Authority, Designated National Authority.

⁵² Rwanda State of Environment and Outlook: Our Environment for Economic Development. REMA, UNEP, African Development Bank, African Development Fund

(18Mt of biomass and 38Mt of soil carbon), and comprise almost 90% of the high carbon area.⁵³ Around 2% of the land that is relevant for carbon and biodiversity is not included in protected areas, and represents a good opportunity to structure REDD+ projects with significant biodiversity co-benefits.

Some of the major co-benefits and ecosystem services are economic and livelihood support, including food security, and poverty alleviation (the value of ecosystem services provided by Nyungwe forest alone has been calculated at 285 million USD a year⁵⁴; ecotourism (from under 5 million USD in 2002 to 33 million USD in 2006); and research and medicine. Main threats to biodiversity are the same as those to forests, mainly, population pressure, land scarcity, conversion of natural habitats, mining, agriculture and, introduction of non-native species.

According to the Carbon Market and Forestry Assessment elaborated by REMA and the DNA, the work on REDD+ at the project level has been limited so far. The approach in Rwanda is “to integrate the local communities into the sustainable management of forest resources and to link the protection of the natural forests to the reduction of the poverty of the waterside populations.”⁵⁵ The Carbon Market and Forestry Assessment also cite two Project Idea Notes (PINs) that are under process of approval by the Congo Basin Forest Fund (CBFF). One has been proposed by the National Forest Authority, aimed at increasing forest and tree cover in State and District forests, both remnant natural and plantations, as well as on private lands; conducting forest carbon assessments and the application of a monitoring system, and; improving the livelihoods of forest-dependent communities. The second, proposed by the Woods Hole Research Center (WHRC), aims to “develop human capacity in forest policy and management using novel applied research as a vehicle for regional training and capacity building in advanced economic, social and remote sensing methods” in four basin countries including Rwanda.⁵⁶

The country has not yet developed a comprehensive REDD+ strategy and some work remains to be done on elaborating a newer national forest inventory and the inclusion of carbon biomass estimates. UNEP and WCMC calculated the country’s terrestrial carbon stocks to be 130Mt, with 67 t of carbon in ground biomass and about 63Mt in soils, unevenly distributed over the country.⁵⁷ REMA is developing an approval process for all voluntary projects - including REDD+ -

that comprises, among other things, an assessment by technical committees and a letter of approval signed by the director general of REMA. Furthermore, REDD+ projects shall be coordinated by the Department of Forestry and Nature Conservation in Rwanda Natural Resources Authority, which will also be the focal point for all projects. Projects in National Parks require coordination with the Rwanda Development Board (RDB), and the Ministry of Natural Resources should also be kept aware of all project activities.

Regarding ownership of carbon credits and revenue sharing, REMA establishes that:

- If the project takes place on government land where the land was leased for free, the government is entitled to 40% share of the carbon credit revenue for the first 10 years and 50% thereafter⁵⁸
- If the project takes place on government lands leased for a fee, there must be discussions between the government and the developer. Revenue sharing will then depend on individual conditions such as the price of lease, taxes and the use of the revenues by the developer (whether they will be reinvested in the country or not).

4.3 Assessment of key success factors

The assessment team conducted desk research, key informant interviews and workshop sessions to better understand the situation related to the key success factors for forest landscape restoration in Rwanda. The results of this initial assessment were compiled within the framework of the Rapid Restoration Diagnostic, to assess the key success factors required to allow restoration to occur at scale.

Analysis of historical cases of restoration revealed three common themes to successful restoration:

1. **A clear motivation.** Decision-makers, landowners, and/or citizens were inspired or motivated to restore forests and trees on landscapes;
2. **Enabling conditions in place.** These included ecological, market, policy, social, and institutional conditions;
3. **Implementation capacity and resources.** Capacity and resources were in place and mobilized to implement restoration on a sustained basis.

The Rapid Restoration Diagnostic tool can be found in Appendix 3. It is important to note that not all factors are required in order to be successful. In the results tables below, the column labeled “Ability to Improve” refers to the effort required to improve the situation related to the feature, with “High” being the most probable to change and “Low” being the most difficult to change. Preliminary findings include:






53 Carbon, biodiversity and ecosystem services: exploring co-benefits, UNEP, WCMC.






54 Rwanda State of Environment and Outlook: Our Environment for Economic Development. REMA, UNEP, African Development Bank, African Development Fund Carbon Basin Forests Fund, Rwanda. <http://www.cbf-fund.org/en/node/139#sthash.Ey7iyKWY.dpuf>

56 Carbon Market and Forestry in Rwanda, Rwanda Environment Management Authority, Designated National Authority.

57 Carbon, biodiversity and ecosystem services: exploring co-benefits, UNEP, WCMC

58 The Carbon Market and Forestry in Rwanda. Rwanda Environment Management Authority, Kigali, Rwanda

A CLEAR MOTIVATION			
Feature	Preliminary Result	Preliminary Rationale	Ability to Improve
Benefits	 <i>Partially in place</i>	While the potential benefits of restoration are clear, proven economic cases for the forest landscape restoration interventions highlighted above, including agroforestry, remain lacking.	High Quantify economic results through representative test cases
Awareness	 <i>Partially in place</i>	Clear national roadmaps exist via Vision2020, the Economic Development and Poverty Reduction Strategy (EDPRS) and associated sector level strategies. Annual tree week & Umuganda promote reforestation. However, benefits of forest landscape restoration interventions remains unclear to farmers	High Increase interaction with landowners to understand needs and capacities; socialize the benefits of restoration
Crisis events	 <i>In place</i>	Rwanda is prone to widespread soil erosion, runoff and sedimentation. Wide-scale over-farming has led to poor soil fertility and lack of organic matter. Displacement and migration over past 25 years has exacerbated the situation.	N/A
Legal requirements	 <i>Mostly not in place</i>	Laws and policies to govern forests exist but are not adequately enforced. Afforestation and agroforestry commitments are not coded in law. Laws to protect water bodies with forested buffer zones exist, but are also not adequately enforced. There is no specific law related to restoration. How does it come separate from the prevailing legislation on Forestry?	Low Laws and policies are important, but enforcement has been a major problem and is expected to continue to be a problem due to lack of budget and human resources
Culture	 <i>Mostly in place</i>	There is a strengthening, progressive cultural identity of being Rwandan. Desire and potential for regional and global recognition exists. There is a strong performance based culture in the Rwandan government. However, there is not a 'forest culture' per se, but a heavy reliance on woodlots for energy.	Medium There is increasing national pride in Rwanda. Restoration of its land gives Rwanda a chance to become an internationally recognized player. This will require sizeable investment to cultivate.

ENABLING CONDITIONS IN PLACE			
Feature	Preliminary Result	Preliminary Rationale	Ability to Improve
Ecological Conditions	 <i>Partially in place</i>	There are opportunities for restoration. Many steep slopes are not well suited to agriculture. Natural regeneration is a viable option in many of the flat areas. Limited rainfall in Eastern province and a lack of quantity, quality and diversity of native seeds and seedlings throughout Rwanda are issues.	High Capacity of the Tree Seed Center and network of nurseries to be increased and focused on native species
Market Conditions	 <i>Partially in place</i>	The growing population and extent of farming households puts pressure on land. As such, pasture and crop intensifications are major priorities. Domestic demand exists for a range of forest products, but ability to process and transport is limited.	Low Bolster the domestic supply chain for forest products in strategic areas in Rwanda. Link agroforestry with intensification programs.
Policy Conditions	 <i>Partially in place</i>	Land and natural resource tenure are reasonably secure. Tenders with tree nurseries are limited to twelve months in length, which has led to weak seedling production. Though many laws, policies and strategies exist, enforcement, governance and implementation remain inadequate.	Medium It is important that policies and strategies are published by relevant agencies to provide transparency and aid in coordination efforts. However, enforcement is not likely to improve dramatically without additional funds.
Social Conditions	 <i>Mostly in place</i>	From a rights perspective, substantial progress in providing individual land rights. Land tenure claims are still being mapped. However, from a process perspective, landowners are often not adequately consulted to help make participatory decisions in the landscape.	High Increase engagement with civil society and cooperatives, as both have an important role to play in ensuring equity and participation in landscape restoration activities.
Institutional Conditions	 <i>Not in place</i>	Master plans, strategies and policies are not released in a timely or transparent manner by all agencies. This is not yet the case, which causes problems when trying to coordinate across agencies. A shared common vision and framework for restoration among stakeholders is therefore lacking. Inconsistencies exist between policies and strategies of various Ministries, especially related to agroforestry. Responsibilities are defined but too often overlap. Planning is often not coordinated which leads to areas being overcommitted to multiple land uses. Coordination mechanisms need emphasis and strengthening.	High Executive Office and Parliament to increase accountability to ensure that master plans, strategies and policies are published on time. Joint Sector Working Groups allocated additional resources and attention by the Executive Office and Parliament.






IMPLEMENTATION CAPACITY & RESOURCES			
Feature	Preliminary Result	Preliminary Rationale	Ability to Improve
Leadership	 <i>Mostly in place</i>	Rwanda has strong political leadership and commitment. Rwanda has already made a substantial commitment to the Bonn Challenge and the Aichi targets. There is a need to invest to build more restoration champions at the district, sector and village level.	High Honor existing champions. Identify potential champions among civil society and community groups. Identify strategies to build their capacity and honor their efforts.
Knowledge	 <i>Mostly not in place</i>	There is a small but strong university network. Rwandan stakeholders already possess an impressive amount and quality of GIS and other data. However, there is a lack of knowledge produced about opportunities in the drier and flatter lands in the Eastern province. There is a general lack of knowledge and data related to native species. There is also a lack of a cadastral map for forests, which is a major problem. Additionally, extension services are not focused on restoration (e.g. Forests promotes woodlots and Agriculture promotes traditional methods of intensification)	Medium Focus additional resources on native species and on drier areas of the country. Invest in creating and maintaining a cadastral forest map. Increase the quantity, quality and breadth of extension services available to communities.
Finance & Incentives	 <i>Not in place</i>	There are insufficient funds available from government, the private sector, civil society and donors to engage in restoration at scale. Many smallholder farmers are poor and lack access to appropriate loans, grants and/or incentives. Need creative financing mechanisms to help build the capacity of cooperatives, NGOs and private sector companies to implement restoration at scale	Medium Engage poor landowners with funds in exchange for labor. Quantify the economic and social returns of restoration and conduct a campaign to raise a combination of investment and social funds to support restoration at scale.
Technical Design	 <i>Mostly not in place</i>	Currently, government, civil society (and to a limited extent the private sector) are engaged in a limited number of well-designed activities. Projects are often not designed for scale. Most research is focused on exotic species in sloping, wet areas. Technical research should increase its engagement and outreach to smallholder farmers. Need to increase focus on resilience, i.e. designing the landscape of the future	High Bridge the gap between research and practice. Increase focus on native species and include flatter, drier areas. Extension and other outreach services should be increased.
Feedback	 <i>Mostly not in place</i>	Projects often have expensive or insufficient monitoring systems. Monitoring has focused on tree cover and not trees outside the forest. There is a need for high resolution, lower frequency data to quantify restoration progress.	Medium Need for low-cost, scalable FLR monitoring system that can be utilized by a range of stakeholders. Small, early wins need to be identified, championed and communicated nationally and internationally

Table 8: Results of workshop discussions to identify areas of focus.

Key Factors	Urgent	Ease
The economic case is understood at district level		
Better local planning processes		
Better coordination between government agencies		
A government supported campaign		
More government finance and incentives		
Better district level technical extension		
Performance targets for restoration		
Better supply of planting material		
New laws to promote restoration		TBD
Existing laws better implemented		TBD
Better opportunities for private sector		TBD
Better access to credit for farmers		TBD
Better or more research		TBD
Better markets for tree products		TBD
Simplify timber harvest procedure for farmers		TBD

KEY FOR URGENT

	Most Urgent
	Urgent
	Less Urgent
	Least Urgent

KEY FOR EASE

	Most difficult
	More difficult
	Easier
	Easiest

The findings above were discussed in workshops in all five provinces of Rwanda. The goal was to identify the most urgent issues to be addressed, as well as to understand the relative difficulty in addressing the issue. The results of these discussions are summarized in Table 8.

5. Conclusions, Recommendations and Next Steps

The results from the geospatial analysis show that there are approximately 2.25 million hectares of land and freshwater resources in Rwanda that could directly benefit from Forest Landscape Restoration in terms of improved productivity, quality and ecosystem functionality. More precisely, this could be delivered through policies, programmes and incentives that target 1.5 million hectares of mainly agricultural and forest lands with emphasis on the five following interventions:

- Agroforestry on steep sloping land in conjunction with other soil conservation measures such as radical and progressive terracing – 705,162 hectares
- Agroforestry on flat or gently sloping land, including those areas principally managed as pasture and rangelands – 405,314 hectares
- Improved silviculture and rehabilitation of existing, sub-optimally managed woodlots and plantations, including very small (<0.5 hectare) areas – 255,930 hectares
- Protection and restoration of existing areas of natural forests, mainly in or around protected areas but also extending to small isolated fragments – 13,933 hectares
- Establishment or improvement of protective forests on important and sensitive sites such as ridge tops with steep (20-55%) and very steep sloping land (>55%), riparian zones and wetland buffer zones and margins – 122,540 hectares.

Each landscape possesses a unique land-use mix that determines the opportunities for restoration and the benefits those opportunities will deliver. The challenge therefore in arriving at a feasible national forest landscape restoration strategy lies not in identifying which single intervention will deliver the greatest overall benefit, but rather in constructing a practical framework that facilitates synergies between different types of interventions working across different land uses.

Furthermore, any successful restoration framework must deploy interventions that are economically attractive to private landowners and smallholder farmers as well as offer broader benefits to society at large in line with existing national priorities.

5.1 What does the analysis of Rwanda's restoration potential tell us about the types of opportunities and appropriate restoration strategies?

The analysis undertaken brought together geospatial, economic, carbon, policy & institutional and financial assessments. The assessment team worked through this analysis and two of the principal considerations were how to build on the good work that Rwanda has already put in place and how to contribute to existing national policies and priorities.

The key findings on the types of opportunities and appropriate restoration strategies are as follows:

1. *Agroforestry is the central pillar of Rwanda's FLR initiative.*

Forest Landscape Restoration is linked to soil fertility, erosion control, water quality and availability, and on-farm productivity. As such, agroforestry on all types of cultivated and pasture land—steeply sloped, gently sloping and flat—is central to Rwanda's restoration strategy. Significant progress on soil conservation is being made nationally through schemes such as the Land Husbandry, Water Harvesting and Hillside Irrigation project⁵⁹, but agroforestry is still not widespread on most sloping agricultural lands with bench and progressive terraces. Similarly on flatter land, and particularly in the drier parts of the country, there is significant opportunity for interventions such as evergreen agriculture and farmer-managed natural regeneration. Analysis found that this could extend to 1.1 million hectares with an anticipated rate of return of 12 to 21% over the original investment.

59 See: <http://www.gafspfund.org/content/rwanda>

2. *Productivity of existing woodlots and plantations can be significantly improved, but there is limited opportunity to establish new areas.*

During the course of the study, the issue of finding opportunity areas to establish new woodlots and plantations was raised on several occasions. The analysis showed, however, that expanding the area of woodlots and timber plantations is only possible if other national priorities, such as those on agriculture and food security, are sacrificed, given that areas for new woodlots and forests would need to be established at the expense of agricultural land. There may be some opportunities in Eastern Province – particularly in the area of Akagera that was degazetted as a national park in the 1990s.

There is significant potential to improve productivity from existing woodlots. Of particular relevance from a rural livelihood perspective are those areas of mainly *Eucalyptus* less than 0.5 hectares in area. The FAO WISDOM report estimates that average *Eucalyptus* yield in Rwanda is around 9.5 m³ per ha per year, which is well below the regional average.⁶⁰ Furthermore it should be noted that the Rwanda's 2007 forest inventory data gave an even lower figure of 5.5 m³ per ha per year.⁶¹ Unfortunately there is no specific information on the productivity of very small woodlots, though based on interviews and field observation, the assessment team suspect this is probably even lower than the national average calculated by WISDOM. Given the extent of these small blocks of woodlots, it is believed that there is significant potential in boosting productivity in these blocks, which would improve the supply of fuel wood and charcoal and increase on-farm incomes. Existing projects such as PAREF⁶² already have done considerable work in this respect.

3. *Many sensitive sites such as steep slopes, ridge tops and riparian areas need to be protected or restored, as required by law.*

Targeted interventions to restore natural forests in sensitive sites offer considerable societal benefits, such as erosion control and improvement of water quality, act as an important complement to investments in agroforestry, and are consistent with existing forestry policy.⁶³ The analysis shows that many sensitive sites which, by law, are supposed to be protected or restored, are currently under other types of land use that exacerbate major national challenges such as soil loss, reduced water quality and siltation. In the case of very steep slopes and ridge-tops, these areas are often the least productive part of the landscape. Approximately 40,000 hectares of restored or improved forests on ridge tops with steep slopes, in combination with agroforestry interventions on other parts of the landscape, could effectively address many of the sedimentation problems that impact Rwanda's hydropower industry, while contributing to better soil conservation and erosion control. Equally, an investment in 3,000 hectares of new forests and modifying the species mix in 20,000 hectares of existing *Eucalyptus* woodlots would be sufficient to comply with existing forestry policy to protect Rwanda's rivers within a 20m buffer strip. Various approaches could be employed to enhance the capacity of protective forest without having to totally forego revenue generation. For example, sites without tree cover could be restored using commercial native timber and non-native fruit-tree species while those sensitive sites that are currently stocked with low-grade *Eucalyptus*, which does not provide adequate buffering or protective capacity, could gradually be replaced by mixes of native timber species and bamboo, particularly along water courses.

4. *Restoration of degraded natural forests, particularly inside national parks, will improve biodiversity conservation and encourage eco-tourism.*

Analysis shows that an area of approximately 14,000 hectares within or around Rwanda's remaining natural forests require restoration. This includes the Gishwati and Mukura forest reserves and Nyungwe national park and surrounding areas. Restoration within existing forest areas could be based on encouraging natural regeneration and protection, which would be cheaper than replanting although this would still require some interventions including thinning and removal of bracken ferns which became established in Nyungwe after the 1997 fires. Boundary planting of mainly *Pinus* in a 100m buffer around these areas is a well-established practice. However, if the natural

60 Drigo, R., & Nzabanita, V. (2011). *Spatial analysis of woodfuel production and consumption in Rwanda applying the Woodfuel Integrated Supply/Demand Overview Mapping methodology* (WISDOM). Rome: FAO – Forestry Department – Wood Energy.

61 Institut Des Sciences Agronomiques Du Rwanda (ISAR). 2008. Inventaire des Ressources Ligneuses du Rwanda. Rapport Final.

62 Funded by the Government of Rwanda, Kingdom of Belgium and Kingdom of Netherlands, PAREF (Projet d' Apuit à la Reforestation) is a project that provide Afforestation programs in order to create a vibrant, healthy local ecology that ensure a sustainable management of Forest for sustainable growth of country's economy.

63 Republic of Rwanda's National Forestry Policy

qualities of these areas are to be enhanced to improve biodiversity conservation and encourage further eco-tourism it might be desirable to begin trials with commercial native species such as *Entandrophragma excelsum*, *Markhamia lutea* and, in drier areas, *Milicia excelsa*. Through discussions with ministry officials in REMA and RNRA it was noted that Rwanda currently does not have experience in germinating native tree species seed nor silvicultural experience. However this knowledge is widely available within the region and therefore should not be a major limitation.

5. *Improved connectivity within an ecological corridor between the Gishwati, Mukura and Nyungwe forests should be a national priority, but full reconnection of the three areas is not feasible.*

Several organizations have promoted the idea of reconnecting these three important areas of natural forest, primarily on the justification to enable isolated primate populations in the Gishwati area to maintain a sufficiently broad gene pool.⁶⁴ The analysis shows, however, that the full reconnection of these three forests would cause significant social disruption, as the proposed corridor area is home to many small farmers and some large estate crop enterprises. However, improved connectivity is achievable if the conservation objectives are redefined in light of these constraints, and should be an important national biodiversity objective. In this respect, it is suggested that the corridor would be an ideal candidate for piloting restoration of protective forests on steep slopes, ridge-tops and along waterways using native species. Such action would enhance connectivity (particularly for bird and small mammal species) and would help RNRA gain valuable experience on regeneration of native species and test different schemes to elicit the support and involvement of local communities and enterprises. The GEF-supported LAFREC project that is currently being designed is particularly well placed to advance such an approach. Finally it was also noted that beyond the corridor there are still several small and very small remnants of natural forest. It is recommended that these areas should be identified, mapped and district authorities supported to make sure incentive schemes are put in place to protect them. Given the limited extent of remaining natural forest in Rwanda these very small and small blocks will be an important foundation for future forest landscape restoration activities. It is estimated that in total the remaining natural forest cover extends to no more than 112,000 hectares.

6. *There is a strong basis for sustainable land management through restoration of dryland forest landscapes in Eastern Province.*

The assessment team struggled to gain the same insights into the situation in Eastern Province compared to what was achieved for the other four provinces. Several government agency staff members also mentioned to the team that most of the national forest policy and programmes are currently targeted, to the western part of the country, given that the climate is not as dry and the majority of existing natural forest is located in this part. However, it is important to focus policies and programmes in the drier areas because variation in rainfall patterns from climate change, whether it be from drought or flooding, is likely to increase the vulnerability of drier and flatter areas in a significant way. Forest Landscape Restoration can be one useful component of climate adaptation strategies for that region. Furthermore, there are still some areas of dry forest and woodland that exist outside protected areas in Bugesera, Ngoma and Kirehe districts that are still in good condition. Any landscape restoration strategy in the Eastern Province should incorporate and build upon these overlooked resources, which, according to local government and project staff, are still under threat.

5.2 What does the analysis tell us about the current bottlenecks and constraints to achieving Rwanda's restoration potential?

1. *There is insufficient shared vision and coordination among ministries and agencies on the role of FLR in delivering national priorities.*

Master plans, strategies and policies must be released in a timely and transparent manner by all government agencies. This is not yet the case, which causes problems when trying to coordinate across agencies. A shared common vision and framework for restoration among stakeholders is therefore lacking. Inconsistencies exist between policies and strategies of various Ministries, especially related to agroforestry. Responsibilities are defined but too often overlap. Planning is often not coordinated which leads to areas being overcommitted to multiple land uses. Coordination mechanisms need emphasis and strengthening.

64 See http://en.wikipedia.org/wiki/Gishwati_Forest

2. *The availability of quality tree seed and the production of planting stock that farmers and others land managers desire is currently a major limitation which, if not addressed, risks hampering Rwanda's FLR ambitions.*

The Rwandan Tree Seed Center receives orders from the district level forest officers, who decide upon the species and quantities. There is insufficient interaction between the farmers and the district level forest officer, whose responsibilities and performance targets do not include agroforestry. The resources and capacity of the Rwandan Tree Seed Center are also lacking, leading to inadequate quality, quantity and diversity of seeds. Compounding the problem, a well-intended policy that requires nurseries to bid on contracts every 12 months has led to an unstable network of nurseries with limited capacity and investment capital due to the uncertain nature of their business. There is great opportunity for improvement in these areas with relatively limited investment.

3. *There remains significant gaps in knowledge and technical capacity on basic restoration approaches that will need to be addressed.*

The level of commitment and dedication at all staffing levels in government agencies and with district administrations is clearly impressive. The combination of performance targets and individual motivation has permitted a strong results-oriented culture to flourish within the public sector. However, several local and international staff who were interviewed also highlighted that the tragic events of 1994 constituted a complete disruption of experience and skills transfer from one generation of foresters to another and that the effects of this can still be felt to some degree. In particular, the lack of knowledge on the regeneration and silviculture of native commercial tree species, the lack of knowledge on – and system to monitor – the commercial volumes of timber and variations of growth rates, the lack of a framework to help district officials assess the best “value for money” restoration options for their area and a lack of technical options to improve productivity and harvesting of woodlots and plantations are all symptomatic of the skills, experience and insight that were lost during the genocide and have yet to be fully regained.

It should be noted that the Government have taken some very positive proactive steps to address this, for example, a modular training framework sponsored by RNRA was being designed while the restoration assessment was underway and the PAREF project is planning a new national inventory. These efforts could be further built upon by more proactively establishing

links between national university researchers and government agency and district staff and by using landscape pilot activities to test, apply and adapt experiences from elsewhere to the Rwanda situation. Network such as the Africa Forest Forum are a ready source of regional experience and know-how and donors and international organizations should, under the guidance of RNRA, invest in supporting targeted exchange visits.

4. *There continues to be a lack of information available on and understanding of FLR among farmers particularly on native species and options*

Government extension services are not sufficiently resourced and the private sector is currently playing a limited role, so information about FLR is not reaching farmers effectively. The assessment team reviewed the current flow of information to farmers and realized that capacity needs to be built among the community based organizations that convene and support the farmers themselves (e.g. cooperatives, associations, etc.) as well as with the government agencies that are tasked with aggregating and disseminating information on FLR approaches. Information was most lacking on the potential benefits and availability of native species. There is strong interest in the idea of creating a menu of available “FLR packages” that farmers can choose from. These packages pull together all the necessary inputs, materials and knowledge required to restore productivity and function to the land.

5. *There is a lack of emphasis on the potential role of the private sector, including opportunities and models for public-private finance*

The public sector plays a powerful and important role in Rwanda that often overshadows the roles of civil society and the private sector. With extensive numbers of smallholder farmers who live below the poverty line, opportunities for private finance and large-scale investments are not immediately obvious. However, the role of the private sector is growing in Rwanda and FLR has an opportunity to deliver additional opportunities, including investment packages along the FLR supply chain to companies who provide seed collection, seedling production, seedling transportation and other key functions. These opportunities are most viable when private sector actors work closely with the government to create public-private partnerships and mechanisms. An example of a successful public-private partnership that should be further studied, documented and replicated is the privatization of the management of the buffer zones of natural forests in Rwanda.

5.3 From the identified opportunities and constraints what are the main areas of action that need to be addressed?

Based on the analysis presented in this report and discussions with over 100 district officials and technical officers, the assessment team has identified 5 strategic recommendations, primarily intended for government in the first instance. These are:

1. Improve coordination among government agencies - *ensure that ministries work together, provide guidance to one another in their respective areas of expertise and identify ways to collaborate with the private sector and civil society. This includes district level engagement. Specifically:*

- Utilize the Joint Sector Working Group to coordinate government agencies and help them prioritize and promote implementation of landscape restoration activities.
- Designate RNRA as the lead agency to review, identify, coordinate and communicate existing synergies in agencies and sectorial Master Plans that relate to Forest Landscape Restoration.
- Assign the responsibility and mandate to promote, coordinate and provide technical guidance on agro-forestry to one government agency.

2. Improve the delivery of technical know-how, advice and, most critically, high quality planting stock - *enhance the capacity of existing seed and nursery assets by setting clear performance targets, clarifying the role and mandate of the Tree Seed Centre and creating positive incentives for long-term capital investment, particularly from the private sector. Specifically:*

- Address the current institutional and policy limitations that constrain the Tree Seed Centre from meeting the national demand for quantity, quality and diversity of seeds, including for native trees species. In particular the institutional mandate for the hosting arrangement for the Tree Seed Centre should be reconsidered as well as the existing controls that make the import of even quality certified seed very difficult.
- Allow for diversified sources of seed stock that are certified by the Tree Seed Centre
- Provide extension services for agroforestry and woodlots that show farmers how to adapt different tree species and management practices to their unique situations to improve crop production and timber yield

- Stabilize and strengthen the network of tree nurseries, particularly with respect to encouraging increased investment and technical expertise. Policies, incentives and tendering requirements need to create the conditions that encourage multi-year financial and improved technical investments into nursery operations.

- Incentivize and encourage district administration, national agencies and large commercial operations to increase the proportion of native species that are planted and maintained – particularly with respect to protective forests and restoration of degraded areas of natural forest. A medium term target may be helpful in this respect, for example 20% of all new plantings by 2020 are with native species.

3. Put in place the conditions to increase the demand for trees as well as the products from FLR - *stimulate the use of trees, including native species, in agricultural landscapes by helping farmers improve the return they receive from restoration activities and by increasing awareness of benefits that they can receive. Specifically*

- Increase awareness of district administrative staff of the main economic benefits that are derived from FLR and provide them with the tools to quickly evaluate the economic returns that could be expected from the inclusion of an FLR component into district-level plans and objectives.
- In close consultation with farmers and farmer associations, harness local and international expertise to design and test Rwanda-specific technological packages that meet farmer's immediate and long-term needs.
- Build capacity among existing district and sector level extension services to promote appropriate FLR interventions including, among other measures, by aligning and harmonizing performance targets of agriculture and forest staff with national restoration objectives and goals.
- Target the improvement of small woodlot (<0.5 hectares) productivity, as well as accessibility to and efficiency of local charcoal and fuel wood supply chains, as an important on-farm and livelihood resource. As a first step this means improving national and district level understanding of how small-scale farmers approach the management of their woodlots, the constraints they encounter in marketing associated produce and whether these factors differ for women and men.
- Support a public awareness campaign to highlight the benefits of a diverse range of trees, including native species, targeting in particular farmers and other land managers.

4. Prioritize and support early application of FLR in selected landscapes – *take the opportunity of existing or planned initiatives to test how key FLR interventions can be most effectively deployed simultaneously in configurations that enjoy the support, of and directly benefit, local communities. Specifically:*

- Prioritize action in the Gishwati – Mukura corridor by applying for funds to pilot a landscape approach to restoration. The Sustainable Trade Initiative's 'Sustainable Land and Water Program' is seeking interested organisations to submit landscape project case descriptions that are relevant within the scope of the SLWP.⁶⁵ The Gishwati-Mukura landscape could be a good candidate for the program because of its prominent role in the livelihoods of local communities and the large potential for a landscape approach to restoration.
- Develop a landscape restoration strategy for Eastern province building upon the dry forest and woodland resources that still exist outside protected areas in Bugesera, Ngoma and Kirehe districts.

5. Finance/resourcing recommendation– *identify the full range of opportunities, options and models for unlocking finance while making the business case for FLR. Specifically:*

- Promote private sector investment in forest landscape restoration value chains, sustainable land management practices and technologies for forest protection and climate smart agriculture with a focus on greening and securing supply chains.
- Identify investment-worthy practices, partners and activities in key geographic regions that are already being implemented at some scale and can deliver priority landscape restoration activities and improve livelihoods, but that have the potential to attract new sources of private investment.
- Support for commercialization and making the business case for restoration by providing support to potential investment opportunities to address some of main barriers to attracting private investment, which include: setting up of aggregation entities, execution of operational agreements between partners, development of financial projections for investment returns, enhancing operational and financing management expertise.
- Identify and secure private investment once viable investments have been identified and are fully commercialized with professional business plans. The success of attracting

finance will depend on understanding both the details of the investment opportunities as well as the full landscape of potential private investors.

- Maintaining investment worthiness and promoting scale to ensure that investors have a positive experience with their landscape restoration investments in Rwanda so that they will continue to increase their investments.

5.4 Next steps to support forest landscape restoration in Rwanda

Several of the recommendations listed above are clearly ambitious in nature. However, it is believed that all could be significantly advanced within the timeframe of Vision 2020. In order to get started, Rwanda commits to following practical next steps to deliver immediately and lay a solid foundation for more ambitious medium term action.

1. Next steps to support improved coordination among government agencies and better alignment of mandates

Clearly and understandably this is an area of sensitivity and, given the fact that landscape restoration spans several mandates could easily become an issue of divisiveness if different agencies felt their own authority was being undermined or diluted. In order to lessen the possibility of such an outcome it is suggested that the proposed Joint Sector Working Group focuses on several specific tasks that should help build a shared vision for landscape restoration among different government agencies. This includes:

- As a cross sectoral team, review and validate this report with the option of requesting specific amendments if commonly agreed upon.
- Commission a time bound assessment that:
 - i. maps how current national sectoral strategies and master plans could contribute to the Rwanda FLR initiative, identifying synergies, duplication and gaps, and
 - ii. documents and takes stock of all recently completed, on-going or planned government, NGO and private sector FLR-related projects, illustrating how they combine under the FLR framework and contribute to achieving Rwanda's FLR target

⁶⁵ See <http://www.idhsustainabletrade.com/sustainable-land-and-water-program>

- Undertake an exchange visit for 5–6 members of the JSWG to look at how landscape restoration has been harnessed in support of national development priorities. Costa Rica is suggested as potentially interesting country given that it has undergone large-scale restoration in the past 30 years, its experience in novel financing approaches, the role of eco-tourism as key element of the service sector, similarities in topography and some cash crops.

2. Next steps for the improved delivery of high quality planting stock

As reflected in the strategic recommendations, several, but by no means all, of the issues surrounding the supply of quality planting stock come back to the mandate of and hosting arrangements for the Tree Seed Centre. It is clear that the Centre needs urgently to assume feasible performance targets to improve the quality and variety of tree seed. To do so it would at first be helpful to have a better idea of what really (ideally) is required in terms of variety (species), quantity and quality and where the major shortfalls lie. Having such information would provide the first step in establishing feasible performance targets for the TSC and would act as a basis for identifying a range of options whereby the TSC could help meet existing demand. Priority action shall therefore include:

- Commission a study that would:
 - o ascertain from district level interviews (including district officials, farmers and the private sector) the quantity and variety of seed that nurseries required (ideally) in 2014 / 2015
 - o document the most commonly perceived problems with the quality of tree seed (and planting stock)
 - o suggest additional options (including if necessary a revised role for the TSC) in securing sufficient quality, quantity and variety of planting material, e.g. options for import of certified seed with TSC taking a regulatory rather than solely an operational role.

In addition, it is suggested that RNRA might wish to open discussions with commercial nursery enterprises that already operate in East Africa to explore whether there might be interest in establishing modern seedling production facilities in Rwanda, specifically aimed at diversifying the species range and improving the quality of planting stock.

3. Next steps for the increase local demand for trees and the products from FLR

This is an area where quite a lot of immediate action could be achieved. Bucagu *et al.* (2012) clearly highlights that there is real interest from farmers in planting agroforestry trees. However their preferences do not currently align with often what is on offer. Equally several senior staff noted that Rwanda previously had good experience and knowledge concerning the establishment and silviculture of native species but this was lost during the tragedy of the 1994 genocide. It was reported however that one can still find planted stands of valuable native species such as *Entandrophragma* and the University of Rwanda and Tree Seed Centre could possibly have good grey literature and technical reports that have been archived and forgotten about. In any event several neighboring countries in East and Central Africa have also relevant experience. In this respect four specific areas of action shall be pursued immediately;

- Undertaking a national study to ascertain the main constraints to, and opportunities for, the improved management of small (<0.5 ha) woodlots. Such a study should include:
 - o understanding the role of these woodlots as an on-farm resource, with explicit reference to gender-related dimensions,
 - o documentation of the key factors that shape and influence farmers' approaches to the management of these woodlots including seasonality of labor availability, market access and pricing, supply chain incentives or disincentives, quality of planting stock, technical knowledge and advice, etc...
 - o Indicative estimations of current levels of productivity and the realistic potential gains that could be expected with improved basic management.
- Undertaking an evidence-based scoping study on the potential role and contribution of agroforestry, small woodlots and other on-farm trees in improving farmers' resilience and adaptability to the anticipated impacts of climate change. In particular, assess the likely degree to which these types of FLR interventions could help Rwanda combine existing mitigation and adaptation policy objectives and the degree to which they constitute a "value for money" saving.

- Based on what is known about farmers' preferences, design, prepare and support the broadcasting of a FLR module for farmers' radio and other related ICT activities that are already established in Rwanda.
- Documenting the extent and location of small and fragmented blocks of natural forest, including native species plantations. Review historic archived knowledge on the regeneration and management of native species and, in conjunction with the University of Rwanda undertake trial activities

4. Next steps to initiate early action in priority landscapes

Clearly there is already underway district land husbandry and soil & water conservation to which FLR activities can add further value. The main challenge therefore, is not how to initiate an entirely new landscape restoration initiative but rather to identify the most promising starting points in terms of existing programmes of work into which a FLR component can be integrated. There are several opportunities but the Gishwati-Mukura landscape clearly stands out as one of the most obvious candidates, not least as a new GEF project will be initiated there some time in 2014 or 2015. In addition it was also suggested by several senior government officials that in addition to Gishwati it might be opportune to begin to explore a second site for focused FLR activities. If this was to go ahead the consensus appeared to be that attention should be paid to the which has, until now been relatively overlooked in terms of forest and land management interventions. Two specific new steps shall be pursued in terms of piloting FLR;

- Identifying one or two sectors that coincide with the Gishwati-Mukura corridor and where land husbandry and soil conservation activities are underway and where, ideally, there is also some commercial private sector activity. In consultation and collaboration with relevant District authorities and the sector agricultural and forest extension officers under stakeholder consultations to identify how several of the recommended restoration actions could be effectively combined together and incorporated into ongoing or planned activities. Implement those plans ensuring that there is a robust monitoring and assessment framework in place to capture key lessons; including the effectiveness of the interventions, stakeholder engagement and support, costs of the interventions and attributable benefits derived from the intervention (including an assessment of who were the principal beneficiaries).

- Identifying a short list of potential landscapes in Eastern Province, assessing these against a set of criteria including district support, ongoing activities, community engagement, identified restoration needs, and preparing a proposal.

5. Next steps to initiate early action on the identification and mobilization of innovative finance and resourcing packages

Rwanda's process of attracting private investment for landscape restoration will need to be built from the ground up, working with a multidisciplinary team that includes skills ranging from local rural community engagement specialists, international investment finance experts, and other technical specialists. Attracting private capital at scale will take more than a qualified team of people, and requires building a targeted public private partnership (PPP) that is designed to address the barriers and promote the opportunities for investments in Rwanda's landscape restoration. The sections below provide next step actions needed to develop meaningful scale investment capital from private investors to fund restoration opportunities.

- *Designing and Operationalization of a Rwanda Landscape Restoration PPP Entity*

The purpose of the Rwanda Landscape Restoration public-private partnership (PPP) would be to coordinate investment and mobilize commitments for action across the broad range of actors needed to implement and fund landscape restoration, thus initiating an environmentally sustainable and socially beneficial, commercially viable approach with highly leveraged returns of private over public investments.

- *Identifying investment-worthy practices and partners*

Effort is needed to identify and promote aggregation groups that can be financed through SMEs or cooperatives. Each opportunity would be evaluated for investment-worthiness and prioritized based on investments that warrant further support to become commercially viable. The government or other funding agencies could support a business model competition similar to the Hult Prize⁶⁶, a business model competition that encourages the world's brightest business minds to compete in teams to solve the planet's biggest challenges with innovative business ideas. This type of competition can produce an array of business models that provide viable opportunities for social investors in addition to identifying the challenges for business.

66 <http://www.hultprize.org>

- *Supporting commercialization and making the business case*

Often, potential investments lack the key elements needed to attract private investors in any scale. To implement this recommendation, a package of tailored technical support would be provided to entities/businesses that facilitates:

- o reaching critical scale through facilitation of aggregation entities,
- o reparation of high quality financial projections to demonstrate cost effectiveness and the risk and return profile,
- o identification of key implementation partners,
- o establishment of the required legal entities (if not in place),
- o preparation and execution of contractual arrangements between partners (including communities, technical specialists, and government),
- o Documentation of entities' roles, contractual arrangements, and financial flow mechanisms. The final product for each commercially viable business would be a complete investment prospectus and due diligence questionnaire that would allow private investors to credibly present their investment opportunities.

- *Identifying and securing private investment*

This recommendation supports the identification of potential investors for each commercially prepared investment opportunity using specific knowledge of the investment criteria to produce a map, including publically support risk mitigation opportunities, for each business opportunity. Additional support would be provided to:

- o tailor investment pitch materials for each investor,
- o preform screening of investment prospects' interest,
- o conducting "roadshows" and targeted meetings with the engagement of key implementing partners,
- o support for due diligence,
- o Structuring/negotiation of transaction documents. For investments that are more micro-finance oriented (versus institutional scale), the support would be tailored and could include: working with lenders to offer loan products that fit small holder needs, identifying sources of additional capital needed in increasing the pool of micro-loans, and/or introducing insurance products.

- *Maintaining investment worthiness and promoting scale*

Implementation support under this section would offer technical assistance to investee entities/businesses such that they can:

- o establish performance reporting requirements to ensure effective management by leveraging existing systems and extension services, mobile and remote sensing technologies,
- o develop programs for the on-going training of investees,
- o establish programs to promote higher and broader adoption among new small holders for scaling investors,
- o support the production of quarterly performance reports to investors and share success stories more broadly, and
- o provide oversight support (broad seats, or external experts) for financial and operational management of investment entities.

Conclusion

Realizing Rwanda's significant restoration potential requires a concerted effort to institutionalize restoration at the Provincial, District, Sector and Cell levels. The current Ministries and District extension offices are well positioned to absorb the responsibility of managing restoration programs throughout the country, but will require financial investments to do so. Additionally, market barriers need to be overcome in order to establish a network of nurseries capable of producing high quality seedlings of native and exotic species that are preferred by farmers at moderate to low cost. Extension services in each District could help farmers identify the types of trees that are most useful for their unique needs, ensuring that investments in restoration benefit farmers and giving them an incentive to maintain the trees once they are planted. All of this also requires investments in education and outreach to communicate the value of restoration to the myriad of stakeholders who could be willing to participate in local, regional, or national restoration programs.

Appendix 1: Geospatial methodology

The opportunity areas for forest landscape restoration interventions were derived from a geospatial analysis of about a dozen national-level spatial datasets for Rwanda. The data were collected and analyzed in a geographic information system (GIS) using EsriArcMap 10.2.1 software. The datasets used in the analysis (and their resolutions, where applicable) include land cover (1 km²), forest cover (2500 m²), elevation (10 m²), slope (10 m²), and locations of national parks and forest reserves, wetlands, lakes, rivers, and administrative boundaries.

A1.1 Agroforestry

To identify opportunity areas for new agroforestry on steeply sloping land, the geospatial analysis involved isolating areas of cropland from the land cover data; non-forested areas from the forest cover data; and land with slope greater than 3 degrees (5% incline) and less than 30 degrees (55% incline) from the slope data. The intersection of these datasets, shown in Figure 4, is the opportunity area for agroforestry on steeply sloping lands. To identify areas for agroforestry on flat or gently sloping land, including lands principally managed as pasture or rangelands, we used the same three data sets identified above, with a few differences in methodology. We isolated areas of both cropland and grassland/shrubland from the land cover data; non-forested areas from the forest cover data; and land with slope less than 3 degrees (5%). The intersection of these datasets, shown in Figure 5, is the opportunity area for agroforestry on flat or gently sloping land.

A1.2 Woodlots and Timber Plantations

For the analysis to identify areas for improved management of woodlots and timber plantations, we did not have data on exactly which forest plots are harvested for fuel wood or data on the exact locations of existing timber plantations. Data was also unavailable on how well certain woodlots and timber plantations are currently managed. Given that eucalyptus is the primary source of fuel wood throughout Rwanda, we assumed that all

plots of eucalyptus have the potential to serve as woodlots for harvesting fuel wood. Therefore, we used a national dataset of forest cover by species and quantified the opportunity area for improved management of existing woodlots as the total area of eucalyptus plots (Figure 6). To identify areas of timber plantations, we extracted areas of pine from the national dataset of forest cover by species and quantified the opportunity area for improved management of existing timber plantations as the total area of pine plots (Figure 7).

A1.3 Natural regeneration of forests

The interventions associated with natural forest regeneration include establishing 100-m buffers around existing closed natural forest and restoring degraded natural forest inside parks and reserves. For the ‘buffer of closed natural forest’ intervention, we used the national forest cover dataset and extracted areas defined in the dataset as closed natural forest. Using ArcGIS tools, we then buffered this area of closed natural forest by 100m and, using the forest cover dataset again, eliminated any areas from the buffer that were already forested. Thus, opportunity area for this intervention is defined as all non-forested area within 100-m of existing closed natural forest (Figure 8).

For the ‘degraded natural forest’ intervention, we extracted areas from the national forest cover dataset defined as degraded natural forest and overlaid these areas with the boundaries of reserves and national parks. Any areas of degraded forest that overlapped with these boundaries were quantified as opportunity areas for this intervention (Figure 8).

A1.4 Protective Forests

The protective forest interventions mapped in this analysis included establishing protective forest on steep and very steep ridge tops; within 20-m buffers of riparian areas; and within 50-m buffers of wetlands. For the analysis of opportunity areas on ridgetops, we used ArcGIS hydrology tools and the national elevation dataset to identify the local topographic highs based

on an analysis of the direction and accumulation of overland water flow. These topographic highs were extracted as ridge tops and overlaid with the slope dataset classified as according to the “steep” and “very steep” categories. The criteria for a steep ridgetop was defined as a slope between 12 and 30 degrees (20-55% incline) and the criteria for a very steep ridgetop defined as greater than 30 degrees (>55% incline). Ridge tops located adjacent to steeply sloped land were classified as “steep” and ridge tops located adjacent to very steeply sloped land were classified as “very steep”. To quantify only those ridge tops that are currently non-forested, we used the forest cover dataset to extract only non-forested areas (Figure 9).

The ‘riparian buffer’ interventions included establishing 20-m buffers along rivers that are non-forested, or along rivers currently forested with eucalyptus that should be replaced with native species. The national datasets of forest cover and rivers were used in this analysis. We used the forest cover dataset to extract areas of eucalyptus and areas of non-forest. Using ArcGIS tools, we then buffered rivers by 20m and overlaid the buffered area with the area eucalyptus or non-forest. Areas where these datasets overlapped were defined as opportunity areas for the two riparian buffer interventions. We used a similar approach for the ‘wetland buffer’ intervention, where we used a national dataset of wetlands and ArcGIS tools to buffer the dataset of wetlands by 50 meters. We then overlaid this buffer with the forest cover dataset that has non-forest areas extracted, thus defining the opportunity area as areas within 50-m of wetlands that are non-forested (Figure 10).

Appendix 2: Economic Methodology

A2.1 Introduction

In Rwanda, IUCN and WRI identified three degraded land uses that could benefit from restoration through the strategic introduction of trees and management practices. Relevant governmental and non-governmental institutional stakeholders that are currently involved in restoration activities in Rwanda were identified and consulted to produce the preliminary list of degraded land uses. A series of consultative workshops were held across each of the five provinces with more than one hundred District Officials and other key stakeholders from civil society in attendance. Through the consultative workshops, the following land uses, restoration interventions, and restoration transitions were identified:

1. Traditional agriculture
2. Poorly managed eucalyptus woodlots and plantations
3. Deforested land

Five broad restoration interventions could be used to improve the ecological and economic productivity of degraded land uses through:

1. Agroforestry for crops and livestock
2. Improvement or restoration of natural forests mainly in or around protected areas
3. Improved management of existing woodlots for fuel wood and structural wood, spacing only
4. Improved management of existing woodlots for fuel wood and structural wood with spacing and erosion and fire-prevention best practices
5. Improvement or establishment of protective forests on ridge tops and near water bodies

Based on the current land uses and restoration interventions we identify the following restoration transitions:

1. Traditional agriculture → Agroforestry for crops and livestock
2. Poorly managed eucalyptus woodlots and plantations → Improved management of existing woodlots, spacing only
3. Poorly managed eucalyptus woodlots and plantations → Improved management of existing woodlots with spacing and erosion and fire-prevention best practices

4. Deforested land → Improvement or restoration of natural forests
5. Deforested land → Improvement or establishment of protective forests

We value each transition by valuing the change in ecosystem service production that would result from the transition from the current land use to the restored land use. For example, to value the transition from agriculture to agroforestry we estimate crop production, timber production, erosion prevention, and the associated costs for agriculture and agroforestry. The difference between these values represents the additional goods and services produced by restoring the land. Below, we discuss how we model each ecosystem goods and services as well as the assumptions that were used to represent the land management practices of the current and restored land uses.

A2.2 Benefit and cost structure of restoration transitions

We model the costs and benefits of each restoration transition by dividing benefits into two categories: public and private benefits. Public benefits measure the off-site value of the goods and services produced through restoration. In the analysis we focus on the public value of carbon storage and erosion prevention services. We estimate the private benefits as crop yields, fuel wood and timber production, and the on-site benefit of erosion prevention.

We assign values to the physical units of ecosystem goods and service production based on the public and private benefits of the services. For example, Nordhaus (2011) found that the social benefit of increasing carbon storage was equal to approximately RWf 8,250 for ton of CO₂e. Preventing a single ton of erosion is worth approximately RWf 2,300 per hectare to private landowners while the public benefit of preventing a ton of erosion is worth RWf 3,000. Using this convention, we value the public and private benefits of each restoration transition.

Table A1: Assumptions used to calculate revenue for each land use and restoration intervention.

Restoration transition	Assumptions behind revenue calculation
TAG→AFCL	<ol style="list-style-type: none"> 1. Sale of crops is the only source of revenue and revenue is calculated from simulated crop yield regression. 2. Maize and beans can be sold at market for 515 RWf and 374 RWf per kilogram, respectively. 3. Agroforestry would add 300 additional trees per hectare and tree fodder would be used to feed livestock reducing annual cost of organic fertilizer. 4. We assume the interaction between trees and crops can alter crop yields by -35% to 60% compared to yields of traditional agriculture. 5. At the end of 20-year rotation trees are harvested and their volume is sold for timber for a price of 10,900RWf per cubic metre.
PME→IMP	<ol style="list-style-type: none"> 1. Poorly managed woodlots stock 1100 trees per hectare. We assume improved management plants 1,600 trees per hectare. 2. Trees are coppiced every 7 years if the wood is being produced for fuelwood, but timber is harvested at the end of a 28-year rotation interval. 3. After year 1 we assume 30% of seedlings are replaced for PME and 15% for IME, a process known as "Beating-up". 4. After the 4th year 250 trees are removed from the site and sold for poles for 2,000 RWf per pole. 5. Fuelwood is sold for 8,800 RWf per steere and timber is sold for 10,900RWf per cubic metre.
DL→NR	<ol style="list-style-type: none"> 1. Natural regeneration occurs on deforested land that generates no revenue. 2. We assume natural regeneration occurs over a period of 20 years. 3. Carbon can be sold on the voluntary carbon market for a price of \$7.50 or 4,950RWf per ton of CO₂e.
DL→PF	<ol style="list-style-type: none"> 1. Protective forests are located on deforested land that generates no revenue. 2. We assume a thirty year time horizon. 3. Carbon can be sold on the voluntary carbon market at the end of 30 year for a price of 4,950RWf per ton of CO₂e

Notes: All revenue streams were discounted at a rate of 7%.

Table A1 lists the assumptions used to estimate the benefits for each land use and restoration intervention. For each land use and restoration intervention we modeled the management practices that created the benefits each year. Models used were evaluated by agricultural and forestry experts at four workshops held in Rwanda during October 2013. The models were presented to the workshop participants and they were asked to revise the estimates according to their knowledge of local conditions and current management practices. Experts were also asked to comment on and revise the assumptions of tree densities, rotation intervals, and management practices for each land use and restoration intervention.

A2.2.1 Agriculture to Agroforestry

A2.2.1.1 Agriculture

We model the costs and benefits of traditional agriculture by assuming farmers receive benefits from the production and sale of rain-fed crops less any associated costs. Additionally, we assume that traditional agriculture produces no public benefits in terms of carbon storage and prevented erosion.

Private benefits = Crop production*price - Costs

Public benefits = 0

Costs include labor (land preparation, seed sowing, fertilizer application, weeding, threshing, and harvesting) and material inputs (seeds, fertilizer, and small agricultural equipment).

A2.2.1.2 Agroforestry

We model the costs and benefits of agroforestry by assuming farmers plant 300 agroforestry trees per hectare and that farmers receive benefits from the harvest and sale of crops and fuel wood in addition to receiving a benefit from prevented erosion less any associated costs. We assume 50% of woody biomass is harvested and sold as timber after a 20-year rotation interval. We further assume that the public benefit from agroforestry is measured through increased carbon storage and prevented erosion.

Private benefits = Crop production*price + wood*price + erosion*price - costs

Public benefits = Carbon*price + erosion*price

A2.2.2 Poorly managed woodlots to well managed woodlots

We assume that poorly managed woodlots produce eucalyptus for fuel wood and timber using a stocking density of 1100 trees per hectare. We assume well-managed woodlots stock 1600 trees per hectare. Woodlots used to produce fuel wood are coppiced every 7 years, while timber is grown over a 28-year rotation interval. After the first year we assume 30% of seedlings are replaced in poorly managed woodlots while 15% of seedlings are replaced in well-managed woodlots. After four years 250 trees are removed for thinning and sold for poles at a price of RWf 2,000. Fuel wood is sold for RWf 8,800 per steere while timber is sold for RWf 10,900 per cubic meter.

Private benefits of poorly managed woodlots = Wood production*price - costs

Public benefits of poorly managed woodlots = 0

Private benefits well managed woodlots = Wood production*price - costs

Public benefits well managed woodlots benefits = Carbon*price

A2.2.3 Deforested land to natural regenerated forest

We assume deforested land can be transitioned to naturally regenerated forests. We assume deforested land produces no public or private benefits. Naturally regenerated forests provide carbon storage and erosion prevention services less any associated restoration costs. We assume the costs of the transition are demarcating the site, providing regenerating assistance during the first year, and monitoring the site in subsequent years.

Deforested benefits (public and private) = 0

Public benefits of naturally regenerated forests = $\text{Carbon} \times \text{price} + \text{erosion} \times \text{price} - \text{costs}$

Private benefits of naturally regenerated forests = 0

A2.2.4 Deforested land to protective forests

We assume deforested land can be transitioned to protective forests. We assume deforested land produces no public or private benefits. Protective forests provide carbon storage and erosion prevention services less any associated restoration costs. We assume the costs of the transition are site clearing, seedling purchase, transport, and planting, as well as monitoring and evaluating the site in subsequent years.

Deforested land benefits (public and private) = 0

Public benefits of protective forests = $\text{carbon} \times \text{price} + \text{erosion} \times \text{price} - \text{costs}$

Private benefits of protective forests = 0

A2.3 Costs

The costs considered in the financial analysis are hired and household labor, which covers activities including: bush clearing, planting, monitoring, demarcation, regeneration assistance, thinning, coppicing, beating-up, and establishment and maintenance of anti-erosion ditches. We also considered the costs of inputs such as seeds, seedlings, organic fertilizer, and small agricultural equipment. Table A2 shows an example for Maize.

Table A2: Example agriculture budget for Maize in Rwanda.

Annual maize farm budget for Rwanda (1 hectare)				
Items	Unit	Quantity	Unit Price	Total cost (RWf)
Variable input costs				
Hired labor	Work days	22	1,000	22,000
Household labor	Work days	199	500	99,500
Seeds	Kg	40	93	3,720
Organic fertilizer	Kg	3,000	2	6,000
Capital costs			660	660
Small agricultural equipment			1,900	1,900
Discounted value of costs				2,932,635

We modeled the costs of each land use and restoration intervention using a combination of peer-reviewed data and expert opinions. We presented the budgets to agricultural and forestry experts at four workshops held in Rwanda during October 2013.⁶⁷ The budgets were presented to the workshop participants and they were asked to revise the estimates according to their knowledge of local conditions and current management practices. Experts were also asked to comment on and revise the assumptions of tree densities, rotation intervals, and management practices for each land use and restoration intervention.

A2.4: Ecosystem service modelling

We use mean-annual increment values of representative species for agroforestry, woodlots, and protective forest systems in Rwanda to estimate the amount of aboveground biomass for each land use and restoration intervention. Above ground biomass estimates are converted to carbon estimates using the IPCC Tier 1 methodology. We estimate erosion for each land use and restoration intervention by using provincial-level seasonal precipitation data from Meteo Rwanda and data from a GIS database from the Rwanda Natural Resource Authority. We estimate average crop yields for maize and beans with district level crop yield and planted area data from the ministry of agriculture (MINAGRI) and provincial-level seasonal precipitation data from Meteo Rwanda.

A2.4.1 Timber

To estimate the mean annual increment of timber growth for 1-hectare of agroforestry, woodlot, or planted forest we used data on the distribution of mean annual increments for *Grevillea robusta* from (Kalinganire, 1996), (Belgian Development Agency, 2012) for *Eucalyptus tereticornis*, and (Africa Forest Forum, 2011) for *Pinus patula*, respectively. While (Bucago, Vanlauwe, Van Wijk, & Giller, 2012) have shown that farmers will use a wide range of agroforestry species to meet their individual needs, even within the same geographic area, we modeled the additional timber and fuel wood production of agroforestry with *Grevillea robusta* as it is the most popular species grown on farms (Kalinganire, 1996). Eucalyptus species are the most commonly grown species on fuel wood plantations and on-farm woodlots and *Pinus patula* is commonly grown in planted forests as well as the buffer zones surrounding indigenous forest reserves (Ndayambaje & Mohren, 2011).

⁶⁷ Workshops were held in Southern, Western, Eastern, and Kigali province in October 2013.

Table A3: Mean annual increments of representative tree species used in the economic analysis.

Mean annual increment (Cubic meters)					
Species	Single tree	300 trees per hectare	1100 trees per hectare	1600 trees per hectare	Source
<i>Grevillea robusta</i>	0.0048 (0.002)	1.44 (0.6)			Kalinganire, 1996
<i>Eucalyptus tereticornis</i>	0.0065 (0.001)		7.15 (1.1)	10.4 (1.6)	Belgian Development Agency, 2012
<i>Pinus petulla</i>	0.003 (0.0005)			4.8 (0.8)	Africa Forest Forum, 2011
Notes: Standard errors are in parenthesis. <i>Grevillea robusta</i> was only considered in agroforestry context with a density of 300 trees per hectare. <i>Pinus petulla</i> was only considered for planting densities of 1600 trees per hectare.					

Each land use and restoration intervention was assigned a stocking density for the most common tree species associated with the land use or restoration intervention. Stakeholders widely reported that an additional 300 trees per hectare could be planted as part of an agroforestry intervention. Eucalyptus woodlots are currently stocked at a density of 1,100 trees per hectare, but an improved stocking regime could increase the density to 1,600 trees per hectare (Belgian Development Agency, 2012). A density of 1,600 trees per hectare was also assumed for the planted forests.

Table A3 reports the mean annual increment and its standard deviation for individual species of tree, which we multiplied by stocking density to calculate the aboveground biomass (AGB) for each land use and restoration transition. We assume the average annual growth of each species is distributed normally.

A2.4.2 Carbon sequestration

Estimates of carbon sequestration are calculated for each restoration transition with the IPCC Tier 1 methodology from the Good Practice Guidelines (IPCC, 2003) using the aboveground biomass estimates discussed above. For the Tier 1 method it is important only to know how much carbon degraded land-uses store in above and belowground biomass and how that number would change if the land were restored.

Estimates of biomass, especially in forests, are often reported in terms of standing volume (cubic meters), but since carbon is reported as a weight (tonnes) the standing volume estimates have to be converted. First, standing timber volume (cubic meters) is converted to weight (Kg) using a biomass conversion expansion factor (BCEF) appropriate for the climate zone and forest type (Equation 1):

$$\text{Above ground biomass}_i(\text{AGB}) = M^3 * \text{BCEF}_s^i \quad [1]$$

Where i indexes the growing stock level and BCEF is the Biomass Conversation Expansion Factor.

Belowground biomass, or Root Biomass Dry Matter (RBDM), is calculated using an equation that converts aboveground biomass to RBDM:

$$\text{RBDM} = e^{(-1.805 + 0.9256 * \ln(\text{AGB}_i))} \quad [2]$$

Where AGB is above ground biomass for growing stock level i . Once the standing volume of timber biomass has been converted to a weight, the weight of carbon is estimated by assuming biomass is 49% carbon by weight (IPCC, 2003). The total carbon sequestered per hectare is found by:

$$C (\text{tonnes}) = (\text{AGB} + \text{RBDM}) * 0.49 \quad [3]$$

Where 0.49 is the conversation factor for tons of dry matter to carbon (IPCC, 2003). The estimate could be converted to units of CO₂e by multiplying it by 3.67, which is the ratio of the atomic mass of CO₂e and C, respectively.

A2.4.3 Erosion

The Universal Soil Loss Equation (USLE) was developed as a tool to easily quantify the long-term average annual soil loss of cultivated land under various conditions in order to allow farmers and policy makers to select land use practices that will keep erosion to an acceptable level (Hudson, 1993). Additionally, most of the soil and climactic data collected in Africa is intended to be used with the USLE (Bishop & Allen, 1989). However, information was not available to link erosion to declines in crop yields, water quality, or power generation, so results are presented entirely in physical units and are not part of the NPV and ROI calculations.

We combine monthly precipitation data from 2007 to 2009 from Meteo Rwanda, with soil erodibility and soil cover values from a GIS database provided by the Rwandan Natural Resources Authority, and slope estimates from the 2008 Rwandan Agricultural Survey, at the provincial level, to estimate the amount of erosion associated with each land use and restoration intervention using the Universal Soil Loss Equation:

$$Erosion = R * K * LS * C \quad [4]$$

Where

R = Energy delivered during each precipitation event

K = Soil erodibility index

LS = Plot length and Slope

C = Soil cover factor

Table A4 displays the information used to estimate erosion for each land use and restoration intervention. Annual precipitation data was converted into an estimate of energy intensity, R , by dividing the total precipitation by the average number of annual precipitation events, which we assumed to be 124 per year, and assuming each event lasts an average of 3 hours. The soil erodibility index, K , and soil cover factor, C , were queried from a GIS database provided by the Rwandan Natural Resources Authority for each land use and restoration intervention. Plot lengths were estimated from the 2008 Rwandan Agricultural Survey by taking the square root of the average plot size for each province.

Table A4: Parameter values used to estimate erosion

Land Use	Universal Soil Loss Equation Variable				Average annual erosion (t/ha)
	R	K	LS	C	
AG	332	0.12	1.5	0.3	17.928
AF	332	0.12	1.5	0.1	5.98
PME	431	0.15	1.5	0.15	14.55
IME	431	0.15	1.5	0.1	9.70
DF	428	0.16	1.5	0.1	10.27
NR	428	0.16	1.5	0.01	1.03
PF	428	0.16	1.5	0.01	1.03

A2.4.4 Crop yields with traditional agriculture and agroforestry

Crop production in Rwanda is largely rain-fed, with more than 1 million hectares relying solely on rain while less than 5,000 hectares are irrigated and fertilizer is applied to less than 3% of cropland (Habiya Mbere T., *et al.*, 2009). Variations in rainfall can cause variations in crop yields over time, introducing an element of uncertainty into the data. In order to account for this uncertainty we use a panel data set of crop production and seasonal

precipitation from 2007 to 2009 at the provincial level from RNRA and Meteo Rwanda, respectively, to estimate a fixed-effects cobb-douglas production function of maize and bean yields for each district:

$$Yield = Precipitation^{\beta_1} * Area^{\beta_2} \quad [5]$$

The fixed-effects model estimates the change in average per hectare crop yield within a district as a function of the total land area devoted to the crop and the amount of precipitation received during the growing season. Variables, such as soil type and slope, that do not change within a district do not factor into the estimate because they are constant with respect to time (Gujarati, 2008). Table A5 reports the means of the data used in the regression.

Table A5: Means of data used in crop yield regression

Crop yield regression data means		
Variable	Maize	Beans
Average yield (t/ha)	3.63 (8.22)	0.91 (0.22)
Land area (ha's)	2,669 (1681)	590 (175)
Precipitation (mm)	591 (175)	591 (175)
Observations	115	114
Notes: Standard errors in parenthesis		

Table A6 shows the results from the regression analysis. The coefficient estimates for precipitation and land area are both significant at the 99% level and the signs of both parameter estimates are consistent with expectations. More growing season precipitation is correlated with higher crop yields, on average. The negative sign of the Land Area coefficient reflects the fact that as cultivation of maize or beans is expanded more marginal land is used.

Table A6: Crop yield regression results

Crop yield regression results		
Variable	Maize	Beans
Precipitation (mm)	0.85*** (0.14)	0.37*** (0.09)
Land area (ha)	-0.77*** (0.11)	-0.29*** (0.21)
Observations	115	114
R-squared	0.6	0.53
F-Value	6.69	4.92
Notes: Standard errors in parenthesis		

We estimate the crop yields that could be achieved with agroforestry using information from (Dreschel, Steiner, & Hagedorn, 1996), which reported the impacts of agroforestry systems on crop yields in Rwanda as a percentage of traditional agricultural yields. The authors found that, depending on the agroforestry system and crop, the yield response could range from between -35% to + 65% compared to traditional agricultural yields (Dreschel, Steiner, & Hagedorn, 1996). To estimate the yield of agroforestry, we first calculate the yield of traditional agriculture and multiply its value by the expected crop yield response.

A2.5 Net Present Value (NPV) and Return on Investment (ROI)

The Net present value (NPV) concept allows various sums of money to be compared over time. We estimate the NPV that a land owner would receive for each land use and restoration intervention by forecasting all future costs and revenues and then subtracting the present value of costs from the present value of revenues, discounted at a 7% rate of discount. Next, we calculate the NPV of each restoration transition by subtracting the NPV of each land use from the NPV of the restoration intervention. If the NPV of the restoration transition is greater than 0 it suggest restoring the degraded landscape is an worthwhile endeavor while a NPV less than 0 suggests restoring the degraded landscape will generate fewer benefits than costs. The NPV of all costs and revenues are forecasted for the economic time horizon, which varies between 20-30 years depending on which land use or restoration intervention is being considered.

We use the NPV from each land use and restoration intervention to calculate the ROI of each restoration transition following (Goldstein, Pejchar, & Daily, 2008). Higher ROI's reflect investments that return more benefits per RWf invested.

We calculate NPV and ROI as follows:

$$NPV = \sum_{t=0}^T \delta^t (B_t - C_t) \quad [6]$$

$$ROI = (NPV_{ri} - NPV_{lu}) / (TC_{ri} - TC_{lu}) \quad [7]$$

Where B_t is the total annual benefit received from the land use or restoration intervention from the production of ecosystem goods and services, C_t is the annual cost associated with that revenue, and δ^t is the discount factor. In the ROI calculation, NPV_{ri} is the NPV of the restoration intervention, NPV_{lu} is the NPV of the current land use, and TC_{ri} , TC_{lu} is the total cost of the restoration intervention and current land use, respectively.

A2.7 Repeated random sampling

The benefit streams and non-monetary benefits of restoration depend on inherently random ecological parameters, including precipitation and tree growth rates. However, the uncertainty over which values these parameters will take introduces an element of risk into the analysis. In order to take account for this uncertainty we use a repeated random sampling technique known as Monte Carlo simulations. Several authors have used Monte Carlo simulations in forestry settings to account for risk in economic analyses (van Kooten, van Kooten, & Brown, 1992) (Moore, Ruel, Lapointe, & Lussier, 2012)). This technique also allows confidence intervals to be constructed around the estimated NPV of restoration (Naidoo & Ricketts, 2006) on transitions as well as to identify the situations under which a restoration transition is unlikely to create a benefit.

Table A7 lists the assumptions and data sources used in the Monte Carlo simulations. A Monte Carlo simulation creates data by drawing values from the distribution of a given variable instead of assuming a single average value that does not take into account than range of value that might be observed in the field. Since ecological outcomes such as tree growth determine the net benefit of each land use and restoration intervention we used the Monte Carlo method to generate data representing a range of outcomes one might expect on different land uses. We assume mean annual increments are normally distributed and parameterized distributions for three tree species with peer-reviewed or secondary data sources.

In order to estimate and characterize the distribution of crop yields, we estimate the distribution of total growing season precipitation using a Kernel Density Estimator (KDE). Monthly precipitation data were retrieved from Meteo Rwanda for twelve districts from Rwanda for 2007 – 2012. Some district data was missing values for certain months in a non-systematic fashion. We used the average monthly value of precipitation for observable years to fill in the missing monthly precipitation values. Denoting the random sample of monthly precipitation observations as $x_i \in \{x\}$, the KDE for precipitation can then be written as:

$$\hat{f}(x; h) = \frac{1}{nh} * \sum_{i=1}^n k\left(\frac{x-x_i}{h}\right) \approx \hat{f}_h(x) = \frac{1}{n} * \sum_{i=1}^n k_h(x - x_i) \quad [8]$$

Where:

$\hat{f}(x; h)$ = kernel density estimator

$k(\cdot)$ = is the kernel function

h = bandwidth (i.e. the smoothing parameter)

Once the optimal bandwidth, h^* , has been identified, the distribution is sampled as follows. A random observation, $x_i \in \{x\}$, is drawn from the monthly precipitation data set and used to estimate the KDE. Once an x_i has been drawn, a random observation is generated from the kernel $k(x_i, h^*)$, centered on x_i and where h^* is the bandwidth that minimizes the MSE.

Table A7: Distributions and data sources used in the Monte Carlo analysis

Transition	Distribution Assumption for Monte Carlo			Sample size
	Timber	Crop increase	Carbon	
TAG to AFCL	MAI~N (1.44, 0.6)	Increase ~Tri(-0.35, 0.6)		100,000 draws of 20-year time horizons
PME to IME	MAI~N (10.4, 1.6)		CO ₂ e~N(300,100)	100,000 draws of 28-year time horizons
DF to NR				100,000 draws
DF to PF	MAI~N (4.8, 0.8)			100,000 draws of 30-year time horizons
Notes: MAI for TAG TO AFCL is for <i>Grevilea robusta</i> at a stocking density of 300 trees/ha. MAI for PME to IME is for <i>Eucalyptus tereticornis</i> and a stocking density of 1600 trees/ha. MAI for DF to PF is for <i>Eucalyptus tereticornis</i> and a stocking density of 1600 trees/ha.				

This exercise is repeated thousands of times in order to generate a large sample of weather data that is used to estimate the distribution of crop yields.

Detailed data was not available on the distribution of crop increase effects of agroforestry so we assume the effect is triangularly distributed because the distribution does not require information on standard errors. We sample from each distribution 100,000 times in most cases and calculate the NPV of each restoration transition based on the data from the Monte Carlo simulation.

Appendix A2 Works Cited

- Africa Forest Forum. (2011). Forest Plantations and Woodlots in Rwanda. Africa Forest Forum. Nairobi: Africa Forest Forum.
- Belgian Development Agency . (2012). Support program to the reforestation in 9 districts of the northern and western provinces of Rwanda. Belgian Development Agency. Belgian Development Agency.
- Bucago, C., Vanlauwe, B., Van Wijk, M., & Giller, K. (2012). Assessing farmers' interest in agroforestry in two contrasting agro-ecological zones of Rwanda. *Agroforestry Systems*, 88, 141-158.
- Goldstein, J. H., Pejchar, L., & Daily, G. C. (2008). Using return-on-investment to guide restoration: a case study from Hawaii. *Conservation letters*, 1, 236-243.
- Habiyambere , T., Mahundaza , J., Mpambara , A., Mulisa , A., Nyakurama , R., Ochola , W. O., *et al.* (2009). Rwanda State of Environment and Outlook. Kigali: REMA.
- Kalinganire, A. (1996). Performance of *Grevillea Robusta* in plantations and farms under varying environmental conditions in Rwanda. *Forest ecology and management*, 80, 279-285.
- Naidoo, R., & Ricketts, T. (2006). Mapping the Economic Costs and Benefits of Conservation. *PLOS Biology*, 140, 2153- 1264.
- Ndayambaje, J., & Mohren, G. (2011). Fuelwood demand and supply in Rwanda and the role of agroforestry. *Agroforestry Systems*. 83, 303-320.
- Van Kooten, G., van Kooten, R., & Brown, G. (1992). Modeling the Effect of Uncertainty on Timber Harvest: A Suggested Approach and Empirical Example. *Journal of Agricultural and Resource Economics*. 17, 162-172.

Appendix 3: Rapid Restoration Diagnostic

There are a number of factors that -when present- increase the likelihood that forest landscape restoration will successfully occur. These “key success factors” fall into three themes:

1. **Motivate.** Decision-makers, landowners, and citizens are inspired or motivated to restore forests and trees on landscapes.
2. **Enable.** Background or enabling conditions (e.g., environmental, market, policy, social, institutional) that facilitate forest restoration are in place.
3. **Implement.** Capacity and resources are effectively mobilized to implement forest restoration on the ground.

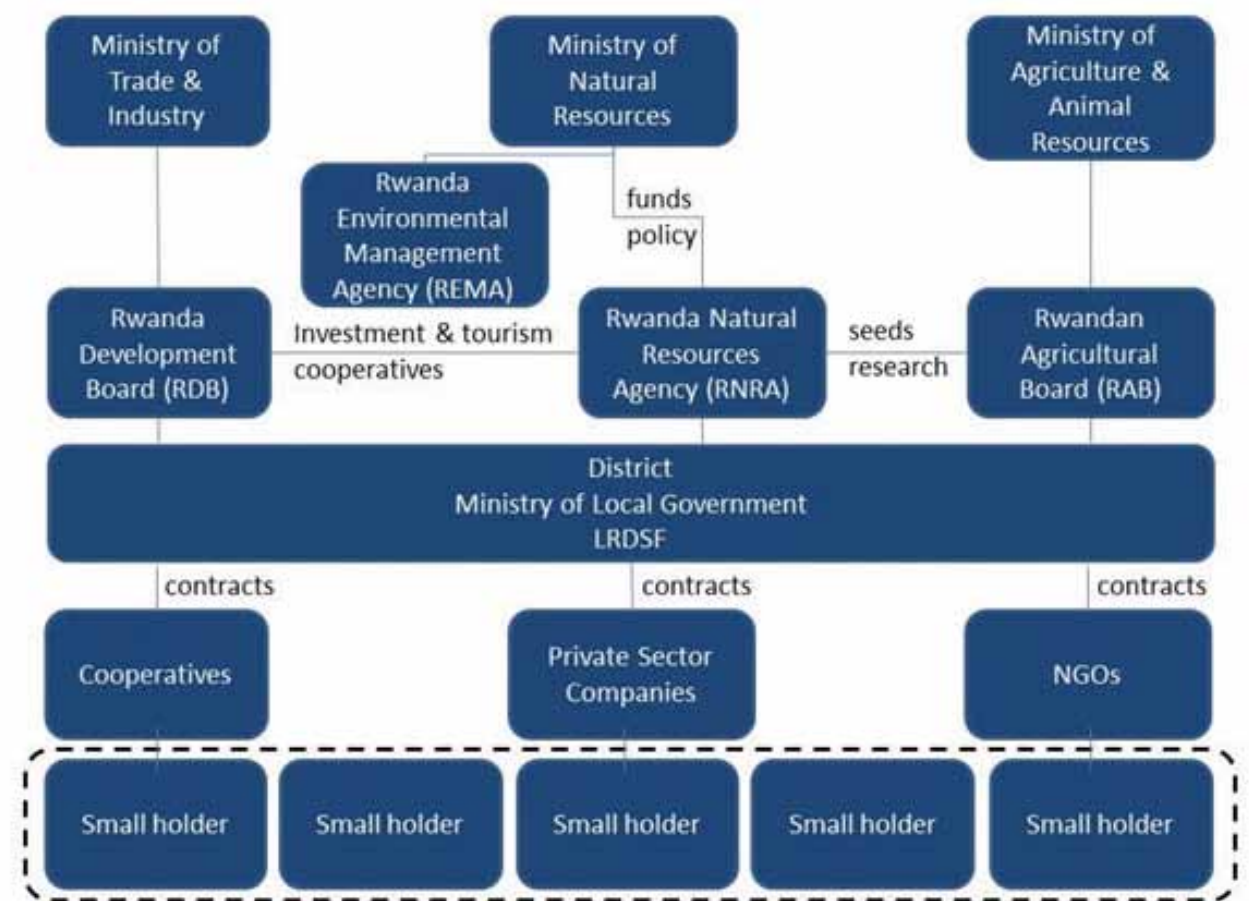
WRI and IUCN will be publishing a “Rapid Restoration Diagnostic” that helps identify which success factors already exist and which are currently missing within landscapes being considered for restoration. It is designed to help decision-makers identify factors that must be addressed before investing large amounts of human, financial, or political capital in forest landscape restoration. The preliminary version of this diagnostic that was used in Rwanda is shown in Table A8:

Table 1: Key success factors for forest landscape restoration

Theme	Feature	Key success factor
1. Motivate	Benefits	• Restoration provide economic, environmental, social and cultural benefits
	Awareness	• Benefits of restoration are publicly communicated • Opportunities (e.g., where, how much) for restoration are identified
	Crisis event	• Crisis events are leveraged
	Legal requirements	• Law requiring restoration exists and is enforced
2. Enable	Ecological conditions	• Soil, water, climate, and fire conditions are suitable for restoration • Plants and animals that can impede restoration are absent • Native seeds, seedlings, or source populations are readily available
	Market conditions	• Competing demands for alternative use for degraded lands are declining • Accessible markets for products from restored areas exists
	Policy conditions	• Land and natural resource tenure are secure • Policies affecting restoration are aligned and streamlined • Restrictions on clearing natural forests exists and is enforced
	Social conditions	• Local people are empowered to make decisions about restoration • Local people are able to benefit from restoration
	Institutional conditions	• Responsibility for restoration is clearly defined • Effective institutional coordination is in place
3. Implement	Leadership	• National and/or local restoration champions exist • Sustained political commitment exists
	Knowledge	• Restoration “know-how” relevant to candidate landscapes exists • Restoration “know-how” transfered via peers or extension services
	Technical design	• Restoration design is technically grounded and climate resilient
	Financing and incentives	• “Positive” incentives and funds for restoration outweigh “negative” incentives for <i>status quo</i> • Incentives and funds readily accessible
	Feedback	• Effective performance monitoring and evaluation in place • Early wins are communicated

Appendix 4: Institutional stakeholders for Restoration in Rwanda

Primary Stakeholders of FLR in Rwanda



• Primary stakeholders

- MINIRENA / REMA / RNRA (Natural resources): land, water, forests, agroforestry advice
- MINAGRI / RAB (Agriculture): seeds, research, extension, including agroforestry
- MINILOC / LRDSF (Local government): implementation, administration and monitoring
- MINICOM / RDB (Trade & industry): cooperatives, private sector, investment, tourism

• Secondary stakeholders

- MINIFRA (Infrastructure / Energy): hydropower, payments for ecosystem services
- MIDIMAR (Disaster management): assistance during landslides, fires, etc.
- MINADEP (Defense): labor force for restoration activities
- MININTER (Internal security): labor force for restoration activities

• Other key stakeholders

- MINECOFIN / NISR (Finance / Statistics): budget allocation, data and information
- MIFOTRA (Labor): human resource allocation and capacity building



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