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Client

Economics of Land Degradation (ELD) Initiative

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Date: 29.05.2020

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LIST OF ACRONYMS AND ABBREVIATIONS

AFR100	African Forest Landscape Restoration Initiative
ANR	Assisted Natural Regeneration
BAU	Business as usual
BMZ	Federal Ministry of Economic Cooperation and Development (Germany)
CBA	Cost-benefit Analysis
ELD	Economics of Land Degradation
FAO	Food and Agriculture Organization
FLR	Forest Landscape Restoration
FMNR	Farmer Managed Natural Regeneration
Ha	Hectare
ICRAF	World Agroforestry Centre
IUCN	International Union for Conservation of Nature
LDN	Land Degradation Neutrality
m.a.s.l	Meters above sea level
NP	National Park
NWFP	Non-wood forest product
REDD+	Reducing Emissions from Deforestation and Degradation
SDG	Sustainable Development Goal
SLM	Sustainable Land Management
TEV	Total Economic Value
WRI	World Resources Institute
UNCCD	United National Convention to Combat Desertification

GLOSSARY

Agroforestry

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos etc.) are deliberately used on the same agricultural lands (with crops and/or animals), in some form of spatial arrangement or temporal sequence. There are three main categories of agroforestry systems, namely agrisivicultural (combination of crops and trees, e.g. homegardens); silvopastoral (combination of forestry and grazing of domesticated animals on pastures, rangelands, or on-farm); and agrosylvopastoral (a combination of trees, crops and animals, e.g. scattered trees on croplands used for post-harvest grazing). (FAO, 2015)

Deforestation

The conversion of forest to another land use, such as arable land, urban use, logged area or wasteland, where tree canopy cover falls below the 10% threshold in the long-run. (FAO, 2007)

Evergreen agriculture

Evergreen agriculture is a form of agroforestry focused on the integration of particular trees into annual food crop and agricultural systems. The intercropped trees sustain a green cover on the land throughout the year, resulting in multiple benefits such as constant vegetative soil cover, increased nutrient supply in soil surface residues, improved soil structure and water infiltration, increased direct production of food, fodder, fuel, fiber and income, and enhanced carbon storage and biodiversity. (Garrity et al., 2010)

Farmer Managed Natural Regeneration (FMNR)

FMNR is a form of coppicing and pollarding, drawing on traditional practices. It involves the systematic regeneration, management and regrowth of trees and shrubs from felled tree stumps, roots and seedlings, mainly on agricultural land. In FMNR systems, farmers protect and manage the growth of trees and shrubs that regenerate naturally in their fields from root stock or from seeds dispersed through animal manure.It is a simple, low-cost way for farmers to increase the number of trees in the fields. (SDG Partnerships Platform, 2020)

Forest

Forest is defined as as land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use. (FAO, 2015)

Forest cover

Forest cover is defined as 25% or greater canopy closure at the Landsat pixel scale (30-m × 30-m spatial resolution) for trees >5 m in height. (Hansen et al. 2010)

Forest degradation

The long-term reduction in overall supply or quality of benefits from forest, which includes wood, biodiversity and other products or services, but where the forest may naturally regrow under some circumstances. It does not necessarily cause a change in land use, unlike with deforestation. The drivers of forest degradation may include timber/logging, wildfires, livestock grazing, fuelwood collection and charcoal production. (FAO, 2011)

Forest loss

A stand-replacement disturbance or the complete removal of tree cover canopy at the Landsat pixel scale. (Hansen et al. 2013)

Forest landscape restoration (FLR)

FLR is the ongoing process of regaining ecological functionality and enhancing human well-being across deforested or degraded landscapes. FLR is more than just the planting of trees – it is restoring a whole landscape to meet present and future needs and to offer multiple benefits and land uses over time, using techniques ranging from policy change to erosion control to afforestation. (IUCN, 2020)

Forest gain

The inverse of loss, or the establishment of tree canopy from a nonforest state. (Hansen et al. 2013)

Land degradation

There is no set definition for the term land degradation, as it must be considered in the context of various principles, criteria, indicators and metrics. When in use in this report, the term refers generally to the deterioration or loss of the biological, economic and productive capacity of the soils (on crop, range, forest or other land) for present and future use. (GEF, 2020)

Land degradation neutrality (LDN)

LDN represents a paradigm shift in the field of land management policies and practices. It is described as a state whereby the amount and quality of land resources that is necessary to support ecosystem functions and services and enhance food security remains stable or increases within specified temporal and spatial scales and ecosystems. SDG 15.3 aims to achieve LDN by 2030. (UNCCD, 2020c)

Sustainable Land Management (SLM) practices

The use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions. SLM practices protect and enhance the multiple services and functions provided by land, including provisioning, regulating, supporting and cultural services. (UNCCD, 2020b)

Tree cover

Tree cover is defined as all vegetation greater than 5 meters in height, and may take the form of natural forests or plantations across a range of canopy densities. Tree cover loss is defined as "stand replacement disturbance," or the complete removal of tree cover canopy at the Landsat pixel scale. (Global Forest Watch, 2019)

EXECUTIVE SUMMARY

Introduction to Regreening Africa and aim of this report

The *Reversing Land Degradation in Africa by Scaling-up EverGreen Agriculture (*short: *Regreening Africa)* project (2019-2022) is managed by the World Agroforestry (ICRAF) and the *Economics of Land Degradation* (ELD) Initiative hosted by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The project is co-funded by the European Commission and the German Government. It seeks to reverse land degradation among 500,000 households and across one million hectares in eight Sub-Saharan African countries (Mali, Senegal, Ghana, Niger, Kenya, Rwanda, Ethiopia and Somalia) by scaling-up EverGreen Agriculture.

The core objective of *Regreening Africa* is to accelerate the scaling-up of restoration activities using locally appropriate techniques such as Farmer-Managed Natural Regeneration (FMNR), tree planting and other forms of agroforestry, along with the development of agroforestry value chains. Expected outcomes include improved livelihoods, food security and climate change resilience through restored landscapes and ecosystem services. The project further seeks to contribute to various international land restoration initiatives, including the AFR100 and Great Green Wall Initiatives.

UNIQUE forestry and land use was commissioned to undertake a literature review and economic analysis to inform the project's strategy to reverse land degradation and scale-up restoration. This report contributes to the project by (i) developing a summary of the trends in deforestation and woody biomass loss in the target countries, assessing its links to land degradation and presenting an overview of its economic consequences globally and in Sub-Saharan Africa in particular; (ii) compiling an overview from literature of sustainable land management (SLM) practices suitable for agricultural and drylands across the target countries, and (iii) presenting an economic meta-analysis of one of the approaches, i.e. FMNR, based on three (ELD) case studies (Nouhou et al. 2019, Sanogo et al. 2019, Westerberg et al. 2019) carried out in the framework of the Regreening Africa project, (iv) providing a cautious economic and spatial projection exercise on potential benefits of further up-/ out-scaling of FMNR in West and East Africa. The focus lies on the target countries of the Regreening project.

Deforestation and land degradation in East and West Africa

Amongst other aims, Regreening Africa seeks to contribute to the UNCCD agenda on SDG 15.3: achieving Land Degradation Neutrality (LDN) by 2030. **Land degradation in the Sahel is strongly driven by unsuitable or inappropriate land use and management practices that result in deforestation and the conversion of grasslands and forest lands for agricultural purposes.** The removal of trees and vegetation accelerates rainfall runoff and soil erosion, diminishing productivity of the land and increasing vulnerability to flooding. The project's approach to reverse degradation and scale-up restoration through SLM practices hangs on counterbalancing the expected loss of productive land with the recovery of degraded areas across multiple land uses through improved land use planning and community or multi-stakeholder driven restoration options (UNCCD, 2020). An understanding of the dimensions of deforestation and woody biomass loss, and their links to land degradation, are therefore key to informing the strategy to reverse these trends through SLM, and to achieving SDG 15.3.

On a global scale, trees and forests need to be considered as renewable, critical natural capital for their ability to regenerate, provide long-term benefits and ecosystem services, and perform important, unique provisioning, regulating, supporting and cultural functions. Deforestation, tree loss and land degradation therefore have broad reaching, global consequences on both bi-ophysical and economic levels. The annual cost of land degradation in Africa due to land use cover and change (mainly deforestation and conversion for agriculture) is estimated to reach USD 66 billion (2007 values), which is over 7% of the region's GDP (Nkonya et al., 2015). The cost of taking action against land degradation is much lower than the cost of inaction, and the returns on these actions can be high. On average, one US dollar investment into restoration of degraded land returns five US dollars (Nkonya, 2015).

Although deforestation is high is many places, other places show various land and forest restoration success stories, indicating that the potential to upscale these practices across the region is high**.** For example, over 5 million ha have been restored in the Maradi and Zinder regions in Niger in the past two decades (Sendzimir et al., 2011), and 15 million ha of degraded land have been restored in Ethiopia under the Great Green Wall Initiative (UNCCD, 2020a). Studies have also found that following severe droughts and famines between the late 1960s and early 1990s, farmers and land users across the region have adapted and increasingly employ improved soil and water management practices. There is evidence of a long term transition from degradational land use trajectories to more sustainable and productive production systems (Hermann et al., 2005).

Sustainable land management (SLM) practices

SLM broadly includes a variety of soil, water, biodiversity and land management practices that are crucial for maintaining a healthy ecosystem, sustaining livelihoods and achieving national LDN and AFR100 targets (World Bank, 2008). It is an important consideration in the regreening process, and includes approaches such as FLR, FMNR and tree planting (i.e. agroforestry in general). It is important to note that these land restoration systems are overlapping and complementary. SLM practices generally require low levels of technology or equipment, making it an easy approach for farmers and local management committees to adopt.

Forest Landscape Restoration (FLR) operates in the context of SLM and aims to restore ecological functionality and enhance human well-being across deforested or degraded landscapes. The planting of trees is therefore just one facet of the approach, which aims to restore whole landscapes (including forest, grasslands and other land uses). Aside from classic forestry activities such as afforestation, reforestation, enrichment planting and assisted natural regeneration, FLR practices can also entail agroforestry and FMNR in particular, invasive species control, erosion control and others, implemented across the entire landscape (Stanturf et al., 2017). FLR best practices are highly complementary to the project's restoration efforts (to agroforestry and FMNR in particular). FLR is further relevant to the project in achieving LDN targets, and for its link to the AFR100 Initiative, which is a country-led effort to restore 100 million hectares of deforested and degraded landscapes across Africa by 2030. All *Regreening Africa* project countries except Somalia have made AFR100 commitments.

Agroforestry is the collective name for land use systems and practices in which woody perennials are deliberately and systematically integrated with crops and/or animals on the same land management unit. Within agroforestry systems, it is possible to grow or maintain multiple high-value production systems such as wood (including high value trees for timber and poles), non-wood forest tree products (NWFPs), apiculture, fodder and horticulture. Studies have shown that land restoration done through sustainable agricultural practices – particularly through the incorporation of trees – can bring additional revenue in terms of overall better yields and fuel-wood (Sidibé, Myint and Westerberg, 2014).

Evergreen agriculture as a form of agroforestry is defined as the integration of particular tree species into annual food crop systems. Scaling up context sensitive techniques such as FMNR, tree planting and other forms of tree management through evergreen agriculture is a core objective of the Greening Africa project. Interventions in East and West Africa involve a mix of enclosures, tree protection and management. It also entails direct tree planting through seeds or cuttings (sourced for example through decentralized nurseries), where natural regeneration is limited, or to meet species-specific, production or conservation objectives.

FMNR, an SLM technique used in evergreen agriculture and agroforestry, is the focus of the economic analysis. The approach aims to create a vegetative cover (i.e. agroforestry parkland system) by proactively nurturing natural tree regeneration (either from stumps or from seeds) to increase tree cover in fields with the goal of increasing the value or quantity of woody vegetation on farmland. It can be used wherever there are living tree stumps with the ability to coppice (re-sprout) or seeds in the soil that will germinate. Publications by the ELD Initiative confirm that this practice has enabled farmers in southern Niger, central Senegal, northwest and northeast Ghana, southern Burkina Faso and Mali (among others) to improve the fertility of millions of hectares of cropland. The beginnings of successful farmer-managed restoration are also evident in Malawi, Zambia and other countries. (ELD Initiative, 2020). In the project context of arid and semi-arid regions, FMNR emerges as a highly appropriate technology for disaster risk reduction and improving land productivity. It is a quick, affordable and easy to replicate system, driven by landowners and communities themselves (Rinaudo et al., 2018).

Returns from FMNR

Three Cost Benefit Analyses of FMNR in Niger, Senegal and Ghana were conducted in 2019. These three CBAs were carried out by the ELD Initiative in the framework of the Regreening project in the same areas as the current project sites of the ICRAF component of the Regreening project in those particular countries. The studies employed the 6+1 step approach[1], an analysis method that has been adopted by the ELD Initiative to guide users through the process of establishing scientifically sound cost-benefit analyses to inform decision-making processes.

The review of the case studies leads to the conclusion that FMNR exhibits a higher profitability than the next best business as usual (BAU) system. In Niger the net income including environmental services increased by USD 68 per ha per year. In Ghana net income increased by USD 43 per ha which is 78% more than net income of farmers not practicing FMNR. In Senegal net income increased by 84%, which is a similar increase as in Ghana. These results are in accordance with other findings in the literature, where FMNR was found to have a positive effect on income.

[1] https://www.eld-initiative.org/en/knowledge-hub/6-1-step-approach/

Projection of benefits of upscaling FMNR across target countries

The projection brings together the biophysical with the economic. Its starting point is the assumption that the target countries have the potential for a successful and widespread scaling-up of restoration using different SLM practices like FMNR. For each country GIS maps indicate the areas for scaling-up restoration. The economic analysis projects significant economic benefits. The results are sensitive to the discount rate selected. The type of FMNR adopted also makes a large difference on the net present value of economic benefits.

Chapter 1 of this report provides a summary of current trends and dimensions of deforestation, its links to land degradation and the economic consequences of these trends.

Chapter 2 provides an overview of existing and potential land restoration and SLM approaches, with a focus on Forest Landscape Restoration (FLR) and specific agroforestry systems such as FMNR and evergreen agriculture. The costs, benefits and returns from FMNR are also assessed with an economic meta-analysis.

Chapter 3 presents the results of a spatial and economic projection exercise, which assesses the economic benefits of further upscaling current FMNR, tree planting and other agroforestry initiatives.

INTRODUCTION

The European Commission/German Federal Ministry of Economic Cooperation and Development (BMZ) co-funded project *Reversing Land Degradation in Africa by Scaling-up EverGreen Agriculture (*short: *Regreening Africa)* (2019-2022) seeks to reverse land degradation among 500,000 households and across one million hectares in Sub-Saharan Africa. The target countries are Mali, Senegal, Ghana and Niger in West Africa, and Kenya, Rwanda, Ethiopia and Somalia in East Africa. The overall aim of the project is to improve livelihoods, food security and climate change resilience, while restoring ecosystem services provided by restored landscapes. The project also seeks to contribute to various international land restoration initiatives, including the United Nations Convention to Combat Desertification (UNCCD) driven agenda on achieving Sustainable Development Goal (SDG) 15.3: Land Degradation Neutrality (LDN) by 2030; the United Nations Decade on Ecosystem Restoration (2021-2030) and the Great Green Wall Initiative, as well as individual country-led contributions under the African Forest Landscape Restoration (AFR100) Initiative.

Regreening Africa will accelerate scaling-up of evergreen agriculture using locally appropriate techniques including Farmer-Managed Natural Regeneration (FMNR), tree planting and other forms of agroforestry, along with the development of agroforestry value chains. The project is managed by the World Agroforestry (ICRAF) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), which hosts the *Economics of Land Degradation* (ELD) Initiative.

To support these efforts and inform the strategy on reversing land degradation in target countries, this study aims to:

1. Comment on current trends in deforestation, its links to land degradation and the economic consequences of these trends;
2. Develop an overview of existing and potential land restoration approaches;
3. Assess the benefits, costs and success factors of past or ongoing FMNR restoration efforts;
4. Conduct a projection to extrapolate these findings and assess future effects of continued landscape degradation in a business as usual (BAU) scenario, and assess the economic benefits of further upscaling the current FMNR, tree planting and other agroforestry initiatives.

Chapter 1 of this report presents an overview on the dimension of deforestation and woody biomass loss in West and East Africa and its links to land degradation. The economic consequences of these trends are also highlighted.

Chapter 2 presents an overview on approaches for scaling-up sustainable land management (SLM) practices and land restoration through agroforestry, and offers an economic meta-analysis of one of the approaches, i.e. FMNR, based on three (ELD) case studies (Nouhou et al. 2019, Sanogo et al. 2019, Westerberg et al. 2019) carried out in the framework of the Regreening Africa project.

Chapter 3 provides a cautious economic projection exercise on potential benefits of further up-/ out-scaling of FMNR in West and East Africa. The focus lies on the target countries of the Regreening project.

1 BACKGROUND

1.1 The link between deforestation and land degradation

Land degradation in the Sahel is driven by natural hazards, underlying socio-economic issues and unsuitable or inappropriate land use and management practices. Practices that involve deforestation and forest degradation are a key component, which over time can trigger a series of biophysical processes leading to land degradation. The removal of trees and vegetation accelerates rainfall runoff and soil erosion, diminishing productivity of the land, destroying habitats and increasing vulnerability to flooding. Severe land degradation has in turn aggravated issues of desertification in some places (Emmanuel, 2017). *Regreening Africa* seeks to scale-up restoration through SLM practices, in order to contribute to the achievement of LDN among other aims. The approach hangs on counterbalancing the expected loss of productive land with the recovery of degraded areas across multiple land uses through improved land use planning and community or multi-stakeholder driven restoration options (UNCCD, 2020). An understanding of the dimensions of deforestation and woody biomass loss, and their links to land degradation are therefore key to informing the strategy to reverse these trends through SLM, and to achieving SDG 15.3.

Various programs, projects, studies and/or competent institutions at national or sub-regional level have documented tremendous rates of deforestation in pockets of West and East Africa during the past decades. According to the FAO, deforestation in Africa reached a rate of 3.4 Million ha per year in 2010 (FAO, 2010), and between 1990 and 2000, southern Africa experienced the highest rate of deforestation on the continent, losing 1.62 Million ha (FAO, 2003). **At the same time, various land and forest restoration success stories are emerging in the Sahel.** For example, over 5 million ha have been restored in the Maradi and Zinder regions in Niger in the past two decades (Sendzimir et al., 2011). 15 million ha of degraded land have been restored in Ethiopia under the Great Green Wall Initiative. In Burkina Faso, Mali and Niger, about 120 communities have been involved in creating a green belt over 2,500 ha of degraded and drylands, with over two million seeds and seedlings planted (UNCCD, 2020a). Studies have also found that following severe droughts and famines between the late 1960s and early 1990s, farmers and land users across the region have adapted and increasingly employ improved soil and water management practices. There is evidence of a long term transition from degradational land use trajectories to more sustainable and productive production systems (Hermann et al., 2005). The potential to upscale these practices across the region are high.

Chapter 1 provides a summary of these trends in deforestation and land degradation, and presents the economic consequences of not undertaking land restoration interventions.

1.2 Dimensions of deforestation in West and East Africa

The literature differentiates between direct (proximate) drivers and indirect (underlying) drivers of deforestation in Africa (Kissinger et al., 2012). Indirect drivers are mainly governance issues (e.g. weak land use policy enforcement and planning, uncertain land tenure, lack of land ownership, land conflicts, and weak monitoring and reporting requirements). Direct drivers of deforestation mainly relate to land use choices and investments. In the context of the target countries, this includes agricultural practices (forest clearing for commercial cropland and pasture, as well as permanent and shifting agriculture by smallholders for subsistence), overharvesting of wood products (fuel wood, timber and charcoal), mining activities and infrastructure development.

Challenges exist in describing the true scale of deforestation. Quantitative figures such as forest cover are available worldwide. However, good quality data on forest condition and state of degradation is somewhat lacking. Countries and international organizations monitor forests and measure the scale of deforestation using a variety of methods, definitions and time scales. The subsequent results are therefore divergent, of different levels of quality and accuracy, making cross-country comparisons or even single country assessments difficult to report on. Below we report on findings from Hansen et al. (2013) who calculated Global Forest Change considering a globally consistent forest definition and method. However, for numerous countries, reported national estimates do not match the Global Forest Change findings. In the end, to improve comparability and analysis of deforestation, as well as reduce costs, global data for national forest monitoring and reporting needs to be harmonized. This could be achieved by countries making their spatial forest monitoring data available for public review at a centralized location to streamline results (Harris et al., 2018). It should however be noted that significant progress has been made over the past years in quantifying deforestation and tracking forests using remote sensing and reliable satellite data.

Vast tracts of forests were both lost and gained in the Sahel over the course of the Hansen et al. (2013) study period. Figure 1 below shows the level of tree cover across Africa. The middle belt of Western Africa presently shows close to 0% tree cover, with a progressive increase in the southern belt, between 10 to 80%. Large tracts of Eastern Africa also show close to 0% tree cover, with denser clusters appearing in patches towards the southeast. Figure 2 shows a color composite of tree cover, forest loss and forest gain across Africa. Twenty terapixels of data were processed using one million CPU-core hours on 10,000 computers in order to characterize year 2000 percent tree cover and subsequent tree cover loss and gain through 2012 (Hansen et al., 2013). It is apparent that forest loss (red) is occurring at a significant rate across the project countries in both West and East Africa, with pockets where forest loss and gain is occurring simultaneously (magenta) across the southern part of West Africa and southeast regions. Country-specific data is listed in Table 1.

Table 1: Tree cover, forest loss and gain summary (km^2), ranked by total loss, 2000-2012

Country	Total loss	Total gain
Ghana	5,406	1,345
Kenya	3,059	1,005
Ethiopia	2,821	625
Mali	1,694	0
Senegal	832	2
Rwanda	178	71
Somalia	76	3
Niger	1	0

Source: Hansen et al. (2013)

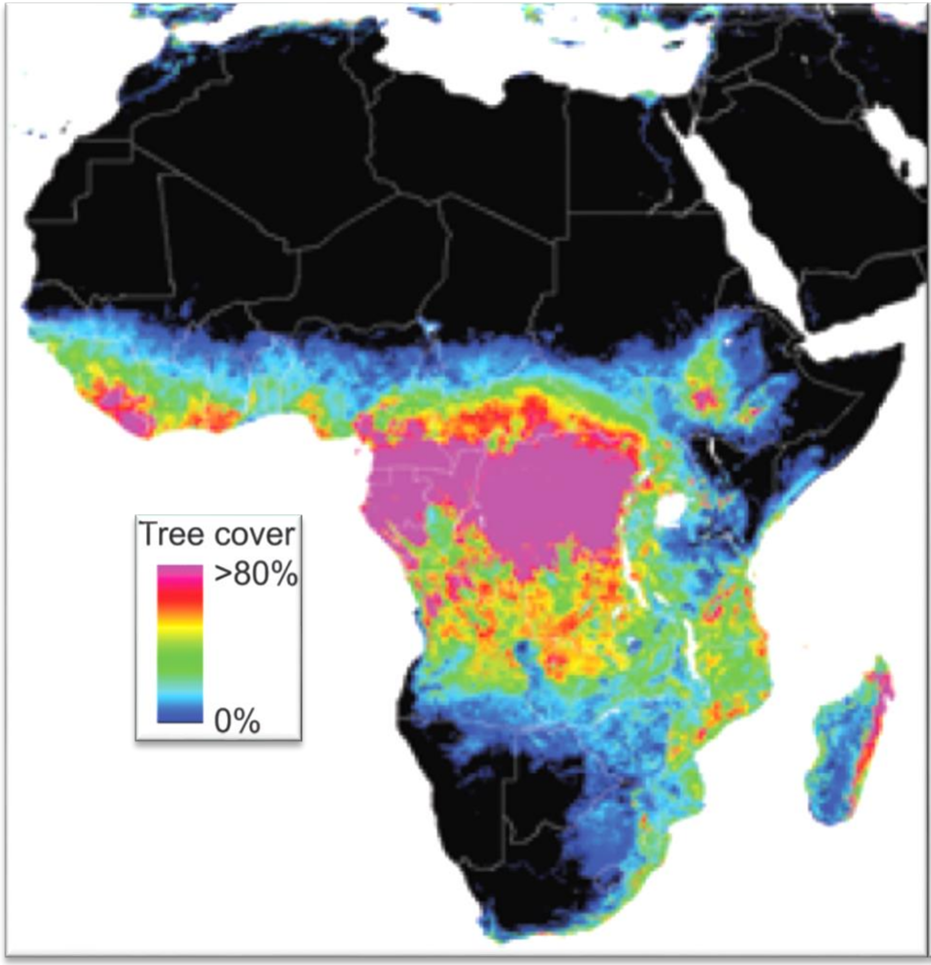


Figure 1: Tree cover across Africa

Source: Hansen et al., 2013

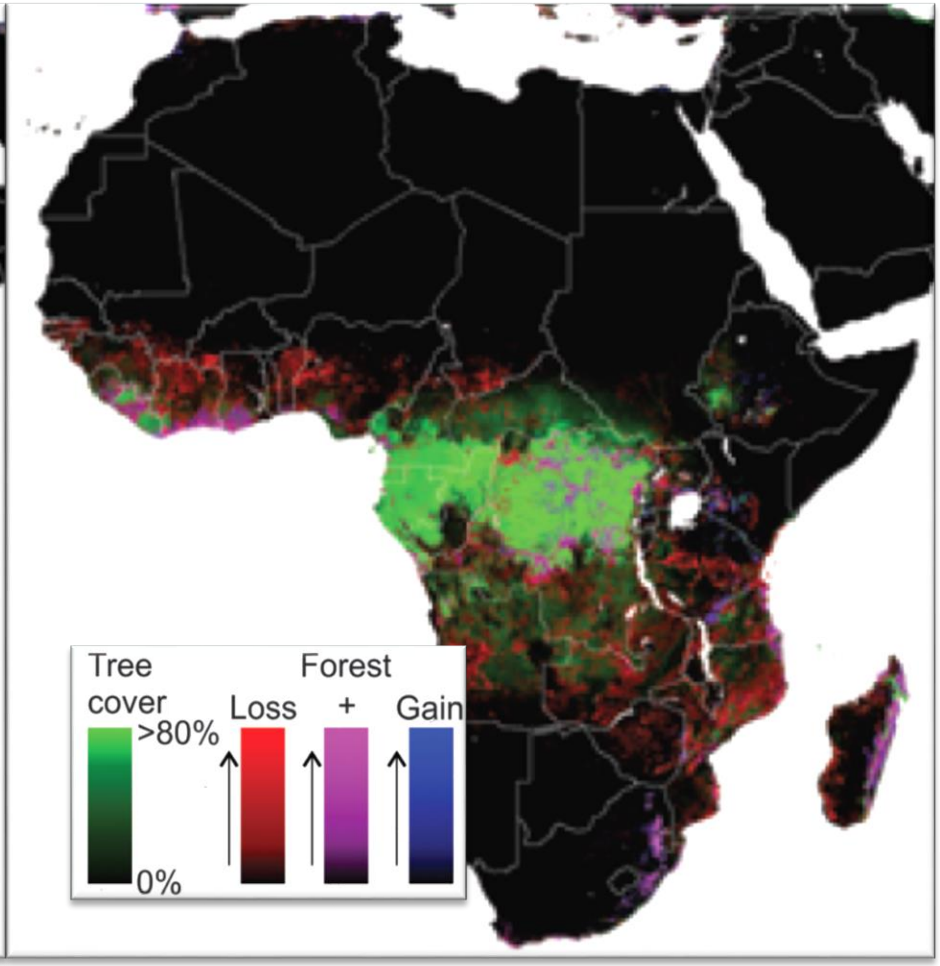


Figure 2: Color composite of tree cover, forest loss and forest gain

Source: Hansen et al., 2013

1.3 Economic consequences of deforestation and land degradation

On a global scale, trees and forests need to be considered as renewable, critical natural capital. Renewable in the sense that they regenerate and provide long-term benefits and ecosystem services, and critical because they perform important, unique functions such as protecting humans and ecosystems from natural hazards and providing habitats to a vast diversity of flora and fauna. Forests represent one of the largest terrestrial carbon stocks. Deforestation, tree loss and land degradation therefore have broad reaching, global consequences on both biophysical and economic levels. The Millennium Ecosystem Assessment (MEA, 2005) places ecosystem services into four broad categories: supporting, provisioning, regulating and cultural (see Table 2).

Table 2: Types of ecosystem services

<u>**Supporting services**</u> ▪ Nutrient cycling ▪ Soil formation ▪ Primary production	<u>**Regulating services**</u> ▪ Climate regulation ▪ Flood regulation ▪ Disease regulation ▪ Water purification
<u>**Provisioning services**</u> ▪ Food ▪ Fresh water ▪ Wood and fiber ▪ Fuel	<u>**Cultural services**</u> ▪ Aesthetic ▪ Spiritual ▪ Educational ▪ Recreational

Source: TEEB, 2020

Between 1995 and 2014, the monetary value of renewable assets more than doubled in low and middle-income countries, keeping up with population growth on average[2] (Lange et al., 2018). The presence and function of forests produce a stream of revenue for both the state, private enterprises and individuals. Deforestation can thus have negative economic consequences for a country or region by removing such opportunities for long-term, self-sustaining productivity and income. According to UNEP, deforestation deprived Kenya's economy of US$ 68 million in 2010 (UNEP, 2012). Land use cover change (LUCC) because of deforestation is a significant direct cause of land degradation in Africa. The annual cost of land degradation in Africa due to LUCC is estimated to reach USD 60 billion (2007 values), which is about 7% of the region's GDP (Nkonya et al., 2015).

The Total Economic Value concept (TEV) aggregates and assigns values to all ecosystem services. That is to say, from future potential uses of the genetic resources and from pure existence values; or from functional values of hydrological and carbon cycling (i.e. ecosystem services). Based on their numerous ecosystem services tropical forests have an estimated average TEV of USD 5264 per ha (de Groot et al., 2012). Accordingly, conversion of tropical forest into an alternative land use can result in an economic loss if the TEV of the alternative is lower than that of

[2] Note: agricultural lands have resulted in greater value gains than forests.

forest. For example, change from one hectare of forest into one ha of cropland could lead to a loss because the TEV of cropland is typically lower than the TEV of tropical forest.

The consequences of deforestation have strong implications for land degradation over time, in both ecological and monetary terms. The annual costs of land degradation at the global level amount to about 300 billion USD, of which Sub-Saharan Africa accounts for the largest share, at 22%. Of this global cost, 78% is due to land use and cover change, i.e. conversion of forest, grassland and other lands for agricultural purposes. 54 % of the total cost is attributed to losses in regulating, supporting and cultural services (for example, carbon sequestration), which are considered global public goods (Nkonya, 2015). The cost of taking action against land degradation is much lower than the cost of inaction, and the returns on these actions can be high. On average, one US dollar investment into restoration of degraded land returns five US dollars (Nkonya, 2015). Approaches for land restoration through sustainable land management practices are presented in Chapter 2.

2 UPSCALING SUSTAINABLE LAND MANAGEMENT PRACTICES THROUGH AGROFORESTRY

2.1 SLM approaches

Chapter 1 presented the relevance of deforestation for the *Regreening Africa* project, and its link to land degradation. Chapter 2 presents an overview of existing and potential SLM practices for upscaling across degraded agricultural lands. FMNR is discussed in particular for its potential as a low cost and high impact approach to restoring drylands.

The adoption of sustainable land management (SLM) practices through agroforestry is increasing across East and West Africa, and the potential for upscaling these practices is high. *Regreening Africa* is supporting institutions across the target countries to develop and scale-up land restoration techniques, develop agroforestry value chains, develop evidence-based policy recommendations, train implementors and facilitate cross-country learning.

SLM broadly includes a variety of soil and land management practices that are crucial for maintaining a healthy ecosystem and achieving the national LDN targets. SLM is the integration of land, water, biodiversity and environmental management to meet rising demands for food, fiber and other goods while sustaining livelihoods and the range of services provided by healthy ecosystems (World Bank, 2008). It is an important consideration in the regreening process, and complements and includes approaches such as FLR, FMNR, tree planting and agroforestry in general. SLM practices generally require low levels of technology or equipment, making it an easy approach for farmers and local management committees to adopt. As per Branca et al. (2013), these may include:

- Agroforestry and the general incorporation of trees into agricultural land
- Evergreen agriculture
- Agronomy (cover crops, crop rotation, intercropping with nitrogen fixers)
- Organic fertilization (compost, green manure)
- Minimal soil disturbance (minimum tillage, mulching)
- Water management (terracing, contour farming, water harvesting)

The economic and financial benefits of implementing SLM are well researched and established; it is overall a highly profitable and beneficial system (Reichhuber et al., 2019). The following section presents some common and high potential SLM practices in east and west Africa: Forest Landscape Restoration (FLR) and specifically, agroforestry practices (including evergreen agriculture and FMNR). It is important to note that these land restoration systems are overlapping and complementary.

Forest landscape restoration (FLR)

Forest Landscape Restoration (FLR) operates in the context of SLM. It is the ongoing process of regaining ecological functionality and enhancing human well-being across deforested or degraded forest landscapes. The planting of trees is therefore just one facet of the approach, which aims to restore whole landscapes to meet present and future needs and to offer multiple benefits and land uses over time.

FLR techniques centre on classic forestry activities on forest lands. These include afforestation, reforestation, enrichment planting, assisted natural regeneration and others. In addition, FLR practices can entail agroforestry and FMNR in particular, invasive species control, erosion control and others, implemented across the entire landscape (Stanturf et al., 2017), and ultimately results in numerous benefits for agricultural and degraded lands in general.

The project aims to contribute to the AFR100 Initiative, which is a country-led effort to respond to the African Union mandate to restore 100 million hectares of deforested and degraded landscapes across Africa by 2030. AFR100 will accelerate restoration to enhance food security, increase climate change resilience and mitigation, and combat rural poverty.

The International Union for Conservation of Nature (IUCN) and World Resources Institute (WRI) have identified the following best practices that can help ensure that restoration is successful, lasting and beneficial (AFR100, 2020). Many are compatible with agroforestry practices including tree planting and FMNR.

- Involve trees and other woody plants in landscapes where appropriate
- Scale up successes from individual sites
- Restore functionality, ecosystem services, not “original” forest cover
- Balance local needs with national and global priorities
- Employ a range of restoration strategies
- Adapt to circumstances over time
- Avoid strategies that lead to the conversion of natural ecosystems

All *Regreening Africa* project countries except Somalia have made AFR100 commitments. More information is available in Chapter 3.

SLM through agroforestry

Agroforestry is a collective name for land use systems and practices in which woody perennials are deliberately and systematically integrated with crops and/or animals on the same land management unit. This approach is central to the sustainable management of land and maintenance of healthy landscapes (Leakey, 1996).

Based on an analysis of agroforestry interventions in 57 developing countries, a study conducted by Pretty et al. (2006) showed that agroforestry practices can result in increased yields and land preservation in the long run. Other studies have shown that land restoration done through sustainable agricultural practices – particularly through the incorporation of trees – can bring additional revenue in terms of overall better yields and fuelwood (Sidibé, Myint and Westerberg, 2014).

Depending on the specific context, agroforestry benefits can include increased soil fertility, increased water availability and improved tree and grass cover. Within agroforestry systems, it is possible to grow or maintain multiple high-value production systems such as wood (including high value trees for timber and poles), non-wood forest tree products (NWFPs), apiculture, fodder and horticulture. Horticultural systems include cash crops, fruits and nuts, e.g. Vitellaria paradoxa (shea), Mangifera indica (mango) and Anacardium occidentale (cashew). The largest group of fruit trees used in the drylands consists of indigenous trees such as Adansonia digitata (baobab), Parkia biglobosa (African locust bean or nere), Uapaca kirkiana (sugar plum), and Ziziphus mauritiana (Chinese date). In the semi-arid and dry sub-humid areas of Africa, the exotic Mangifera indica is extremely important (Place et al., 2016).

Evergreen agriculture (see below) and FMNR (see Section 2.2) are forms of agroforestry.

Evergreen agriculture

Evergreen agriculture as a form of agroforestry has been defined as the integration of particular tree species into annual food crop systems. The intercropped trees (i) sustain a green cover on the land throughout the year to maintain vegetative soil cover, (ii) bolster nutrient supply through nitrogen fixation and nutrient cycling, (iii) generate greater quantities of organic matter in soil surface residues, (iv) improve soil structure and water infiltration, (v) increase greater direct production of food, fodder, fuel, fiber and income from products produced by the intercropped trees, (vi) enhance carbon storage both above-ground and below-ground, and (vii) induce more effective conservation of above- and below-ground biodiversity (Garrity et al., 2010).

Scaling up evergreen agriculture is a core objective of the Greening Africa project. It entails the use of context sensitive techniques such as FMNR, tree planting and other forms of tree management. Restoration options need to be tailored to different landscape areas and different stakeholders, taking into account the socio-ecological variations and level of resource degradation. Interventions can involve a mix of enclosures, tree protection and management by farmers and community organizations in fields and communal lands. It also entails direct tree planting through seeds or cuttings (sourced for example through decentralized nurseries), where natural regeneration is limited, or to meet species-specific, production or conservation objectives. When planting seedlings and trees, selection of species should take into consideration the ecological conditions of the planting site, whether it addresses one or several needs of local farmers or communities, and whether good quality planting material for that species is available or can be produced within a reasonable time frame (ICRAF, 2018). Decision makers may consult vegetation maps or identify growing conditions from databases such as the ICRAF *AgroforesTree* database or the CAB International's Forestry Compendium (Kindt, 2006).

2.2 FMNR

FMNR is a form of agroforestry and is categorized as a sustainable land management practice. The main objective of FMNR is to create a vegetative cover that is commonly referred to as an agroforestry parkland system or practice, depending on the scale (Place et al., 2016). It involves proactively nurturing natural tree regeneration (either from stumps or from seeds) to increase tree cover in fields with the goal of increasing the value or quantity of woody vegetation on farmland. It can be used wherever there are living tree stumps with the ability to coppice (re-sprout) or seeds in the soil that will germinate. Farmers will generally choose three to five of the strongest stems or shoots from the tree stumps they wish to retain on their land, pruning away the remainder. These stems can periodically be harvested to provide firewood and timber. For larger trees, farmers will often allow one stem to develop into a full-size tree. The potential of FMNR was first propagated by Tony Rinaudo in 1983, who at that time managed an integrated development project in the Maradi District of Niger (Rinaudo (2007), see box).

In the project context of arid and semi-arid regions, FMNR emerges as a highly appropriate technology for disaster risk reduction and improving land productivity. It is a quick, affordable and easy to replicate system, driven by landowners and communities themselves (Rinaudo et al., 2018). In the face of worsening climate change impacts and a decline in tree densities, farmers across the Sahel and other dryland regions are investing in on-farm trees as a practical way to increase agricultural production, incomes and improve food security. It can provide natural protection or increase adaptive capacity of farmers against floods, rainstorms, drought and landslides.

Over the past decades, hundreds of thousands of farmers in the Sahel have transformed vast expanses of arid landscapes into productive agricultural land, improving food security for about three million people by adopting FMNR (Reij and Winterbottom, 2015, Figure 3). For several generations, natural regeneration, well known to farmers, has been an inexpensive way to grow and reproduce native trees and shrubs that provide useful food, fuel or forage. Publications by the ELD Initiative confirm that this practice has enabled farmers particularly in southern Niger, central Senegal, northwest and northeast Ghana, southern Burkina Faso and Mali to improve the fertility of millions of hectares of cropland.

Pioneering FMNR

"In 1983, the typical rural landscapes in the Maradi, Niger were still windswept and with few trees. It was apparent that even if the Maradi Integrated Development Project, which I managed, had a large budget, plenty of staff and time, the methods being employed would not make a significant impact on this problem. Then one day I understood that what appeared to be desert shrubs were actually trees, which were re-sprouting from tree stumps, felled during land clearing...there was a vast, underground forest present all along and that it was unnecessary to plant trees at all. All that was needed was to convince farmers to change the way they prepared their fields."

Rinaudo (2007)

Tony Rinaudo is an Australian agronomist who began promoting the concept of FMNR in the 1980s. He restored 50,000 km^2 of land with 200 million trees in Niger, in the context of severe famine and drought. He was awarded the UNCCD Land for Life Award in 2013, and the Right Livelihood Award in 2018 for demonstrating how drylands can be greened at minimal cost, and improving the livelihoods of millions of people.

Box 1: Tony Rinaudo on FMNR

For example, the Talensi FMNR project, a collaboration between World Vision Australia and World Vision Ghana, increased resilience among subsistence farming households in the semi-arid region of North Ghana (Talensi). Specifically, to reverse deterioration of soil fertility and the natural resource base, the focus was on restoring multi-purpose indigenous trees to farmland and community-managed forests through promotion of FMNR and accompanying sustainable agriculture techniques. FMNR activities included re-growing trees on farmers' crop and pastoral fields, and protecting and pruning tree regrowth in community-managed FMNR forests, with supplementary measures such as anti-erosion techniques, bulk composting, field mulching, bushfire suppression, livestock management and honey production also implemented. Notable project achievements:

- 94% of FMNR adopters saw an increase in soil fertility (vs. 26% among the comparison group)
- 66% of FMNR adopters saw a reduction in soil erosion (vs. 17% in the comparison group)
- 46% observed that the FMNR practices have generated more wild fruits and food (fruits, nuts, rabbits and partridges).

Weston, (2013) found that for every GH¢ invested in the project on FMNR, GH¢17 would be generated in social, environmental and economic return over the later two years of the project, plus the four years thereafter. When factoring into costs the value of time invested by lead farmers and volunteers, this ratio becomes 13:1. When calculating impacts over a 10 year duration after project closure, NPV at year 13 is forecasted to result in an investment return ratio of 43:1 (or 34:1 taking into account value of time invested).

The beginnings of successful farmer-managed restoration are also evident in Malawi, Zambia and other countries (ELD Initiative, 2020).

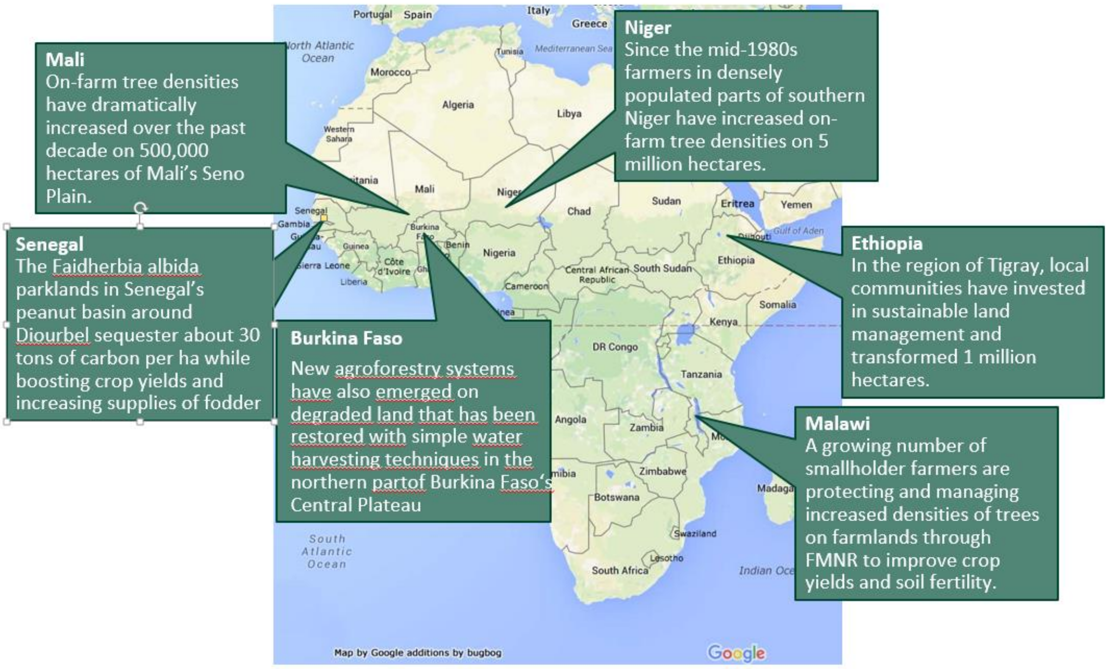


Figure 3: Examples of successful regreening (based on Reij and Winterbottom, 2015)

Amongst these cases, some common success factors are evident (World Vision, 2019; UNSDG Partnership Platform, 2019; Binam et al., 2015).

- Regreening and FMNR efforts are driven and supported by various actors and factors, however, it is almost always led by farmers themselves (Rinaudo et al., 2018)
- Partnering with large scale projects, local government and local departments of agriculture, forestry and environment, and NGOs can enable farmers to gain policy, financial, technical or mediation support. However, it is important to note that FMNR is generally accepted to be farmer driven, and is often also successful without external support (World Agroforestry Center, 2013).
- The existence of community natural resource management groups or committees, communal management systems, as well as the involvement of village leaders can contribute to a supportive social context, encourage the enforcement of by-laws and reduce occurance of conflicts (SDG Partnerships Platform, 2019).
- Stakeholder engagement, awareness and local capacity building further contribute to the long term success and ownership of FMNR activities (Francis et al., 2015).
- The success of FMNR practices has been additionally evident in areas where farmers have good access to urban centers and markets to sell their wood and non-wood FMNR products. Combining FMNR with value addition, market linkage interventions or even savings and loan schemes maximizes farmers' and communities' income generation and economic development opportunities. (World Vision Australia, 2018).
- According to Binal et al., (2015), the scale of FMNR implemented on a farm has as a kind of multiplier effect. Farmers who practice it at an active, continuous level (i.e. the higher the density of trees present), reap higher benefits of the system than those who practice a lower level of it. This is because the value of the tree products increases. For instance, during the first year of practicing natural regeneration, farmers will obtain fuelwood from pruned branches. From the second year onwards, the branches will be large enough to sell. Farmers practicing FMNR at different levels are also more resilient during periods of food shortages and scarcity as one of the many coping strategies they use is the gathering of food, exploitation of fuelwood and sales from agroforestry parklands.

Reij and Winterbottom (2015) have additionally identified six steps to successfully scaling up regreening efforts. These include (i) identifying and analyzing existing regreening successes; (ii) building a grassroots movement for regreening; (iii) addressing olicy and legal issues to improve the enabling environment; (iv) developing and implementing a communication strategy; (v) developing and strengthening agroforestry value chains and (vi) expanding research activities to fill knowledge gaps.

Agroforestry systems face difficult growing conditions in the drylands. The table below summarizes the recommendations by Place et al. 2016 for scaling-up promising "Tree-based Systems" (TBS) for each dryland zone. The authors recommend FMNR for each dryland zone.

Table 3: Promising tree-based production systems (TBS) for each dryland zone

	Arid zone	Semi-arid zone	Dry sub-humid zone
Characteristics	▪ Dominated by pastoral production systems (extensive grasslands with few trees, shrubland or scrub) ▪ Successful establishment of trees very difficult in the absence of irrigation ▪ Low incentives to plant and manage trees due to migratory nature of populations and lack of individual tenure on land	Dominated by agro-pastoralism with rain-fed cropping systems based on millets and sorghum	Dominated by cereal production, particularly maize-mixed farming systems.
Recommended Tree-Based Production System	▪ Deploy assisted natural regeneration of trees and shrubs in pastoral arid conditions as a foundational practice for improving livestock production with enhanced ecosystems services, including carbon sequestration. ▪ Invest in the assisted natural regeneration of high-value commercial tree species (Gum Arabic, myrrh, and frankincense) that are adapted to arid zone conditions ▪ In the irrigated area of the arid zone, including the oases agroecosystems, high-value fruit tree production is an attractive investment opportunity in situations where transportation and market linkages are present ▪ Invest in the development of sustainable charcoal and fuelwood management systems where unsustainable production systems are currently degrading the future production potential	▪ FMNR of useful trees on the agricultural land as a foundational practice ▪ Planting high-value trees for nutrition and income generation ▪ Assisted natural regeneration of the dry forests and community woodlands ▪ Development of sustainable charcoal and fuelwood production systems	▪ FMNR with useful trees as foundation ▪ Supplement FMNR investments with the accelerated cultivation of planted trees in the croplands and field boundaries ▪ Widespread expansion of high-value trees for nutrition and income generation at small and medium scale ▪ Regeneration and improved management of the forests and community woodlands

2.3 Returns from FMNR

This chapter distills the results of three CBAs of FMNR in Niger, Senegal and Ghana conducted in 2019. These three CBAs were carried out by the ELD Initiative in the framework of the Regreening project. Details about the study sites, methodologies applied are provided below. It is important to recognize that the the ELD case studies were conducted in the same areas as the current project sites of the ICRAF component of the Regreening project in those particular countries. The studies employed the 6+1 step approach[3], analysis method that has been adopted by the ELD Initiative to guide users through the process of establishing scientifically sound cost-benefit analyses to inform decision-making processes.

Table 4: Description of ELD Case studies

	Niger (Nouhou et al. 2019)	**Senegal (Sanogo et al. 2019)**	**Ghana (Westerberg et al. 2019)**
Source of data and sample size	▪ Expert interviews, focus groups, Survey (65 households)	▪ Expert interviews, focus groups, survey (15 households)	▪ Expert interviews, focus groups, survey (483 households)
Main methods used	▪ Cost benefit analysis	▪ Cost benefit analysis	▪ Cost benefit analysis, production function modeling, experimental economics
Sites	▪ 3 villages in the Maradi district ▪ Same district as ICRAF Regreening project sites ▪ Same district as ICRAF Regreening project sites in Niger	▪ 1 village in the region of Kaffrine, ▪ model village for climate smart agriculture supported by several organizations and Ministries ▪ Same region as ICRAF Regreening project sites in Senegal	▪ Lawra district of the Upper West region, ▪ intervention area of Center for Indigenous Knowledge and Organization Development (CIKOD) – a community-focused NGO ▪ Region next to ICRAF Regreening project sites in Ghana

When analyzing the returns from FMNR it is important to differentiate between a financial and economic analysis. A cost-benefit analysis (CBA) can be done from the perspective of any number of actors: a private investor, a community, a political jurisdiction, a country or even the global community. Table 5 summarizes key differences between financial and economic analysis.

[3] https://www.eld-initiative.org/en/knowledge-hub/6-1-step-approach/

Table 5: Methodological difference between economic and financial analysis

Financial analysis	Economic analysis
▪ Perspective of single actor ▪ Costs and benefits with commercial value to that actor ▪ Cash flows in and out of an entity ▪ A tool for private investment decision-making	▪ Perspective of multiple actors ▪ Costs and benefits with benefits to any actor included in analysis, measuring total economic value ▪ Economic (i.e. not only cash flows) benefits ▪ A tool for public investment decision-making; can aid private decision-making as well

Source: Gromko et al. 2019

A financial analysis takes a narrower perspective than an economic analysis, i.e. typically a private sector entity implementing the investment. Costs and benefits are restricted to the financial flows that actually materialize, such as upfront and management costs, increased revenues from products sold, and any fiscal incentives from the public sector. Benefits from ecosystem services can be included in a financial analysis, but only those that will affect the cash flows of the business, e.g. reduction in soil erosion that lead to improved agricultural productivity and higher revenues from agriculture. Many ecosystem services benefits will be excluded. Carbon benefits, for example, should only be included insofar as carbon credits could be sold to a buyer.

Economic analysis, on the other hand, is much broader. Such an analysis is more appropriate when a public sector entity is making an investment, as they have an interest in understanding the diverse costs and benefits of a particular Forest Landscape Restoration (FLR) activity. The scope of stakeholders can be adjusted depending on the purpose of the analysis, often set at a communal, jurisdictional or global level. Ecosystem services need not be commercialized in order to be included; benefits from climate change mitigation relate to the social good of mitigating climate change rather than the private benefit of selling carbon credits. Another important distinction is that an economic analysis should carefully account for transfers between stakeholders. For instance, a fiscal incentive provided to a private company by a government entity is included in a financial analysis, but is a “net zero” in an economic analysis since the company benefits as much as the government entity has increased costs.

The results reported on can be categorized as based largely on financial CBAs. The MEA framework is critical for integrating ecosystem services into CBAs. Supporting ecosystem services resulted in each case study in increased crop yields. While all three case studies considered provisioning and supporting ecosystem services, they differ in some other key factors. Among them (i) the aridity of the location, (ii) the tree density, (iii) the types of trees regenerated, and (iv) crops cultivated (Table 6). The Senegal case study is in so far unusual in that it assumes that conventional farmers have zero trees on their plots compared with 25 trees of farmers who practice FMNR. Binam et al. (2015) show that FMNR is practiced almost everywhere in the Sahel as most of the households have a good knowledge of the technique; it is more the degree of the practice that varies.

Table 6: Description of sample

FMNR	Niger (Nouhou et al. 2019)	Senegal (Sanogo et al. 2019)	Ghana (Westerberg et al. 2019)
Zone	Semi-arid	Semi-arid	Dry sub-humid
Ha per household	5.4 ha	2.5 ha	0.8 ha
Tree density per ha (FMNR versus conventional)	61 versus 14	25 versus 0	33 versus 13
Type of tree	Faidherbia albida and Scerocayra birea, Piliostiguma reticulatum and Hypheane tebaica	Adansonia digitata, Tamarindus indica, Zyziphus mauritiana	Ebony, Shea, dawadawa, Mango, Neem
Crops cultivated	Sorghum, millet, cowpea	Groundnuts and millet	Maize, sorghum, groundnuts, with legume intercropping, SLM

The review of the case studies leads to the conclusion that FMNR exhibits a higher profitability than the next best business as usual (BAU) system (Table 7) In Niger the net income including environmental services increased by USD 68 per ha per year. In Ghana net income increased by USD 43 per ha which is 78% more than net income of farmers not practicing FMNR. In Senegal net income increased by 84%, which is a similar increase as in Ghana. The net income levels in the Senegal case study are much higher than in Ghana and Niger. This could be due to the selected village and very high values for environmental services at that location. The values of environmental services in economic terms are often very site-specific.

Table 7: Summary of case studies

FMNR	Niger (Nouhou et al., 2019)	Senegal (Sanogo et al., 2019)	Ghana (Westerberg et al., 2019)
Net income FMNR (USD/ha/year)	n.a.	2,187	98
Net income non-FMNR (USD/ha/year)	n.a.	1,187	55
Increase in net income (USD/ha/year)	68	84%, 1,000	78%, 43
Increase in hh income per year	367 USD	2,500 USD	34 USD
NPV (10% discount rate, USD/ha)	858 (Additional net benefit to non-FMNR, 20 year horizon)	2887 (Total net benefit of FMNR, 8 year horizon)	880 (Total net benefit of FMNR, 20 year horizon)

These results are in accordance with other findings in the literature, where FMNR was found to have a positive effect on income. Weston et al. (2015) demonstrated that FMNR in the Upper East Region of Ghana can increase household income up to USD 887/year (EUR 710), capturing the value of social, health, environmental and economic benefits. Considering crop production only, Haglund et al. (2011) found that annual crop revenue among 400 Nigerian farmers was EUR 40 higher for farmers practicing regeneration (EUR 110 for FMNR and EUR 70 for non-FMNR farmers). Binam et al. (2015) show that if an average household in the Sahel were to decide to practice FMNR continuously, it would result in an increase in gross income by USD 72 per year per household (not including environmental services).

3 PROJECTION

3.1 Approach and methodology

The projection brings together the biophysical with the economic. Its starting point is the assumption that the target countries have the potential for a successful and widespread scaling-up of restoration using different SLM practices like FMNR. The sections below provide more details on the spatial and the economic approach to the analysis.

3.1.1 Spatial projection

The spatial projection identifies areas that are similar to the ELD/ICRAF *Regreening Africa* project sites, in terms of biophysical, ecological and socio-demographic characteristics to allow for statistically rigorous and spatially explicit extrapolation of the upscaling potential. The analysis of GIS data is performed along three main steps as presented in the illustration below.

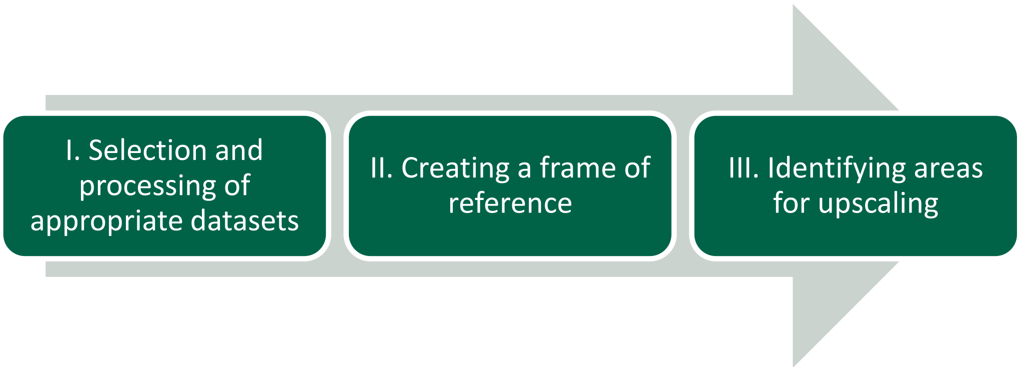


Figure 4: Stepwise GIS-based approach to spatial projection

The spatial analysis accesses and uses satellite imagery and information on climate, vegetation and soil types, elevation, slope, and socio-demographic data to account for factors influencing potential, demand and supply of SLM and in particular FMNR. Considering the large scope of the analysis, which involves eight countries from different regions in Africa, only those datasets are selected for the analysis, which provide the necessary level of detail and are available for each country covering the same attributes. The selected datasets are regional or global datasets presenting standardized information in the same format and attributes for all countries. The analysis is carried out at the same administrative level as the available reference data (third administrative level for most countries, corresponding to municipalities, e.g. *woredas* in Ethiopia). The table below lists the datasets used in the analysis.

Table 8: List of datasets used during the analysis

Category	Dataset / Feature	Data source
Climate	▪ Mean annual temperature ▪ Mean annual rainfall ▪ Resolution: ~1km²	https://www.worldclim.org/data/index.html
Terrain	▪ Elevation ▪ Slope ▪ Resolution: 90m	http://srtm.csi.cgiar.org/srtmdata/
Soil	▪ SOC ▪ Soil depth ▪ Water holding capacity ▪ Resolution: 250m	https://www.isric.org/projects/africa-soil-pro-files-database-afsp
Land cover and vegetation	▪ Africa LC types – (deter-mining forest, agriculture area) ▪ Resolution: 20m	http://2016africaland-cover20m.esrin.esa.int/download.php
Infrastructure	▪ Road density ▪ Accessibility to the next larger town ▪ Resolution: 1km²	https://malariaatlas.org/research-project/accessi-bility_to_cities/
Demographic data	▪ Population density ▪ Resolution: 150m	https://www.arcgis.com/home/item.html?id=0f83177f15d640ed911bdcf6614810a5
Incidents	▪ Frequency of fire occur-rence – since 2000	https://firms.modaps.eosdis.nasa.gov/
Administrative data	▪ Shapefiles of regional ad-ministrative units	https://gadm.org/
Site of successful ICRAF regreening projects	▪	http://landscapesportal.org/

The downloaded datasets were processed and brought to the same status in terms of resolution, coverage and projection. All datasets were resempled to fit the resolution of the dataset with the highest resolution. A set of statistical values for each attribute was calculated (i.e. average, min, max, standard deviation and sum). The result of this processing step is a matrix, which lists all regions in the selected countries, with the calculated values for each attribute (see Annex).

Based on the values for each region, it is possible to identify those regions with potential for scaling-up restoration. The regions with a current ICRAF managed *Regreening* project serve as a reference for comparison. They are considered to be areas with high potential for restoration projects, since there are already such projects running there. The bio-ecological values valid for the areas are than used as base for comparison with the values from other regions. For example, the table below shows how the reference level for the attribute *elevation* was computed based on average values of elevation for the project regions and their standard deviations. Combining the average value with the standard deviation provides a specific range to serve as reference.

Table 9: Example on establishing the reference level for the spatial attribute elevation

Country	Elevaton m a.s.l (1)	Standard Deviation (2)	Range – min (1) – (2)	Range – max (1) + (2)
Ethiopia	2008	393	1616	2401
Ghana	198	21	160	230
Kenya	1600	570	1030	2170
Mali	337	60	277	398
Niger	264	50	214	314
Rwanda	1639	225	1414	1865
Senegal	18	13	6	31
Somalia	758	269	489	1026

Every region in the target countries is compared to the action areas of successfull projects along the list of attributes (details listed in the annex). The regions whose values provide the best match for the ranges set by the reference regions qualify for upscaling. That is, if a region in Ethiopia has an elevation of 1900m, it is inside the established range. If the elevation of the region is 500m, it is outside the range and is therefore not a good match. Running this analysis through all the attributes produces a score from 0 to 12 for each region based on the number of similar attributes. The score indicates the potential for regreening. The analysis differentiates between three levels:

- **Priority**: Regions with a match of 90% (10 out of 12 attributes within reference range). Recommended for upscaling of the Regreening project.
- **High**: Regions with a match of 60% (7 out of 12 attributes within reference range). Recommended for national restoration targets.
- Low: Regions with a match of 40-60% (4-7 attributes within reference range).

3.1.2 Economic analysis

The economic analysis develops cautious scenarios of what successful restoration via FMNR would mean in terms of economic benefits, taking into account provisioning ecosystem services as well as regulating services. Existing primary data from the ELD *Regreening Africa* studies (see section 2.3) provided the basis for this analysis. The study highlights the sensitivity of the results with respect to variations in a number of relevant factors.

For the estimation of benefits, the study adopts the approach of benefit transfer. This approach allows the study to make use of the economic values for ecosystem services estimated for the case study countries by transferring the information to the other targeted countries. It is important to note that this benefit transfer can only be as accurate as the initial studies. However, the meta-analysis conducted in section 2.3 used findings from the wider literature to contextualize, validate and discuss the results obtained from the case studies.

The economic analysis is performed along three main steps, as presented in the illustration below. An economic indicator is selected in step 1. In step 2, economic benefits are projected for a number of different scenarios. Finally, an assessment of sensitivities is performed in the step 3.

Figure 5: Stepwise benefit transfer approach to economic analysis

The projection of economic benefits is based on the increase in net income per ha per year for each country. The increase in net income per ha per year is selected as a key indicator because it is independent of farm sizes. Further, the case studies provide different estimates for this indicator, depending on tree density, type of tree, crops cultivated and production system. The economic benefits are projected along two stylized types and modeled based on the case study results, in order to show the potential range of economic benefits (Table 10).

Table 10: FMNR Assumptions by production system

Characteristic	Type 1	Type 2
Tree density per ha (FMNR versus conventional)	61	33
Type of tree	Faidherbia albida, Scerocayra birea, Piliostiguma reticulatum and Hypheane tebaica	Ebony, Shea, *dawadawa*, Mango, Neem
Crops cultivated	Sorghum, millet, cowpea	Maize, sorghum, groundnuts, with legume intercropping
Increase in net income	**68 USD/ha**	**43 USD/ha**

The economic benefits are presented in terms of their net present value, which is the sum of a discounted flow of additional net income estimated over a time horizon of 20 years. Future values are discounted using a discount rate so that values at different times can be easily compared. This is done by assigning a weight to future events based on society's preference for events that occur at different points in time. Determining the discount rate is a difficult and potentially controversial element of a cost-benefit analysis because it has a large impact on the perceived value of a project (Gromko et al. 2019). The study estimates the results for 2 different discount rates, 10% and 40%, reflecting different time preferences of stakeholders.

The analysis focuses on three different scenarios in consistence with the results of the spatial analysis (see section 3.1.1):

A. Farmers adopt FMNR on an area, which has the size of the current targets of the Re-greening project. 100% adoption rate is reached by year 2020.
B. Farmers adopt FMNR on an area, which has the size of the estimated **priority areas** for upscaling the Regreening project. 100% adoption rate is reached in year 2025.
C. Farmers adopt FMNR on an area, which has the size of the estimated areas with **high potential** for upscaling restoration. 100% adoption rate is reached in 2030.

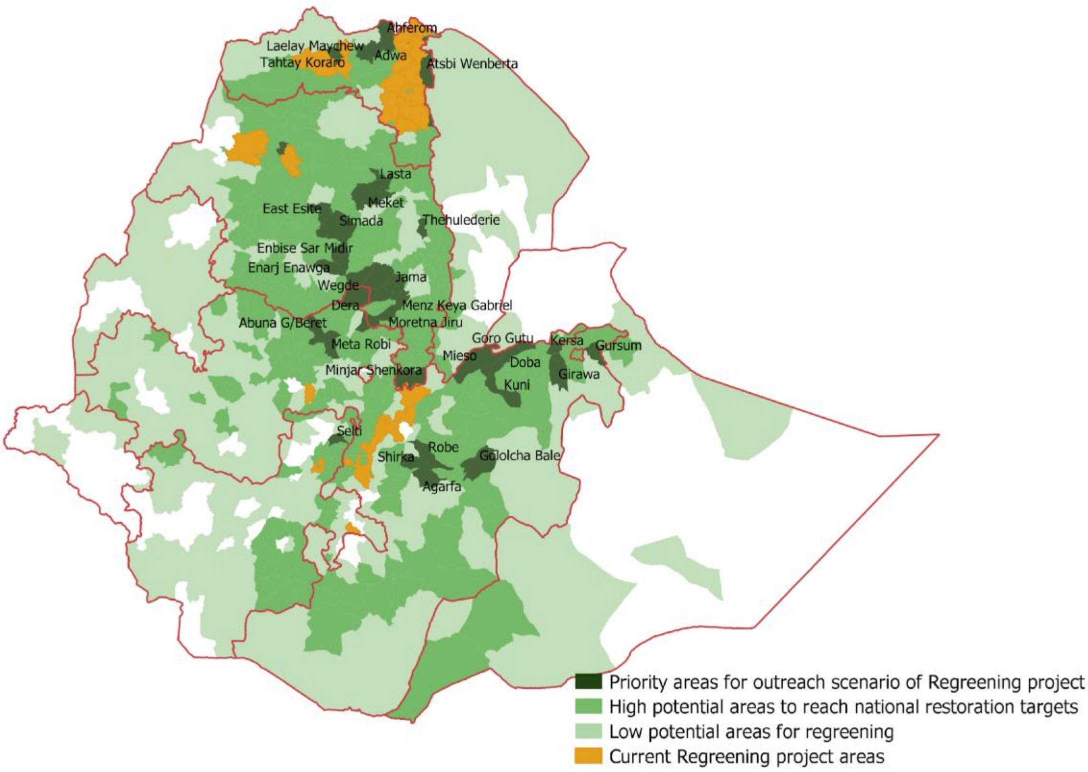
3.2 Ethiopia

The Regreening project in Ethiopia could potentially double its targeted area by reaching out to more districts. Its target is currently to restore 200,000 ha of land. The spatial analysis conducted for this study recommends an area of 400.000 ha for upscaling the project. The priority areas for scaling-up the project are colored in dark green on the map below. Priority districts are marked.

Table 11: Upscaling potential for the Regreening project in Ethiopia

Regreening project target in ha (Scenario A)	Regreening project target areas	GIS based projection of areas with priority for upscaling Regreening project areas in ha (Scenario B)
200,000	Tigray, Amhara, Oromia, SNNPR	400.000

Map 1: Restoration potential in Ethiopia



Ethiopia has signed onto AFR100 and committed 15 million hectares of land to be restored. This is very close to the GIS based projection of upscaling potential for restoration resulting from this study, which is 15.2 million ha.

Table 12: Upscaling potential for restoration in Ethiopia

National AFR100 restoration target in ha	GIS based projection of areas with high upscaling potential recommended for restoration in ha (Scenario C)	Regions
15 million	15.2 million	88% in Amhara, Oromia; 12% in Afar, Dire Dawa, Harari People, Somali, SNNPR, Tigray

Scaling-up restoration in Ethiopia along this outreach potential would result in significant economic benefits. The exact figures are provided in the table below. The current Regreening project is expected to lead to an economic benefit between USD 64 and 101 million in additional income until 2040. The results are sensitive to the discount rate selected. The type of FMNR adopted also makes a large difference on the net present value of economic benefits.

Table 13: Projection of economic benefits for Ethiopia (in '000 USD)

Present value of net additional income	Scenario A	Scenario B	Scenario C
Typ 1	101.399	170.734	4.927.899
Typ 2	64.120	107.964	3.116.171

3.3 Ghana

In Ghana, there is significant potential to scale up Restoration. The initial target of 80.000 ha could be increased to 450.000 ha based on the spatial analysis. The priority areas for scaling-up the project are colored in dark green on the map below. Priority districts are marked.

Table 14: Upscaling potential for the Regreening project in Ghana

Regreening project target in ha, Scenario A	Regreening project target areas	GIS based projection of areas with priority for upscaling Regreening project areas in ha (Scenario B)
80.000	Upper East Region (Bawku West and Garu Tempane districts), Northern Region (Mion District)	450.000

Ghana has signed onto AFR100 and committed 2 million hectares of land to be restored. This is significantly higher than the GIS based projection of upscaling potential for restoration resulting from this study, which is 1.3 million ha.

Table 15: Upscaling potential for restoration in Ghana

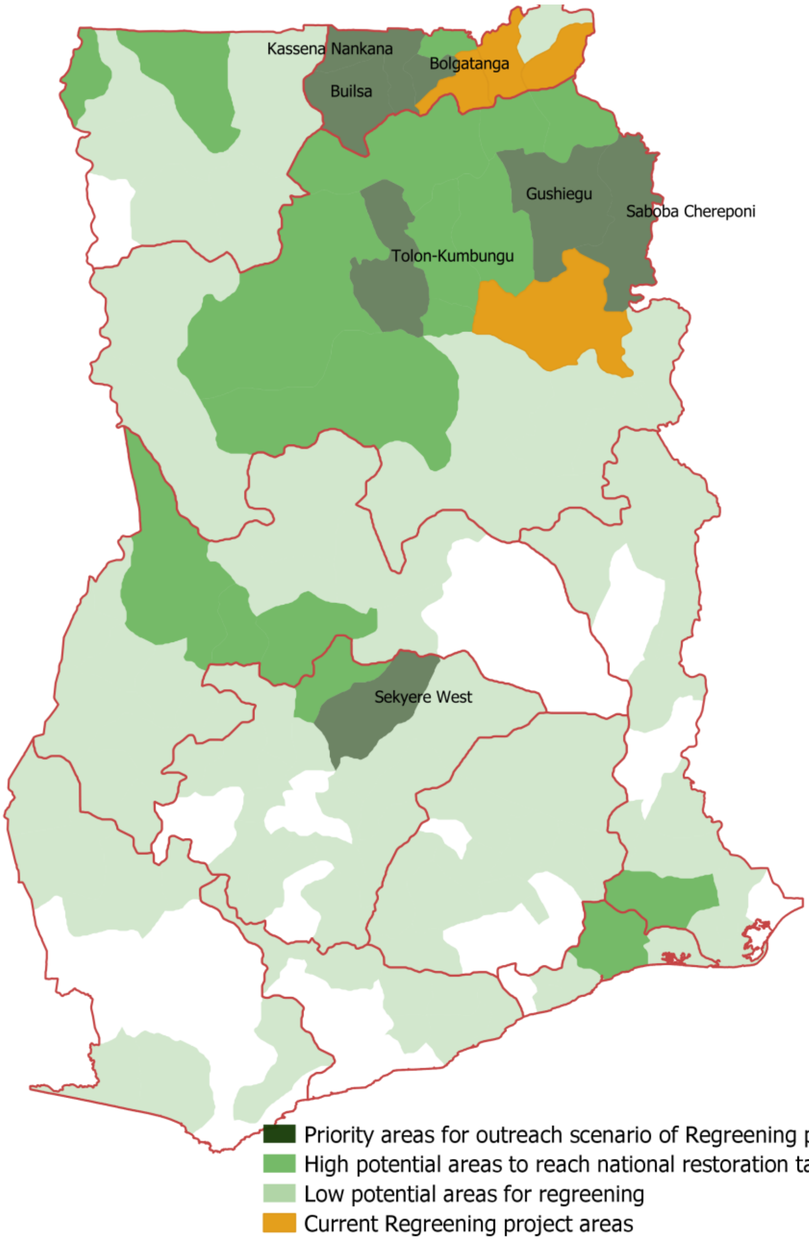
National AFR100 restoration target in ha	GIS based projection of areas with high upscaling potential recommended for restoration in ha (Scenario C)	Regions
2 million	1.3 million	80% inside the upper eastern and northern region. 20% inside Ashanti, Bong Ahafo, Upper West, Volta

Scaling-up restoration in Ghana along this outreach potential would result in significant economic benefits. The exact figures are provided in the table below. The current Regreening project is expected to lead to an economic benefit between USD 25 and 40 million in additional income until 2040. The results are sensitive to the discount rate selected. The type of FMNR adopted also makes a large difference on the net present value of economic benefits.

Table 16: Projection of economic benefits for Ghana (in '000 USD)

Present value of net additional income	Scenario A	Scenario B	Scenario C
Typ 1	40.560	192.076	421.465
Typ 2	25.648	121.460	266.515

Map 2: Restoration potential in Ghana



3.4 Kenya

According to the spatial analysis, in Kenya the Regreening project could find several districts with similar conditions for scaling up. The initial target of 150.000 ha could be increased to 230.000 ha. The priority areas for scaling-up the project are colored in dark green on the map below. Priority districts are marked.

Table 17: Upscaling potential for the Regreening project in Kenya

Regreening project target in ha (Scenario A)	Regreening project target areas	GIS based projection of areas with priority for upscaling Regreening project areas in ha (Scenario B)
150.000	Western Region (Migori and Homa Bay counties), Central Rift Region (Nakuru, Elgeyo Marakwet and Baringo counties)	230.000

Kenya has signed onto AFR100 and committed 5.1 million hectares of land to be restored. This a slightly higher than the GIS based projection of upscaling potential for restoration resulting from this study, which is 4.2 million ha.

Table 18: Upscaling potential for restoration in Kenya

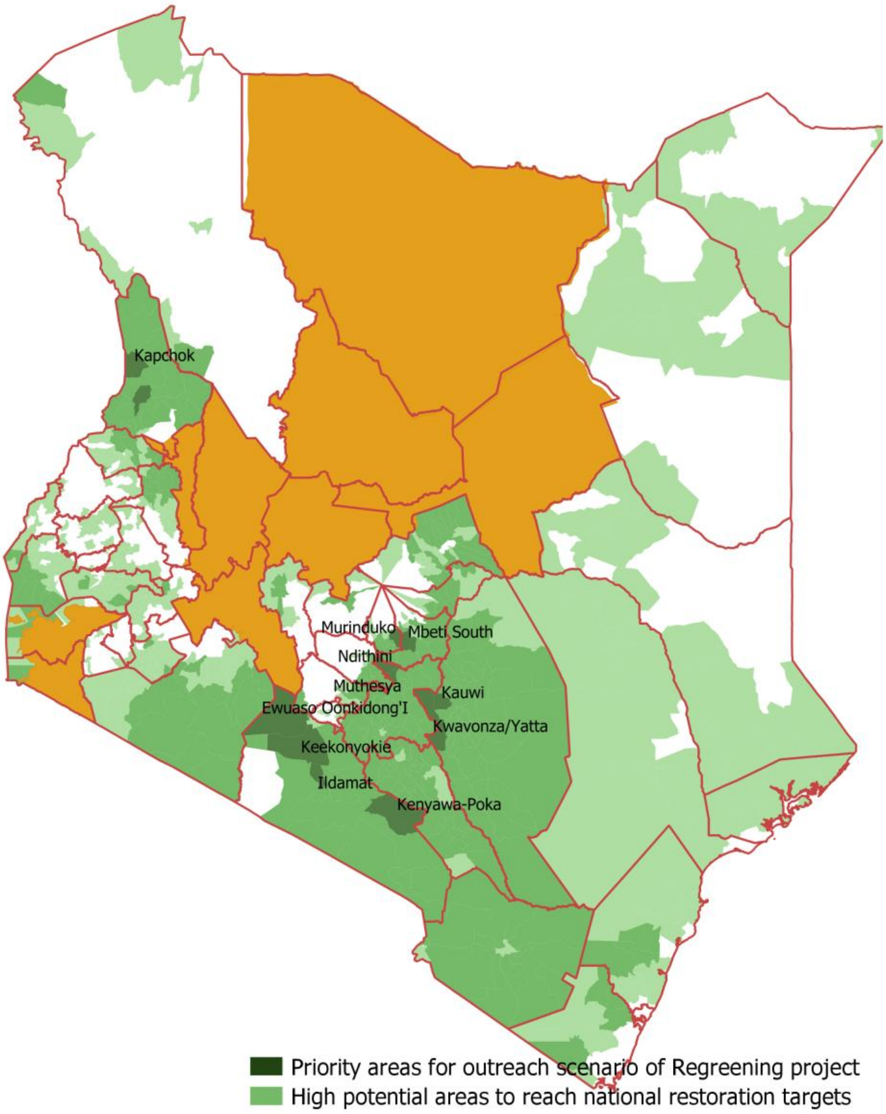
National AFR100 restoration target in ha	GIS based projection of areas with high upscaling potential recommended for restoration in ha (Scenario C)
5.1 million	4.2 million

Scaling-up restoration in Kenya along this outreach potential would result in significant economic benefits. The exact figures are provided in the table below. The current Regreening project is expected to lead to an economic benefit between USD 48 and 76 million in additional income until 2040.

Table 19: Projection of economic benefits for Kenya (in '000 USD)

Present value of net additional income	Scenario A	Scenario B	Scenario C
Typ 1	76.049	98.172	1.361.656
Typ 2	48.090	62.079	861.047

Map 3: Restoration potential in Kenya



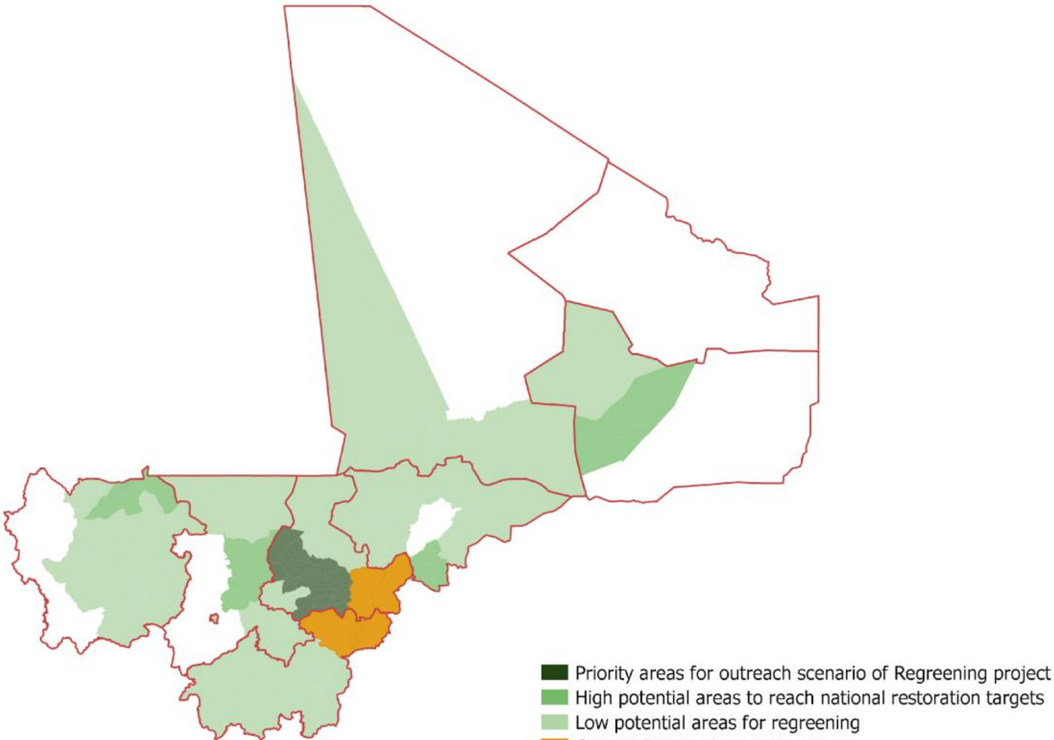
3.5 Mali

According to the spatial analysis, in Mali the Regreening project could find one other districts with similar conditions for scaling up. The initial target of 160.000 ha could be increased to 750.000 ha. The priority area for scaling-up the project is colored in dark green on the map below.

Table 20: Upscaling potential for the Regreening project in Mali

Regreening project target in ha (Scenario A)	Regreening project target areas	GIS based projection of areas with priority for upscaling Regreening project areas in ha (Scenario B)
160.000	Koutiala, Yorosso, Tominian, San	750.000

Map 4: Restoration potential in Mali



Mali has signed onto AFR100 and committed 10 million hectares of land to be restored. The GIS based projection of upscaling potential for restoration only identified four additional areas amounting to 5.9 million ha, which are shaded in medium green on the map.

Table 21: Upscaling potential for restoration in Mali

National AFR100 restoration target in ha	GIS based projection of areas with high upscaling potential recommended for restoration in ha (Scenario C)	Regions
10 million	5.9 million	Gao, Kayes, Koulikoro, Mopti, Segou, Sikasso

Scaling-up restoration in Mali along the outreach potential identified by the GIS analysis would result in significant economic benefits. The exact figures are provided in the table below. The current Regreening project is expected to lead to an economic benefit between USD 51 and 81 million in additional income until 2040.

Table 22: Projection of economic benefits for Mali (in '000 USD)

Present value of net additional income	Scenario A	Scenario B	Scenario C
Typ 1	81.119	320.126	1.912.803
Typ 2	51.296	202.433	1.209.567

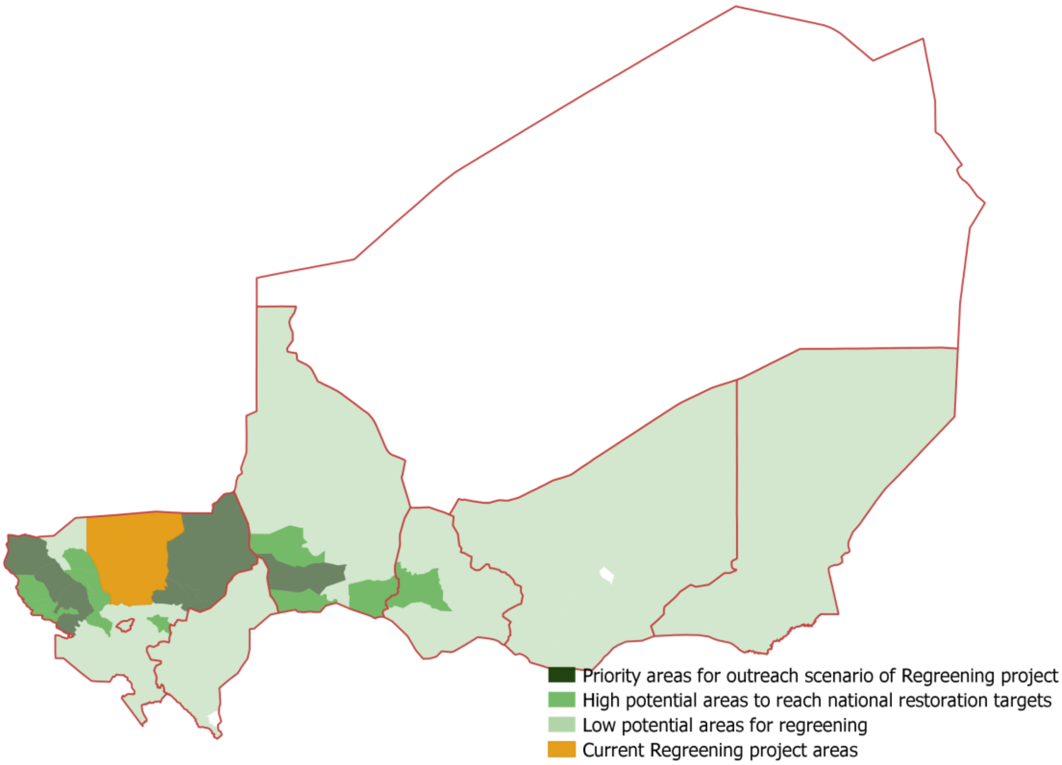
3.6 Niger

In Niger, there is still large potential to scale up restoration. The initial project target of 40.000 ha could be increased to 900.000 ha based on the spatial analysis. The priority areas for scaling-up the project are colored in dark green on the map below.

Table 23: Upscaling potential for the Regreening project in Niger

Regreening project target in ha (Scenario A)	Regreening project target areas	GIS based projection of areas with priority for upscaling Regreening project areas in ha (Scenario B)
40.000	Simiri, Ouallam, Hamdallaye	900.000

Map 5: Restoration potential in Niger



Niger has signed onto AFR100 and committed 3.2 million hectares of land to be restored. The GIS based projection of upscaling potential for restoration identified several additional areas for restoration amounting to 3.6 million ha, which are shaded in medium green on the map.

Table 24: Upscaling potential for restoration in Niger

National afr100 restoration target in ha	GIS based projection of upscaling potential for restoration in ha	Regions
3.2 million	3.6 mil	Maradi, Tahoua, Tillabery

Scaling-up restoration in Niger along the outreach potential identified by the GIS analysis would result in significant economic benefits. The exact figures are provided in the table below. The current Regreening project is expected to lead to an economic benefit between USD 12 and 20 million in additional income until 2040.

Table 25: Projection of economic benefits for Niger (in '000 USD)

Present value of net additional income	Scenario A	Scenario B	Scenario C
Typ 1	20.280	384.152	1.167.134
Typ 2	12.824	242.920	738.041

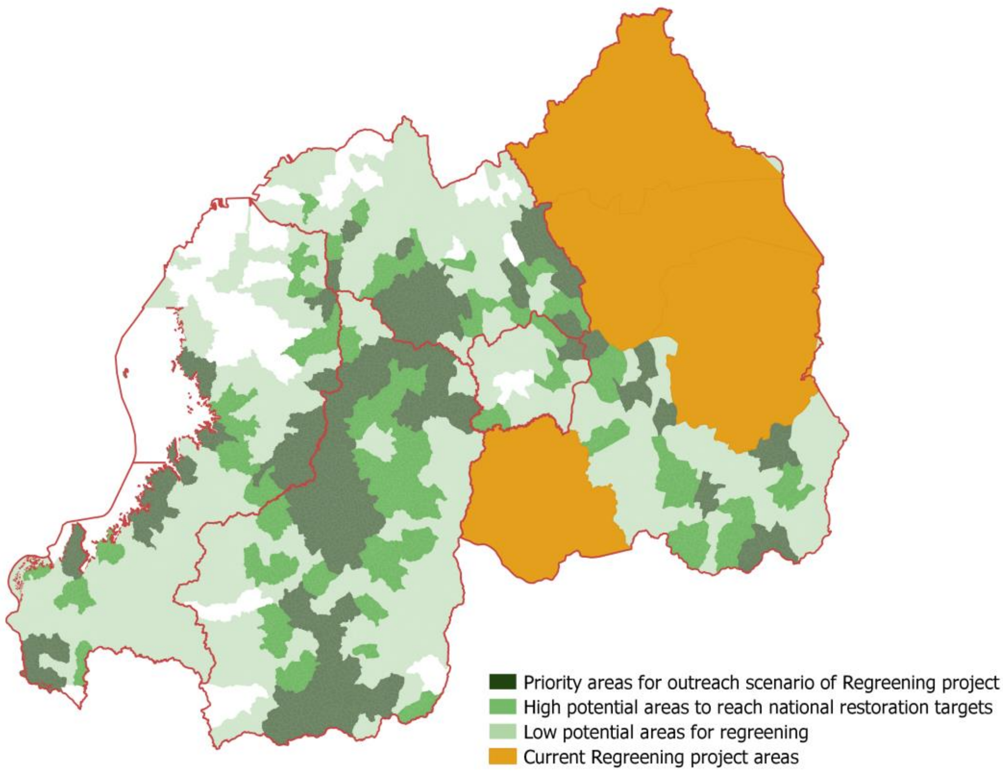
3.7 Rwanda

In Rwanda, there is still large potential to scale up restoration. The initial target of 70.000 ha could be increased to 250.000 ha based on the spatial analysis. The priority areas for scaling-up the project are colored in dark green on the map below.

Table 26: Upscaling potential for the Regreening project in Rwanda

Regreening project target in ha (Scenario A)	Regreening project target areas	GIS based projection of areas with priority for upscaling Regreening project areas in ha (Scenario B)
70.000	Bugesera, Kayonza, Gatsibo, Nyagatare	250.000

Map 6: Restoration potential in Rwanda



Rwanda has signed onto AFR100 and committed 2 million hectares of land to be restored. The GIS based projection of upscaling potential for restoration identified several additional areas for restoration amounting to 0.5 million ha, which are shaded in medium green on the map.

Table 27: Upscaling potential for restoration in Rwanda

National AFR100 restoration target in ha	GIS based projection of upscaling potential for restoration in ha	Regions
2 million	0.5 million	Amajyaruguru, Amajyepfo, Iburasirazuba, Iburengerazuba, Umujyi wa Kigali

Scaling-up restoration in Rwanda along the outreach potential identified by the GIS analysis would result in significant economic benefits. The exact figures are provided in the table below. The current Regreening project is expected to lead to an economic benefit between USD 22 and 35 million in additional income until 2040.

Table 28: Projection of economic benefits for Rwanda (in '000 USD)

Present value of net additional income	Scenario A	Scenario B	Scenario C
Typ 1	35.490	106.709	162.102
Typ 2	22.442	67.478	102.506

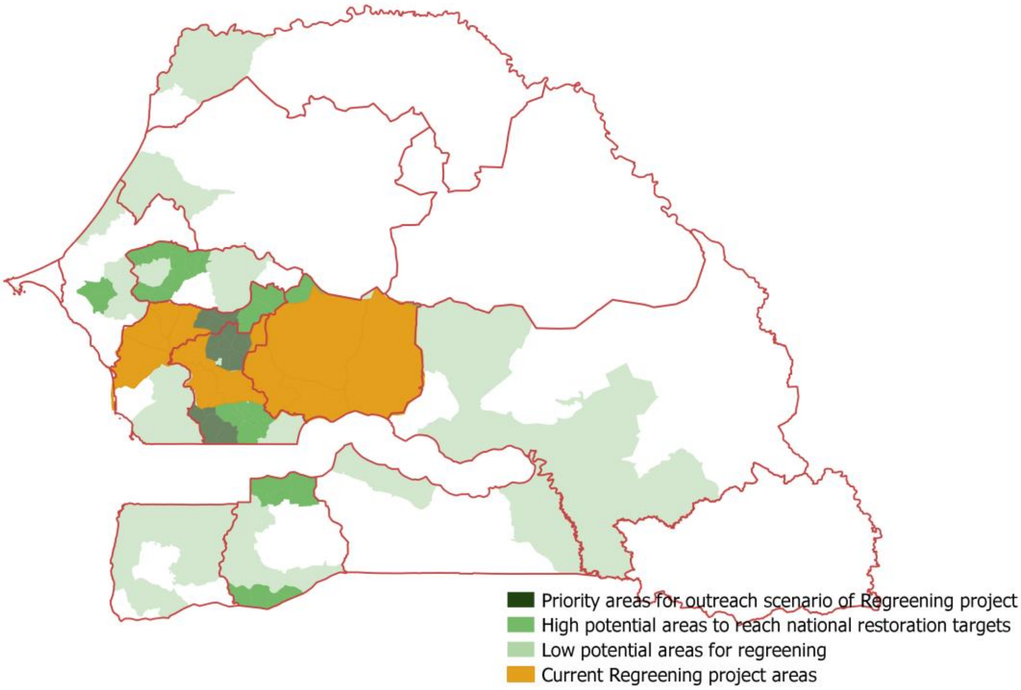
3.8 Senegal

In Senegal, there is still large potential to scale up restoration. The initial project target of 80.000 ha could be increased to 360.000 ha based on the spatial analysis. The priority areas for scaling-up the project are colored in dark green on the map below.

Table 29: Upscaling potential for the Regreening project in Senegal

Regreening project target in ha (Scenario A)	Regreening project target areas	GIS based projection of areas with priority for upscaling Regreening project areas in ha (Scenario B)
80.000	Kaffrine, Kaolack, Fatick	360.000

Map 7: Restoration potential in Senegal



Senegal has signed onto AFR100 and committed 2 million hectares of land to be restored. The GIS based projection of upscaling potential for restoration identified several additional areas for restoration amounting to 1.6 million ha, which are shaded in medium green on the map.

Table 30: Upscaling potential for restoration in Senegal

National afr100 restoration target in ha	GIS based projection of upscaling potential for restoration in ha	Regions
2 million	1.6 million	Diourbel, Fatick, Kaffrine, Ka-olack, Sedhiou, Thes

Scaling-up restoration in Senegal along the outreach potential identified by the GIS analysis would result in significant economic benefits. The exact figures are provided in the table below. The current Regreening project is expected to lead to an economic benefit between USD 25 and 40 million in additional income until 2040.

Table 31: Projection of economic benefits for Senegal (in '000 USD)

Present value of net additional income	Scenario A	Scenario B	Scenario C
Typ 1	40.560	153.661	486.306
Typ 2	25.648	97.168	307.517

3.9 Somalia

In Somalia, the Regreening project could easily triple its size based on the GIS analysis. The initial target of 20.000 ha could be increased to 65.000 ha based on the spatial analysis. The priority areas for scaling-up the project are colored in dark green on the map below. The priority districts are marked. Areas with high potential for scaling-up restoration amount 0.7 million ha.

Table 32: Upscaling potential for the Regreening project in Somalia

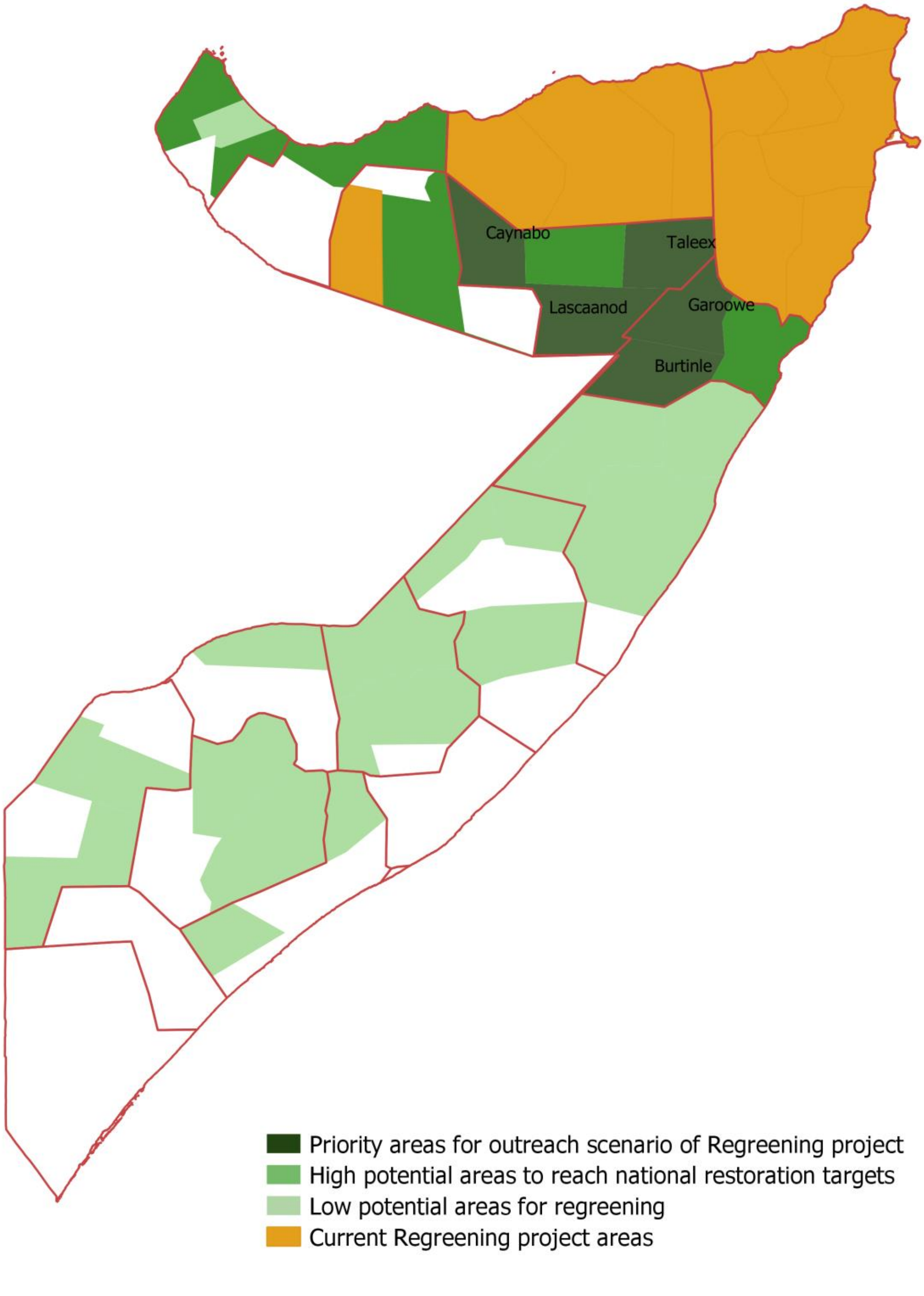
Regreening project target in ha (Scenario A)	Regreening project target areas	GIS based projection of areas with priority for upscaling Regreening project areas in ha (Scenario B)
20.000	Somaliland: Dweyne and Awdac districts; Puntland: Sanaag, Karkar and Bari districts	65.000

Scaling-up restoration in Somalia along the outreach potential identified by the GIS analysis would result in significant economic benefits. The exact figures are provided in the table below. The current Regreening project is expected to lead to an economic benefit between USD 6 and 10 million in additional income until 2040.

Table 33: Projection of economic benefits for Senegal (in '000 USD)

Present value of net additional income	Scenario A	Scenario B	Scenario C
Typ 1	10.140	27.744	226.943
Typ 2	6.412	17.544	143.508

Map 8: Restoration potential in Somalia



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ANNEX

Deforestation in West Africa

Mali

Mali is classified as being in the late transition phase in terms of forests (Hosonuma et al., 2012). Forest cover, deforestation and forest degradation have not been assessed reliably in Mali. Estimates are highly disparate; we take into account the 2015 figures published by FAO (4.7 million ha forest cover). Forest degradation processes have led to widespread desertification, over up to 75% of the national territory, namely in the Saharan and Sahelian zones. Productive forests occur mainly south and west of the country (Sudano-Guinean, Guinean zones). They consist of open woodland, riparian forests, tree/shrub savannahs. Man-made village forests amount to 40,000 ha and 4,000 km of linear plantings. Trees outside forests contribute non-wood forest products; they are found in agroforestry parklands, fruit orchards and village and urban forests (FAO, 2015).

Deforestation is occurring at a faster rate particularly in the Sahelian zone, as a result of excessive animal pressures on woody rangeland resources, as well as in areas providing urban centers with wood fuel and the southern region, where agricultural expansion is uncontrolled. Vegetation types are particularly degraded due to extensive use during the dry season. Various and natural resource land conflicts also result due to rapid population increase and a lack of integration of forest policies into the national economy. Furthermore, recurring droughts in northern Sahel have contributed to a situation that amplifies deforestation.

Forest activities and impacts of deforestation have a strong gender component in Mali; the country ranks third in the world in terms of number (180,000) and share (90%) of women employed in the forestry sector. They are mainly engaged in wood fuel and NWFP collection (Whiteman et al., 2015).

Ghana

Ghana has a land area of over 23 million ha, of which nearly 13,628,179 ha (59%) is under agricultural use. Ghana’s total forest cover is down from 8.2 million ha in 2000 to less than 1.6 million ha (6.9%) in 2011. The annual deforestation rate is projected to be 2% (Forestry Commission Ghana, 2017). The estimated percentage of total land area prone to desertification is 65%, with the Upper East and eastern part of the Northern region facing the greatest desertification threat. As per the country’s REDD+ readiness proposal, the country is in a late forest transition stage. (Forestry Commission Ghana, 2010).

The main types of natural forest in Ghana are closed forests in the southwestern and middle belt, and Savannah forests in the north, with tracts of mangroves present along the coast. The major forest related problem in the country is characterized as gradual degradation of forest reserves, rather than deforestation itself. Drivers include agricultural expansion (50%), wood harvesting and charcoal production (35%), population and development pressures (10%), and mineral exploitation and mining (5%). In the open and drier Savannah areas however, fires and overgrazing play a larger role than in the high forest zones. In addition, wood removal for fuel wood and charcoal production is estimated at 30 million m^3 per year, while forest timber logging and harvesting from the regulated sector amounts to 3.72 million m^3 per year for export, and 1.8million m^3/year by predominantly illegal logging for domestic consumption. Fuel wood extraction is projected to increase from 18 million tons in 2000 to 25 million tons by 2020. (Agyarko, 2000)

To combat deforestation and forest degradation issues, certain measures have been taken in the past decades: (i) government introduced national plantation development programme to restore forest cover, generate employment and reduce the wood deficit (2010); (ii) Cocoa REDD+ emissions reduction program; (iii) Forest Investment Plan (USD 50 million).

Senegal

As of 2016, 42% of Senegal is accounted as forested land. From 2001 to 2018, Senegal lost 3.43kha of tree cover, equivalent to an 8.7% decrease in tree cover. Its coastal regions also host a large spread of mangrove forests, now threatened by coastal development (Global Forest Watch, 2018). Senegal is classified as being in the early forest transition stage, meaning that is it likely that deforestation will accelerate even further in the short term (Hosonuma et al., 2012).

A major threat to inland forests stems from the domestic charcoal industry; more than half of Senegal's 13 million people still rely on charcoal for fuel, with thousands of rural livelihoods dependent on harvesting wood to make charcoal (The Borgen Project, 2019).

Niger

Productive natural vegetation in Niger has suffered a sharp decline since 1990. The Sahelian short grass savanna contracted in area by 26.7% from 1975 to 2013. Gallery forests, representing the most dense and biologically diverse vegetation in Niger, have also declined significantly. Their total area has always been low (approximately 470 km^2 in 1975) but has significantly decreased (66%) in this time period. (CILSS, 2016). Wind erosion, overgrazing on low vegetation, and loss of woody cover from drought and deforestation have resulted in in land degradation and desertification across the country. Niger is currently assessed as being in a late stage of forest transition (Hosonuma et al., 2012).

Deforestation in East Africa

Ethiopia

Current data show that Ethiopia has 17.22 million ha of forest resources, i.e. covering 15.5% of the country's total area. The national deforestation rate since 2010 is estimated as 1.25% per year, and for other woodlands, 1.8% per year. Forest cover has declined from 35-40% in 1990s to 11.2% in 2010. However, planted forests have increased compared to the previous decades. Total forest plantation area in Ethiopia is estimated at 972,000 ha currently. The majority of these plantation forests are non-industrial and are small-scale private plantations and woodlots (FAO, 2015).

Land-use and land-cover statistics show that woody vegetation, including high forests, cover over 50% of the land (9.7 million ha). Of this, 6.8% is high forests, 49% is woodland, 44.2% is shrubland or bushland, and plantations cover less than 1% (FAO, 2017). The wood from these plantations are mainly supplied to the construction sector (as poles and posts) and compose a major part of the national biomass fuel use today (FAO, 2015).

Ethiopia is classified as being in a late stage of forest transition (Hosonuma et al., 2012). The major cause of deforestation in Ethiopia is and has been rapid population growth, leading to an increase in the demand for crop and grazing land, and wood for fuel and construction. New settlements within forest areas are increasing and have resulted in the conversion of forested land into agricultural and other land-use systems. This is mainly driven by the expansion of traditional smallholder agriculture (FAO, 2017).

Kenya

Approximately 3,467,000 ha (6.1%) of the total land area in Kenya is forested. Of this, 654,000 ha (18.9%) is classified as primary forest, i.e. high in biodiversity and carbon storage capacity; and 197,000 ha (5.7%) is planted forest. In total, between 1990 and 2010, Kenya lost 6.5% of its forest cover, or around 241,000 ha (FAO 2015).

Kenya is classified as being in the late stage of forest transition. Kenya's rural population is concentrated within 'high' and 'medium-potential' agro-ecological zones, where rainfall levels are adequate to support agriculture. These are also the areas in which areas of closed canopy forests are located. In these same agro-ecological zones, population growth rates over the last four decades have been substantial. Thus the major drivers of deforestation include transformation of land for agricultural purposes and high reliance on charcoal, with other governance related issues (de-gazetting of forest land, unchecked grazing within forest reserves, poor execution of Taungya reforestation activities) creating an unsupportive enabling environment for forestry (MoFW, 2013).

Somalia

Somalia is characterized as being in a late forest transition phase. According to the 2010 Forest Resource Assessment, 6,747,287 ha (10.6%) of Somalia is classified as forest land. Between 2000 and 2005, the annual area loss resulting from deforestation and other factors is estimated at 76,757 ha/year, with the same trend visible until the year 2010. (FAO, 2010) It is highly difficult to assess the scale of deforestation or forest cover extent in Somalia as the last forest inventory was conducted in 1980, and various definitions for forest and other land uses have not been defined at the national level.

The main threats to its forest sector include rapid population growth, urbanization and high dependence on charcoal, which is a multi-million dollar industry supplying both domestic and foreign demand. Other demands for wood products include building materials, feed for livestock and furniture (UNEP, 2018).

Rwanda

Rwanda has a land area of 25,312,000 ha, with diverse ecosystems including montane forests. Current data on the dimension of deforestation and forest cover, structure and composition for Rwanda is lacking. The latest forest cover information is from 1988, based on the topographical maps of the 1970s. As per the current information, Rwanda's total forest cover is estimated at 696,402 ha (29.6% of the total land area). Plantations cover about 413,274 ha (59%): the most dominant species is Eucalyptus, followed by Pinus. Of this area, natural forests cover a total area of 283,128 ha (41%), comprising Nyungwe National Park (NP) with 111,562 ha, Akagera NP with 113,160 ha, Volcanoes NP with 16,000 ha and Gishwati-Mukura NP with 2,684 ha.

Between 1990 and 2010, Rwanda lost an average of 5,850 ha of forest (1.84%) per annum. FAO (2015) reports that between 1990 and 2015, Rwanda gained 1.7% of its forest cover, or around 6.5 ha annually. In literature, Rwanda is classified as being in the post forest transition phase.

The main drivers of deforestation and forest degradation in the country include agriculture (95% of households practice traditional subsistence agriculture on small plots), infrastructure development, urbanization, mining forest product extraction (firewood, charcoal and timber) and limited forestry extension services (Republic of Rwanda, 2017).

Table 34: GIS values by attribute and country

	Soil depth (cm)		pH Soil		SOC g/kg		Water Holding capacity		Elevation m a.s.l.		Population density		Road density		average Temperature °C		Fire occurance (number of spoted fires)		average precipitation (d/y)		% of forest area	
Country	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Ethiopia	95	146	6.7	7.8	7	12	19	25	1616	2401	17	181	84	178	16	22	0	14481	48	88	0%	18%
Ghana	120	160	6.0	7.0	1	3	21	29	160	230	51	170	110	175	28	28	0	28611	77	93	11%	40%
Kenya	107	150	6.2	7.6	1	9	22	26	1030	2170	10	346	0	1442	16	23	0	2721	46	91	4%	40%
Mali	111	154	6.0	6.6	1	2	21	25	277	398	21	90	102	190	27	28	0	14323	53	73	2%	21%
Niger	140	160	5.0	7.0	1	4	10	30	200	400	5	30	100	160	20	35	120	160	25	40	0%	2%
Rwanda	130	156	5.1	5.7	4	16	23	27	1414	1865	86	384	587	1561	18	20	0	2918	76	125	0%	29%
Senegal	158	171	5.7	6.4	2	8	18	23	6	31	25	223	376	685	27	28	0	23459	45	53	0%	9%
Somalia	47	67	8.0	8.2	3	4	19	23	489	1026	3	13	152	217	23	26	65	702	4	19	0%	2%

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