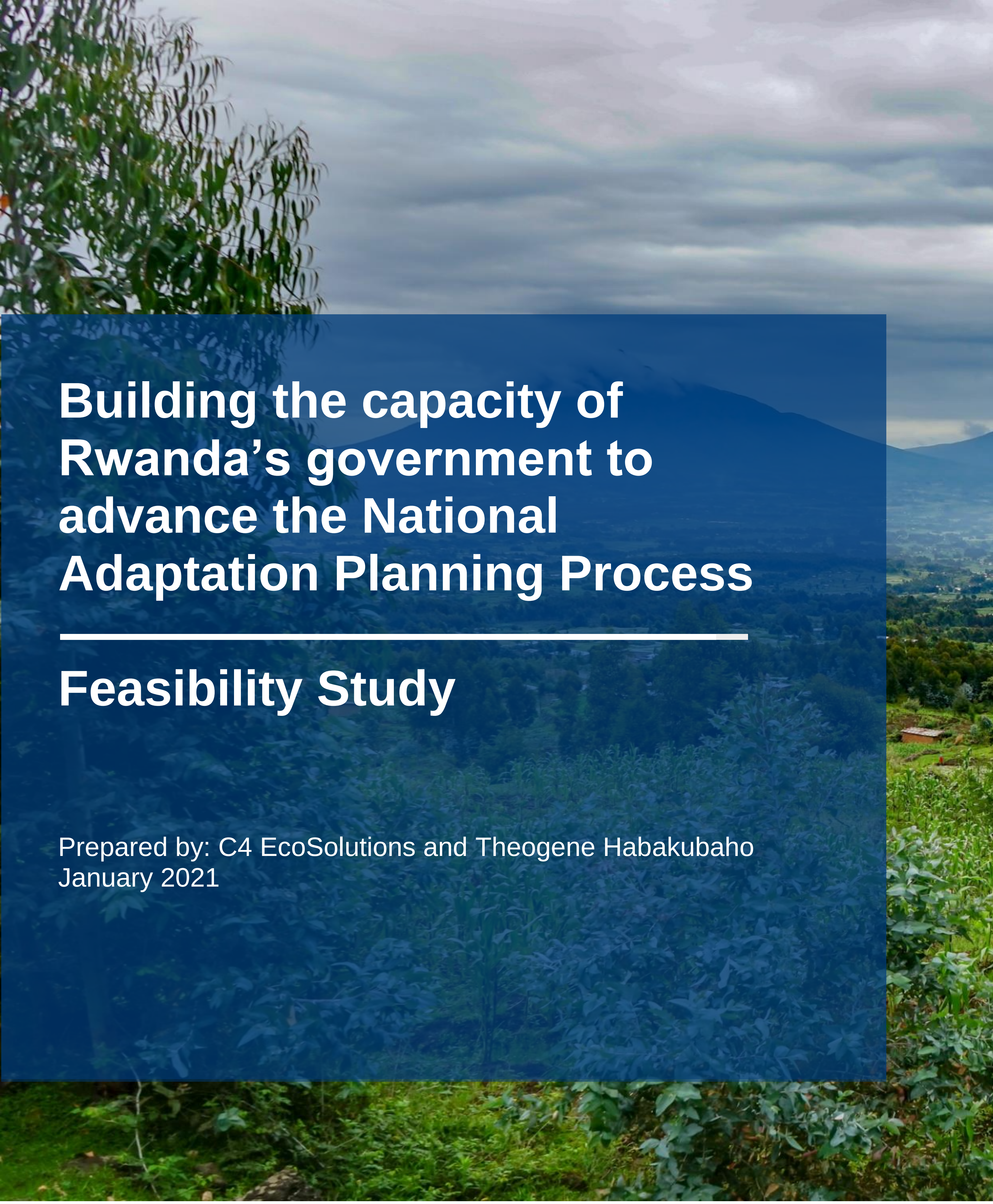

Building the capacity of Rwanda’s government to advance the National Adaptation Planning Process

Feasibility Study

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Executive summary

Introduction

The information contained in this document constitutes the Feasibility Study Report for the project titled 'Building the capacity of Rwanda's government to advance the National Adaptation Planning Process'[1]. This Feasibility Study focusses on: i) assessing the viability and extending the design of the project's proposed ecosystem-based adaptation (EbA) interventions across five pilot sites in Rwanda; and ii) designing the long-term research programme (LTRP) for climate change adaptation in Rwanda. In addition, the Feasibility Study aims to inform the effective implementation of the activities under the project. The assessed interventions and pilot sites include: i) the re-establishment of a buffer zone around Ibanda-Makera Natural Forest as well as the promotion of agroforestry with drought-resilient tree species; ii) restoration of the Muvumba River's catchment as well as the demarcation of a riparian buffer zone; iii) the implementation of silvopastoralism within savannas in the Nyagatare District; iv) the implementation of agroforestry — as well as the stabilisation of plantation verges with vegetation — at the Shagasha Tea Estate; and v) vegetation restoration and the establishment of sustainable urban drainage systems (SUDS) in the Nyandungu wetland.

Detailed description of pilot sites and interventions

<u>Ibanda-Makera Natural Forest, Kirehe District, Eastern Province</u>

The Kirehe District is among the most disaster-prone districts in Rwanda, being highly susceptible to severe droughts during the country's two rainy seasons as well as floods and landslides resulting from sudden occurrences of heavy rainfall after the dry season. The area is in a low plain and is characterised by savanna vegetation interspersed with natural forest, including Ibanda-Makera Natural Forest. Ibanda-Makera is nationally recognised as an important natural forest because of its ecological, hydrological, climatic and socio-economic services, as well as the presence of many endemic and rare plant and animal species. Inhabitants of the two nearby villages rely on the forest for wood, forage, food, medicine and water. Increasing human pressure from agricultural expansion, bush fires and fuelwood collection as well as prolonged drought conditions, however, have resulted in considerable degradation of the forest. Under future climate change, drought conditions and seasonal variability are expected to increase in the area, which will negatively affect local livelihoods, resulting in further exploitation of resources and degradation of the Ibanda-Makera forest.

Proposed EbA interventions to be piloted at Ibanda-Makera Natural Forest include: i) demarcation and establishment of a buffer zone around the forest; ii) promotion of agroforestry in surrounding agricultural land; and iii) introducing highly productive drought-resistant crop species. Moreover, district officials and community members recommended additional activities, including: i) planting forestry trees on hills surrounding the forest, which amount to more than 400 ha of land; ii) supporting community-driven projects such as bee-keeping and fish farming around Ibanda-Makera; and iii) implementing other soil erosion control structures such as ditches, terraces and water ponds to control water from surrounding hills and prevent soil erosion. Results of the multi-criteria analysis (MCA) show that the initially proposed EbA interventions — i.e. the promotion of agroforestry, introduction of drought-resistant crop species and establishment of a buffer zone around the forest — are the most viable EbA options (ranging from 0.65–0.76). Of the additional recommended interventions, bee-keeping was selected to contribute to the reduction of baseline degradation within the forest and to support livelihood diversification. In addition, it was suggested by project management to include a Zero Budget Natural Farming (ZBNF) pilot intervention at one of the sites, and the Ibanda-Makera Natural Forest was selected as an appropriate site for this intervention. ZBNF involves reducing synthetic input of fertilisers and chemicals, while increasing farm resilience to climate hazards as well

[1] henceforth referred to as the "NAP project".

as enhancing carbon capture in soils. The total budget for implementing the proposed interventions at the Ibanda-Makera forest is US$840,000, with $200,000 of this being used on ZBNF.

Given the difficulties associated with tree planting in Rwanda's Eastern Province as a result of limited rainfall, stakeholders recommended to have a contractor who will be responsible for tree planting and follow up for at least two years, using local labour to ensure community ownership. It was also recommended by district officials that the project supports the establishment of Environment Committees in the intervention area and provide them with training on implementing EbA interventions.

Muvumba River, Nyagatare District, Eastern Province

The area in which the Muvumba River is situated consists of steep hillslopes moderately covered in vegetation, which includes mostly agricultural land with patches of gallery forest. These gallery forests are threatened by the expansion of surrounding agricultural land as well as a dependence of local communities on fuel wood as an energy source, both of which result in deforestation. This deforestation in turn leads to the erosion of slopes and the siltation of water sources — including the Muvumba River. Water quality of the river is additionally reduced by pollution from urban settlements, industrial activities, mining and agricultural practices.

Erosion in the Muvumba catchment is further exacerbated by current climate conditions and hazards, including droughts, windstorms and flooding. Droughts occur as a result of unpredictable and low rainfall levels compared with the majority of Rwanda, as well as comparatively high temperatures. These drought conditions reduce agricultural productivity of local communities. Increased flooding during heavy rainfall events occurs along riparian areas of the river, resulting in the erosion of exposed riparian areas and riverbanks. This erosion and resultant loss of fertile soils leads to reduced soil fertility and poor agricultural productivity in upper parts of the watershed. Flooding additionally increases siltation within the river, which decreases the water intake capacity of water supply stations that service local communities. This contributes to 20% of the 466,000 people within the Nyagatare District — 20% of which are extremely poor — not having access to clean water or sanitation, particularly in the dry season.

Climate change is predicted to result in a greater intensity and frequency of heavy rainfall events, which will exacerbate current levels of erosion in catchment areas and siltation of the Muvumba River. This will subsequently negatively impact the capacity of raw water intake stations and treatment plants, compromising the supply of water to communities for domestic use and irrigation.

Proposed project interventions to address these climate change impacts include: i) the demarcation of a riparian buffer zone along the Muvumba River; and ii) the reforestation of catchment areas upstream of water intake and treatment plants with drought-resistant tree species. These interventions will reduce runoff and erosion, ultimately reducing flooding and siltation of the Muvumba River. Two additional activities were suggested by local community representatives during the consultation process, including: i) establish soil erosion control structures such as ditches with grasses in addition to catchment reforestation; and ii) extend the buffer zone beyond 10 metres in areas where gallery forests remain. Each intervention and additional activity scored high in the MCA (0.64–0.75), with the buffer zone determined to be the most feasible. The total budget for the above EbA interventions is US$618,000.

Eastern savannas, Nyagatare District, Eastern Province

The eastern savannas consist of low hills mostly covered by savanna vegetation. Relatively low rainfall and high temperatures compared with the majority of Rwanda results in the eastern savannas being amongst the most drone-prone areas in the country. This results in low agricultural yields and food shortages, as well as severe landscape degradation. The area is also vulnerable to heavy storm events during the rainy seasons which result in elevated water runoff and resultant soil erosion, further contributing to reduced soil quality. Deforestation to clear land for agricultural practices combined with subsequent overgrazing, have resulted in further severe landscape-level degradation.

Under future climate change, the length of the dry season, seasonal variability in rainfall and temperatures in the area will increase. These changes will lead to further degradation of savanna ecosystems and agricultural lands in the area. As a result, agriculture-based livelihoods of many local farmers will be put at risk as soil fertility and the availability of forage for livestock will continue to decrease.

Recommended EbA interventions to be piloted in the eastern savanna site include: i) fencing paddocks with drought-tolerant trees; ii) planting drought-resistant trees in rangelands; and iii) planting fodder and medicinal plants for use by livestock and humans, respectively. These interventions will protect exposed soils from wind and water erosion, prevent livestock from grazing during pasture regeneration periods, provide additional fodder and shade for livestock, generate wood for communities and promote water infiltration. All three of these proposed EbA interventions scored highly during the MCA, ranging from 0.73–0.79. The total budget for the interventions at the eastern savannas is US$597,000.

<u>Shagasha Tea Estate, Rusizi District, Western Province</u>

The major ecological systems in the Shagasha area are the Shagasha Natural Forest and Kivu lake. Tea plantations, agricultural land and woodlots/planted forest constitute the remaining 75% of the area. Intensive agriculture and resultant deforestation in the Rusizi District results in losses of ~14 million tonnes of soil through erosion annually[2]. The relatively high amount of rainfall in the area compared with the majority of the country contributes to this erosion, as well as to flooding and landslides during heavy storm events, which threaten forests, agricultural land and lives. Tea plantations are particularly susceptible to changes in rainfall amounts, dry season lengths and temperature. Future climate change is expected to result in an increasing occurrence of climatic extremes in Rusizi District. Specifically, projections indicate that there will be increases in average temperatures and exacerbated rainfall variability, characterised by the decreasing length of the rainy season, longer dry spells, and an increasing intensity of rainfall events. Long-lived climate-sensitive crops such as tea are particularly threatened by such changes, with rising temperature affecting the suitability of where tea can be grown. In addition, increased rainfall variability and more frequent heavy rainfall events will contribute to increased flooding and erosion, which will negatively impact agricultural lands. Reduced agricultural production will affect the livelihoods of much of the district's 417,000 inhabitants, of which 45% fall within the poverty band.

Proposed project interventions include reducing water stress and soil moisture loss through the planting of drought-tolerant tree species (agroforestry), the plantation of grasses on verges of tea plots and riverbanks and establishing woodlots to provide fuelwood for tea factory operations. Consultations with stakeholders influenced the design and selection of these interventions; initially intercropping was proposed in the ProDoc but it was deemed unviable in this Feasibility Study and was replaced with the establishment of woodlots and extension of grass planting to riverbanks. Both agroforestry and grass-planting interventions scored highly in the MCA, scoring 0.78 and 0.77 respectively, while woodlot establishment was not assessed because this intervention is complementary to the EbA interventions and is itself not EbA. The total budget for interventions at the Shagasha Tea Estate is US$606,000. Unlike the other sites where a contractor is preferred, a community-based implementation approach is recommended as the best implementation approach for this site.

[2] Karamage F, Zhang C, Ndayisaba F, Shao H, Kayiranga A, Fang X, Nahayo L, Muhire Nyesheja E & Tian G. 2016. Extent of cropland and related soil erosion risk in Rwanda. *Sustainability*. 8: 609.

Nyandungu Wetland

This site was proposed as an alternative to the Kimicanga wetland site (Section 2.5). Vegetation in the Nyandungu wetland site consists of natural vegetation in wetland areas and agricultural or exotic vegetation in drier areas. Population growth and rapid urban expansion within Kigali is placing considerable pressure on the city's remaining green spaces, including the Nyandungu wetland. Deforestation, cultivation, urbanisation and the introduction of invasive species within the site have resulted in serious reductions in indigenous vegetation cover and wildlife biodiversity. This degradation of natural vegetation will decrease the ability of wetlands to reduce the impact of flooding, which naturally occurs in the area as a result of: i) a low-lying topography which receives high volumes of surface flow; ii) clayey soils with low water holding capacity; iii) the influx of wastewater from urban areas; and iv) the narrow Mwanana River which often floods during heavy rainfall. This decreased ability of the wetland area to reduce flooding will be an increasing concern under future climate change, as the amount of rainfall and the intensity of heavy storm events is predicted to increase, leading to more frequent and intense flooding.

The project interventions will involve co-financing and upscaling activities under the project aimed to establish the Nyandungu Urban Wetland Eco-tourism Park. This includes the restoration of 130 ha of native wetland and riparian vegetation and using vegetated swales, check dams and bioretention basins to make the wetland a sustainable urban drainage system (SUDS) to mitigate flooding impacts on surrounding communities. The proposed budget for the pilot NAP project interventions to assist the current project is US$567,000.

Recommended approach to the cost-benefit analysis of interventions

An approach for cost-benefit analyses (CBA) to be carried out during project evaluation is presented. CBA is a method used to analyse the costs and benefits associated with a project or policy intervention. This method uses inter-temporal discounting to allow estimation of the net present value of a series of incurred or anticipated costs and benefits. A CBA should include the following steps: i) define the aim of the CBA, including outlining the study site, current land use, ecosystems, communities and sectors; ii) describe the intervention's theory-of-change; iii) identify the costs, benefits and potential impacts associated with the intervention; iv) measure and quantify intervention costs and benefits in monetary terms using ecosystem services valuation methods; v) perform sensitivity analysis to determine which parameters are most critical to ensuring optimal net benefits; vi) determine the distributional impacts of the intervention between user groups over time; and vii) explore potential solutions if unequal distributions of costs and benefits exist.

Primary adaptation benefits of interventions in the Ibanda-Makera pilot site include enhanced incomes from fuelwood and non-timber forest product (NTFP) collection from multi-use tree species, reduced pressure on natural forests, improved agricultural productivity and optimised land and resource usage. Additional adaptation benefits include reduced forest fragmentation, enhanced potential for eco-tourism development and resultant income generation, enhanced regulation of ecosystem services and reduced water use. Other co-benefits include improved diets through the provision of fruit from fruit trees and reduced pressure on water sources. Costs for interventions at this pilot site include the purchase cost of seedlings, time and monetary costs of labour and training, and loss of land from surrounding communities. Potential impacts include extended timeframes for planted species and subsequent delays in the delivery of benefits, displacement of land owned by surrounding communities that could be used for cultivation, and reduced benefits for farmers as there is less space to implement agroforestry.

For the Muvumba River pilot site, primary adaptation benefits include reduced sedimentation of rivers, improved water quality, bank stabilisation, reduced erosion, improved soil conservation and flood attenuation. Additional adaptation benefits comprise of reduced flood impacts, shading for aquatic species, enhanced household incomes from the sale of fruit, timber, fuelwood and NTFPs and improved groundwater recharge. Other co-benefits include recreation opportunities and fodder production. Costs associated with interventions in this site include the cost of seedlings and infrastructure, time and expenses for labour and training, enforcement costs, administrative costs for finalising land tenure arrangements and the displacement of existing activities and land uses. Potential impacts include long timeframes for riparian vegetation establishment meaning delayed materialisation of benefits, loss of agricultural land and an unequal cost-benefit profile favouring downstream communities.

The eastern savannas pilot site interventions have the potential to produce primary adaptation benefits including the restoration to rangeland habitats that increase livestock productivity through improved fodder and shade as well as the provision of fuelwood, timber and NTFPs for local communities. Additional adaptation benefits are comprised of improved soil health and nutrient cycling, water infiltration and groundwater recharge, the optimisation of land usage, enhanced household incomes from the sale of timber and NTFPs and reduced demand on natural forests. Co-benefits include carbon sequestration, flood attenuation, reduced sedimentation of rivers, improved access to medicinal plants and improved nutrition for local communities through the provision of fruit from fruit trees. Intervention costs consist of seedling expenses as well as time and monetary expenses of labour and training. Potential impacts include longer timeframes for the delivery of benefits, changes to grazing regimes and a potential preference for farmers with larger rangelands and access to water for irrigation.

For interventions planned in the Shagasha Tea Estate pilot site, primary adaptation benefits include enhanced household incomes from the sale of fruit, timber and NTFPs, improved tea production from shading, reduced erosion and runoff, increase hill stabilisation, soil conservation, diversification of agricultural income sources, reduced forest fragmentation, development of eco-tourism and improved water quality for irrigation. Additional benefits include reduced impacts of flooding, shade for aquatic species, enhanced regulation of ecosystem services and improved availability of nutritionally diverse foods. Co-benefits consist of recreation opportunities, carbon sequestration and livestock fodder generation. Potential costs of interventions include the expense of purchasing seedlings, time and monetary expenses of labour and training, enforcement costs, loss of land owned by surrounding communities and the reduction of current land uses. Impacts include improved drought resilience of agriculture over time, ore consistent income from agriculture, improved erosion control, extended timeframes for planted species in buffer zones to provide benefits, displacement of land owned by surrounding communities, reduced access to resources and equal benefits for all smallholder farmers within cooperatives.

Finally, for interventions planned in the Nyandungu wetland site, primary adaptation benefits include reduced erosion and runoff, increased water availability and wastewater treatment. Additional adaptation benefits include hill stabilisation, soil conservation, enhanced regulation of water flow and maintained or enhanced agricultural activity. Co-benefits consist of livestock fodder generation and reduced incidences of disease. Intervention costs include construction costs, time and monetary expenses for training and labour and the loss of other potential land uses. Impacts include improved consistency in water availability, more consistent income from agriculture, relatively short timeframes for benefits of wastewater treatment, reduced soil loss and equal benefits for all smallholder farmers within cooperatives.

Linkages between interventions and past and ongoing projects and initiatives

The proposed EbA interventions to be implemented under the LDCF-funded project will be closely aligned with other initiatives previously and currently implemented at the project sites and elsewhere in Rwanda to ensure that the project’s EbA interventions build on the successes of and learn from the failures of relevant initiatives. In the Ibanda-Makera site, the ‘Building Resilience of Communities Living in Degraded Forests, Savannahs and Wetlands of Rwanda Through an Ecosystem

Management Approach' ('LDCF2')[3] project is targeting the degraded Ibanda forest for restoration, which will improve the climate resilience of the overall Ibanda-Makera area that this NAP project is covering (this project's interventions will target the Makera forest section and the surrounding agricultural land). In the Muvumba River site, species chosen for EbA interventions have been selected based on suggestions in the Muvumba Catchment Management Plan (2018–2024)[4]. The same plan mentions the need for the reforestation of the hills in the upstream sections of the catchment, which will be implemented under this project. In the eastern savannas of the Nyagatare District, best practice suggestions from the Landscape Approach To Forest Restoration And Conservation (LAFREC)[5] project's silvopastoralism interventions in the rangelands of Gishwati have been incorporated into the design of this project's silvopastoral interventions. The EbA interventions to be implemented at the Nyandungu wetland complex are already planned under the REMA-led Nyandungu Urban Wetland Eco-Tourism Park project[6], and will receive funding through this NAP project. No projects are currently targeting the Shagasha Tea Estate, but best practices and lessons learned from various EbA interventions implemented in Rwanda have been incorporated into this project's intervention designs.

[3] https://www.thegef.org/project/building-resilience-communities-living-degraded-forests-savannahs-and-wetlands-rwanda
[4] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024). https://waterportal.rwb.rw/node/3133
[5] GEF& World Bank. 2015. Landscape Approach to Forest Restoration and Conservation (LAFREC). https://projects.worldbank.org/en/projects-operations/project-detail/P131464?lang=en
[6] REMA. 2012. Study for Establishing Urban Wetland Recreation and Eco-Tourism Park in Nyandungu Valley, Kigali City (Rwanda): Final Report. Available: https://rema.gov.rw/fileadmin/templates/Documents/rema_doc/publications/Planning%20docs/Nyandungu%20wetland%20plan_2012.pdf

1 Introduction

The information contained in this document constitutes the Feasibility Study for the project titled '*Building the capacity of Rwanda's government to advance the National Adaptation Planning Process*'[7], funded by the Least Developed Countries Fund (LDCF). This Feasibility Study focusses on assessing the viability and extending the design of the project's proposed ecosystem-based adaptation (EbA) interventions across five representative pilot sites in Rwanda. In addition, the Feasibility Study aims to inform the effective implementation of the activities under the project.

Ecosystem-based adaptation (EbA) is a nature-based solution that utilises biodiversity and ecosystem services[8] to reduce the vulnerability of local communities to climate change and increase their resilience (Figure 1)[9]. This cost-effective adaptation strategy involves the conservation, sustainable management and restoration of ecosystems to assist communities in adapting to climate change impacts.

Figure 1. EbA conceptualised in the Driving Forces-Pressures-State-Impacts-Responses (DPSIR) framework[10].

The LDCF-funded project, approved for implementation by the Global Environmental Facility (GEF) in 2019, has the objective of strengthening the institutional, technical and financial capacity of Rwanda's government at both the national and sub-national levels to plan for climate change adaptation in the medium- to long-term. Such strengthening will be achieved through three components, namely: i) increasing technical and institutional capacity for the National Adaptation Plan (NAP) process in Rwanda; ii) advancing climate-resilient technologies and practices; and iii)

[7] henceforth referred to as the "NAP project".
[8] Ecosystem services include *inter alia* protection from extreme climate events, hydrological regulation, increasing soil nutrients, reducing erosion and providing food as well as other non-timber forest products.
[9] IUCN. 2017. Issues brief: Ecosystem-based adaptation. Available at: https://www.iucn.org/sites/dev/files/import/downloads/ecosystem-based_adaptation_issues_brief_final.pdf.
[10] UNEP-UNDP-IUCN. 2010. Making the case for ecosystem based adaptation: Building resilience to climate change.

strengthening monitoring, reviewing and knowledge-sharing to learn from the NAP process in Rwanda.

The Government of Rwanda (GoR) envisions that the NAP process will adopt a cross-sectoral, systematic approach to mainstreaming climate change adaptation at both 'horizontal' (where all climate-vulnerable sectors are concerned), and 'vertical' (where funding, planning, implementing and monitoring are concerned) levels. This will improve Rwanda's adaptive capacity to the impacts of climate change by: i) reducing the vulnerability of local communities to climate change impacts; and ii) facilitating the integration and implementation of climate change adaptation activities into relevant planning processes.

Under Outcome 2 — which involves the adoption and upscaling of climate-resilient technologies and practices — part of the project's approach to informing Rwanda's NAP process is the development of protocols for and implementation of EbA interventions to provide knowledge on best practices and lessons learned for their upscaling and replication across the country. Specifically, Output 2.4 involves implementing EbA interventions at five pilot sites across four catchments in Rwanda. Research on the technical and economic effectiveness of these interventions will then be used to inform the project's long-term research programme (LTRP), which will be established to address the knowledge gaps necessary to inform future adaptation planning and funding in the country. Specific EbA interventions and pilot sites have already been proposed under the LDCF-funded project. The Feasibility Study will assess, add to and further design the proposed interventions, which are briefly described below.

- The re-establishment of a buffer zone around Ibanda-Makera Natural Forest in the Kirehe District, Eastern Province, to protect this ecosystem, as well as the promotion of agroforestry with drought-resilient tree species in the area to enhance the livelihoods of local farmers.
- The demarcation of a buffer zone on the banks of the Muvumba River in the Nyagatare District, Eastern Province, through the restoration of riparian vegetation (which will buffer floods and arrest erosion), as well as the reforestation of the region's upstream catchment areas.
- The implementation of silvopastoralism to strengthen livestock production and increase forest cover of savannas in the Nyagatare District, Eastern Province.
- The implementation of agroforestry, as well as the stabilisation of plantation verges with vegetation at the Shagasha Tea Estate (Rusizi District, Western Province) to enhance the climate resilience of local livelihoods against the adverse effects of climate change.
- Vegetation restoration and the establishment of sustainable urban drainage systems (SUDS) in the Nyandungu wetland (Gasabo and Kicukiro Districts, Kigali Province). This pilot site is an alternative to the original Kimicanga wetland site proposed in the NAP project ProDoc (details and rationale for the change are provided in Section 2.5).

The central purpose of the Feasibility Study was to assess whether the proposed interventions are viable and feasible for implementation at the pilot sites. If not, alternative interventions have been identified and assessed as part of the Feasibility Study. Assessing the viability of the proposed project interventions is necessary because their feasibility was not explicitly assessed in the development of the LDCF-funded project. Furthermore, two years have elapsed since the proposed EbA interventions were designed, and social and environmental contexts may have changed, which means certain interventions may no longer be appropriate. Therefore, to identify the most appropriate EbA interventions for each pilot site, the Feasibility Study includes the following objectives, to: i) design the viable EbA interventions, including identifying specific sites and detailing expected benefits; ii) design approaches and methods for cost-benefit analysis (CBA) and/or economic valuation, which will inform upscaling and restoration; iii) define implementation arrangements at each of the sites; and iv) improve the linkages of EbA interventions to existing initiatives and projects.

2 Detailed description of pilot sites and interventions

2.1 *Site 1: Ibanda-Makera Natural Forest, Kirehe District, Eastern Province*

<u>Site description</u>

Administrative location

The Ibanda-Makera Natural Forest is located in the Kirehe District of Rwanda's Eastern Province. Administratively, it falls within the Nyawera I and Nyawera II villages, both located in the Nasho Cell in the Mpanga Sector. The forest is divided into the relatively well-forested Makera forest, and the heavily degraded Ibanda forest to the northeast of Makera. The latter is targeted for reforestation under the LDCF2 project. The settlements around the Ibanda-Makera forest also fall within the Nasho Cell of the Mpanga Sector. Villages that these settlements and surrounding agricultural lands are located within include (in addition to Nyawera I and II villages) Agasasa, Busasamana I, Busasamana II, Ibanda, Mutwe and Pilote (Figure 2).

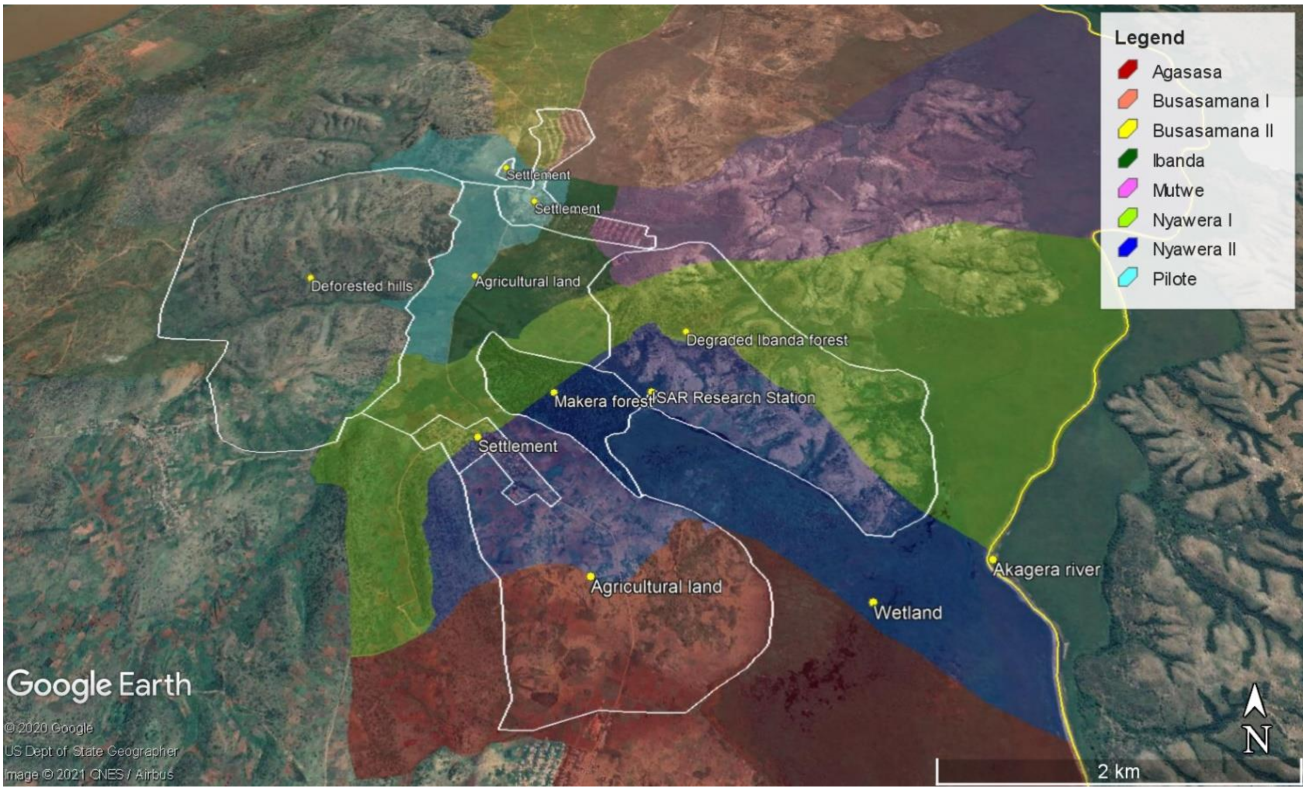


Figure 2. Administrative villages that the Ibanda-Makera forest and surrounding settlements and agricultural lands are located within. All villages fall within the Nasho Cell in the Mpango Sector, Kirehe District, Eastern Province. Map created using Google Earth Pro. Village extents downloaded from World Bank[11]. All other information provided by Theogene Habakubaho.

Climate and climate threats

The Ibanda-Makera Natural Forest's mean annual precipitation is ~677 mm[12] (Figure 3), occurring predominantly during the first rainy season from March–May (240 mm) and the second rainy season from September–December (282 mm) (Figure 4). Both wet seasons have indicated a gradual increase in precipitation from 1981–2017, with the first wet season indicating a larger increase (Figure 5 and Figure 6). The average maximum temperature for Ibanda-Makera forest is ~28°C, while the average minimum temperature is ~17°C[13] (Figure 7, Figure 8 and Figure 9).

[11] https://datacatalog.worldbank.org/dataset/rwanda-admin-boundaries-and-villages
[12] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[13] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

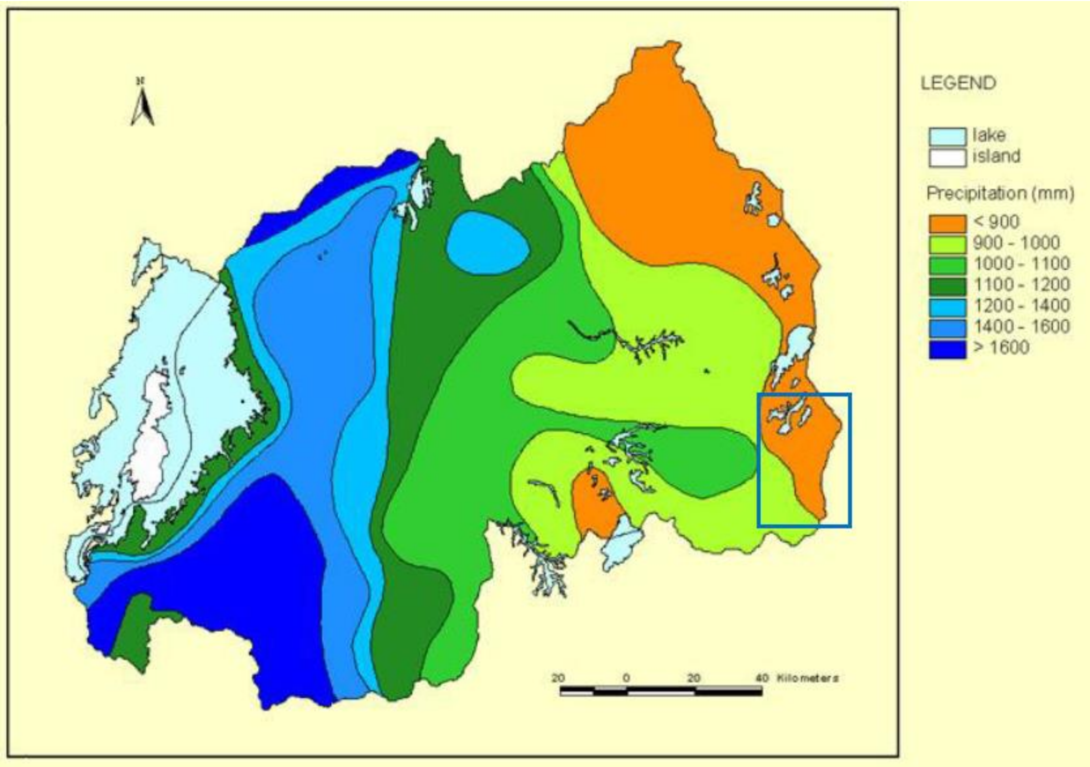


Figure 3. Annual average rainfall for Rwanda[14]. The Ibanda-Makera pilot site is indicated with a blue square.

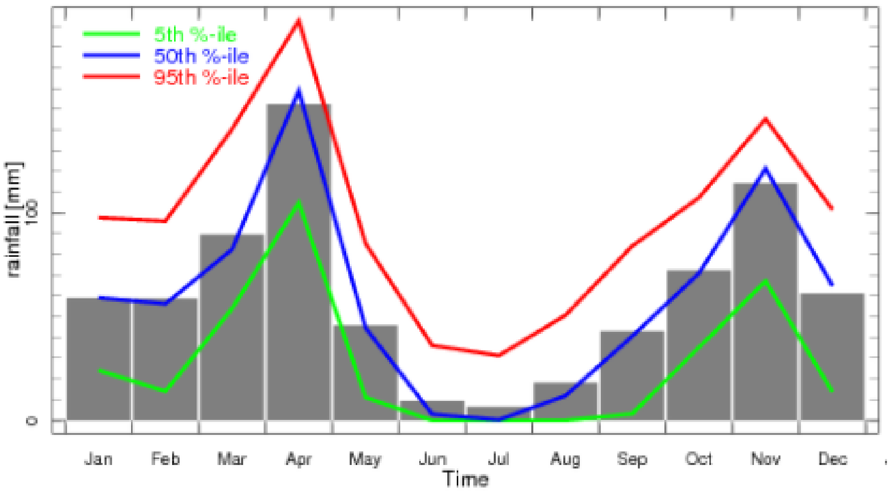


Figure 4. Average monthly rainfall (mm) for the Ibanda-Makera pilot site[15].

[14] Verdoodt A & van Ranst E. 2003. Land evaluation for agricultural production in the tropics. A large-scale land suitability classification for Rwanda.
[15] Meteo Rwanda. 2020. Climate Summary for Local Governments: Mpanga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405507%3Ads#tabs-1.

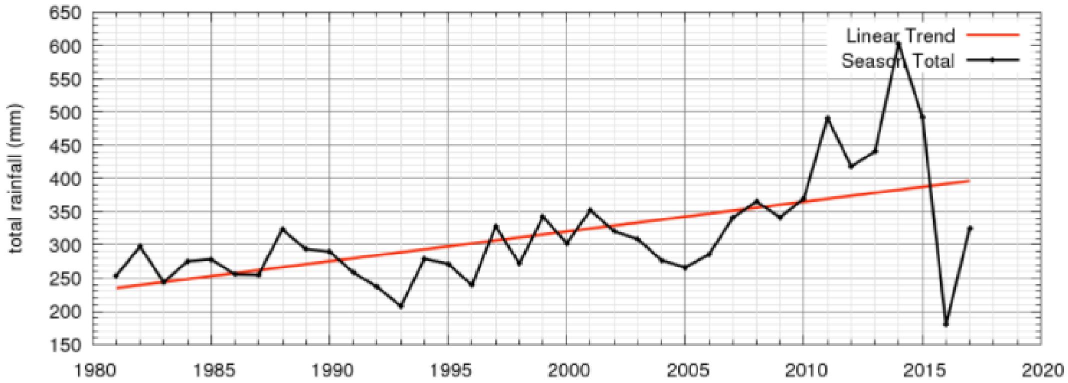


Figure 5. Trend in total seasonal rainfall from March–May for the Ibanda-Makera pilot site [16].

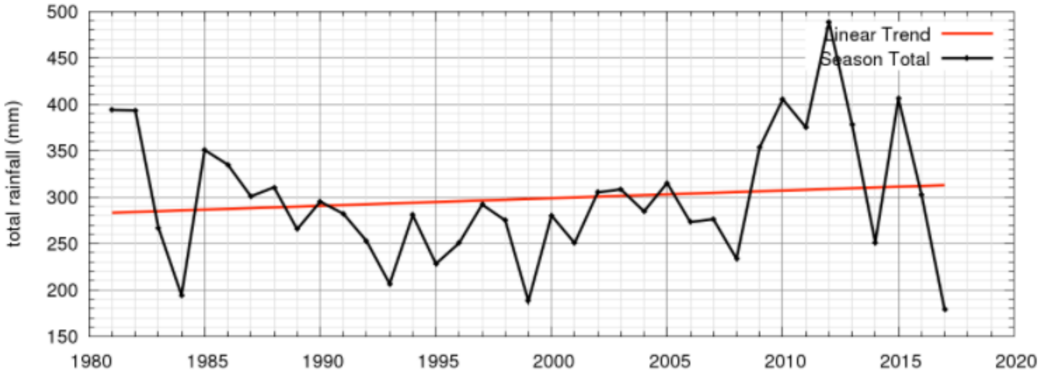


Figure 6. Trend in total seasonal rainfall from September–December for the Ibanda-Makera pilot site [17].

[16] Meteo Rwanda. 2020. Climate Summary for Local Governments: Mpanga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405507%3Ads#tabs-1.

[17] Meteo Rwanda. 2020. Climate Summary for Local Governments: Mpanga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405507%3Ads#tabs-1.

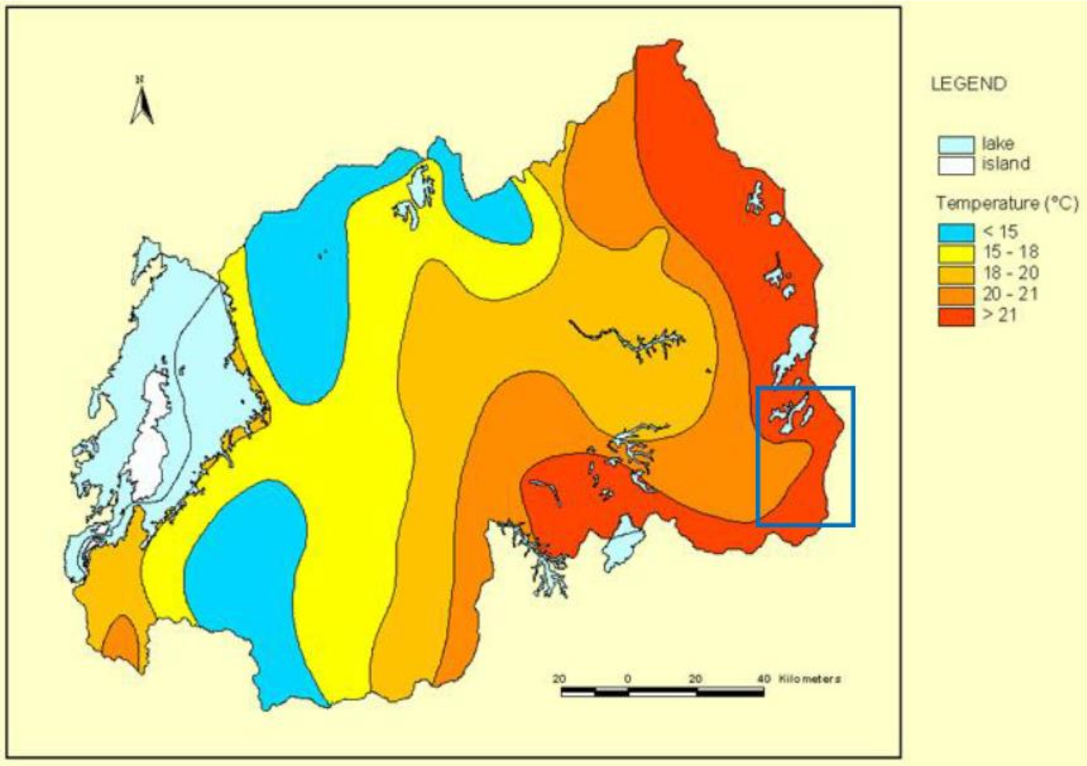


Figure 7. Annual average temperature for Rwanda[18]. The Ibanda-Makere pilot site is indicated with a blue square.

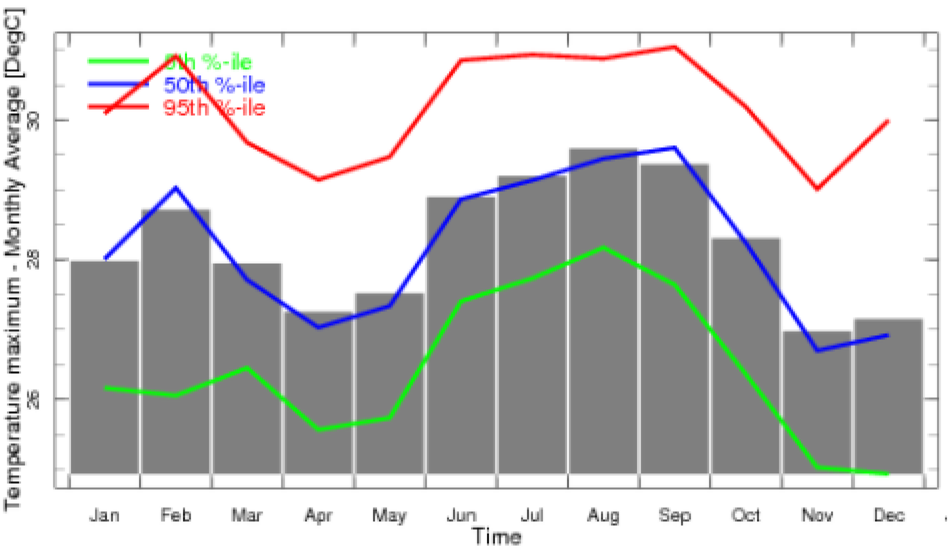


Figure 8. Average monthly maximum temperature (°C) for the Ibanda-Makera pilot site [19].

[18] Verdoodt A & van Ranst E. 2003. Land evaluation for agricultural production in the tropics. A large-scale land suitability classification for Rwanda.
[19] Meteo Rwanda. 2020. Climate Summary for Local Governments: Mpanga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405507%3Ads#tabs-1.

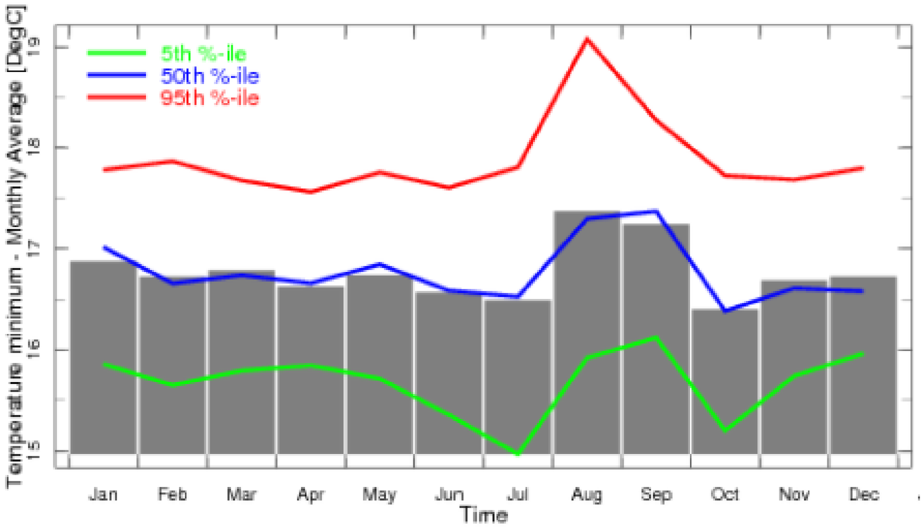


Figure 9. Average monthly minimum temperature (°C) for the Ibanda-Makera pilot site [20].

The Kirehe District in eastern Rwanda, in which the Ibanda-Makera forest is located, is among the most disaster-prone districts in the country[21]. Most of the Eastern province — including the Ibanda-Makera Forest — is highly susceptible to severe droughts during both rainy seasons. Over the last decade, increasingly dry climatic conditions in the region have resulted in declines in agricultural productivity of up to 70%[22]. Consequently, the GoR has had to provide additional food aid to cover the agricultural shortfall. Moreover, these dry conditions have resulted in the further encroachment of agricultural land into the forest, placing increasing pressure on its resources and biodiversity and therefore exacerbating degradation.

Many areas in the Eastern Province are also prone to floods and landslides, which can be exacerbated by the sudden shift from a long dry period to sudden, heavy rainfall that is inadequately absorbed by the soil. The Ibanda-Makera forest area is also exposed to storms with windspeeds of 45–52 km/hr that have a return period of 10 years[23]. Such storm events in 2013 resulted in 376 damaged or destroyed homes and affected 27 ha of cropland in the Kirehe District.

Ecosystem profile

The Kirehe District is characterised by savanna vegetation (dominated by the *Vachellia/Acacia* tree species) interspersed with natural forests[24], of which Ibanda-Makera is one. The forest is bordered by woodlands to its east and swamp-forest to its south. Ibanda-Makera is nationally recognised as a significant natural forest for its scientific importance, as well as its ecological, hydrological, climatic and socio-economic services. The forest contains many endemic and rare plant and animal species[25], and in total harbours approximately 90 tree species, 150 herb species and 78 bird species. Some of the notable animal species include the rare purple-banded sunbird (*Cinnyris bifasciatus*), different migratory bird species including European bee-eater (*Merops apiaster)*, and an isolated population of olive baboons (*Papio anubis*). The average plant height is about 10 m. Dominant plant species include small-fruited teclea (*Vepris nobilis,* locally known as Umuzo), false cape fig *(Ficus vallis-choudae)*, *Dracaena afromontana (Umuhati),* Nile tulip (*Markhamia lutea*, locally Umusave*),* coastal golden-leaf

[20] Meteo Rwanda. 2020. Climate Summary for Local Governments: Mpanga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405507%3Ads#tabs-1.
[21] Adelphi. 2014. Baseline study on climate change impacts on the private sector in Rwanda. Baseline study commissioned by the GIZ global project 'Strengthening the capacity of the private sector to adapt to climate change'.
[22] According to local stakeholders consulted during the proposed project's PPG phase.
[23] MIDIMAR. 2015. The national risk atlas of Rwanda.
[24] https://web.archive.org/web/20160305061619/http://www.ibidukikije.com/2012/03/rwanda-kirehe-districts-characterized-high-temperatures/.
[25] The Ruffor Small Grants Foundation. 2009. Eastern Gallery Forest Conservation Project: Biodiversity survey.

(Bridelia micrantha locally *mitzeeri*), African false currant *(Allophylus africanus*), wild date palm *(Phoenix reclinate*), *Grewia trichocarpa (Umukoma), Lagenaria abyssinica,* Tietie *(Paullinia pinnata)* and Crawcraw vine *(Tacazzea apiculata*). The forest's central portion is a swamp dominated by the papyrus sedge grass (*Cyperus papyrus)*. The edge of the forest contains a combination of the common crown-berry (*Crossopteryx febrifuga)* and violet tree (*Securidaca longepedunculata)*. The presence of orchid species in Ibanda-Makera, such as *Eulophia guinensis, Platylepis glandulosa*, *Cytorkis aquata* and *Malaxis weberbaneriana* indicates that the forest remains less disturbed than surrounding areas.

Baseline drivers and extent of ecosystem degradation

At present, Ibanda-Makera Natural Forest covers an area of ~180 ha (compared with ~1,425 ha in 1984[26] — a decline of ~87%). Historically, six gallery forests occurred in the Kirehe District area where Ibanda-Makera is located, but three of these have disappeared as a result of degradation. Of the three remaining forests, Ibanda-Makera is the largest, most important to local communities, and most biodiverse[27]. Ibanda-Makera can be further subdivided into two parts, namely the Ibanda section in the north east and the Makera section in the south west. Increasing human pressure and prolonged drought conditions are the main drivers of degradation in the forest. Degradation related to human practices (including agriculture and fuelwood harvesting) has transformed large swaths of the forest into bush, thicket and woodland. Only a small remnant of the mature gallery forest patch still exists, attributable to the work carried out by the Rwanda Institute of Agricultural Sciences (ISAR)[28]. However, while efforts have been made to protect the forest, the lack of fuelwood in the area and the limited area of land owned by the local community — and therefore limited incentive for its protection — remain a threat to this forest. The absence of a physical buffer zone between the forest and farming communities contributes significantly to encroachment on the forest.

In the Ibanda section of the forest, livestock is the primary threat to this ecosystem, and as a result, few trees, shrubs and thicket vegetation remain. In addition, the collection of fuelwood remains a common activity in this part, and the presence of traditional beehives may cause bush fires if appropriate harvest practices are not used. The presence of community roads and many pathways — used by local communities to access their rangelands or to collect water from the river inside the forest — is another factor contributing to the fragmentation of the forest. A recent increase in the migration of people to the Eastern Province of Rwanda in search of agricultural land has placed additional pressure on the region's natural resources, including those provided by the forest.

The presence of sandy dry savanna soil and limited rainfall has impeded efforts made in recent years to restore Ibanda-Makera forest — including LDCF 2 interventions (detail on linkages with past and ongoing projects is presented in Section 3). Because of its rapid drainage of water as well as a thin layer of humus, this soil has been an obstacle for tree planting especially in the Ibanda section of the forest. In addition, prolonged drought has affected most of the planted trees and survival success rates remain low.

Another degradation driver reported by local community and district authorities is soil erosion, which affects hills surrounding the forest and reduces the productivity of farmland. In the northern part of the forest, floods also affect farmers during the heavy rain season.

Topography

[26] Ministry of Lands and Forestry. 2017. Forest Investment Program for Rwanda. Available: https://www.climateinvestmentfunds.org/sites/cif_enc/files/fip_final_rwanda.pdf
[27] The Rufford Small Grants Foundation. 2009. Eastern Gallery Forest Conservation Project: Biodiversity survey.
[28] ISAR is a national agricultural research organisation that is focussed on poverty alleviation, food security and environmental sustainability.

The Ibanda-Makera Natural Forest is located in the depression of the Akagera River[29], in a low plain at 1,350 masl while the Ibanda Forest is situated at 1,600 masl. Ibanda-Makera is surrounded in the south by the Akagera Wetlands and in the north by a series of hills with an average altitude of 1,500 masl.

Land uses

Coffee and *Jatropha curcas* (commonly referred to as simply Jatropha, or nettlespurge) are significant cash crops grown by smallholder farmers in the Kirehe District[30]. Other food crops grown in the communities surrounding Ibanda-Makera include bananas, maize, beans and sorghum[31]. Burning for land clearance and wood cutting are also activities associated with land use around the forest[32], along with livestock grazing in the agricultural lands around Ibanda-Makera.

Hydrological profile

Ibanda-Makera forest is situated within the lower Akagera catchment and shared with Tanzania. This catchment drains the area downstream of Rusumo Falls until the confluence of the Akagera and Muvumba River[33]. The Akagera catchment includes numerous lakes and two tributaries that typically do not flow during the dry season. Ibanda-Makera gallery forest is crossed by the Nyamporogoma stream which makes this forest a water catchment for local communities. The dependence of these communities on the forest for their water needs has contributed to its degradation — particularly since other catchment areas in the region have become severely degraded. South of Ibanda-Makera is papyrus swamp which extends to the Akagera River and contributes to the reduction of water loss by evaporation[34].

Local communities

Two settlements are located within 500 m of the Ibanda-Makera forest boundary, one to the forest's north and one directly south (Figure 10). While the actual settlements are not located on the forest boundary, the land owned by these communities extends to the forest edge, and cultivation of crops occurs right up to the margin.

[29] Bizuru E, Nyandwi E, Nshutiyayesu S & Kabuyenge JP. 2011. Inventory and mapping of threatened remnant terrestrial ecosystems outside protected areas through Rwanda. National University of Rwanda.
[30] Ntaribi T & Paul DI. 2019. The economic feasibility of Jatropha cultivation for biodiesel production in Rwanda: A case study of Kirehe district. *Energy for Sustainable Development*. 50: 27–37.
[31] The Rufford Small Grants Foundation. 2009. Eastern Gallery Forest Conservation Project: Biodiversity survey.
[32] The Rufford Small Grants Foundation. 2009. Eastern Gallery Forest Conservation Project: Biodiversity survey.
[33] Rwanda Environment Management Authority. 2015. Rwanda: State of environment and outlook report 2015.
[34] Bizuru E, Nyandwi E, Nshutiyayesu S & Kabuyenge JP. 2011. Inventory and mapping of threatened remnant terrestrial ecosystems outside protected areas through Rwanda. National University of Rwanda.

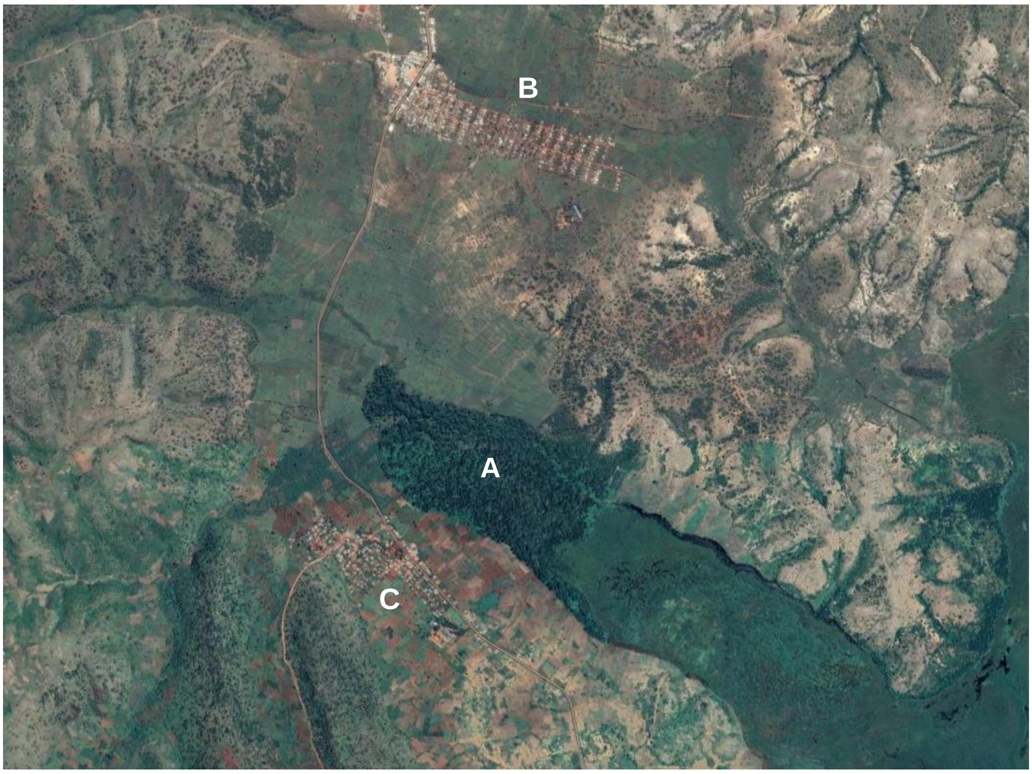


Figure 10. Satellite view of the Ibanda-Makera Natural Forest (A) and nearby local communities (B and C). The crop fields extend all the way from the settlements to the forest margin. Source: Google Maps.

Demographics

The population of Kirehe District is ~329,000 people, of which ~51% are female. The majority of the population is young, with about 83% under 40 years of age and about 54% aged 19 years or younger. People aged 65 years and above comprise only 3% of the population. Kirehe District is one of the most densely populated districts in Rwanda, with 320 people/km^2. Mpanga Sector, where the Ibanda-Makera forest is located, has a total population of 31,948[35]. Over the past ten years, the average annual population growth was 2.3%, which is slightly below the national average of 2.7%. The age structure indicates a young population, characterised by high fertility and high mortality. A decline in the age groups 20–24 and 25–29 for both sexes is the result of the civil conflict of the mid-1990s.

The male population in Kirehe District is generally lower than the female population, with 103 females per 100 males, which is below the national average of 111 females per 100 males. While the ratio of male per 100 females was already low in 1991 (95.1 males for every 100 women in rural Rwanda), it has dropped consistently after the 1994 genocide against the Tutsi. The ratio is particularly low among the population subgroup aged 20–24 years, which is attributed to higher male mortality during the genocide against the Tutsi. Single-parent households are common in the wider project area, and accordingly 20% of the households in the Project Affected Area are headed by women. The age of most of the heads of households is between 18 and 55 years. The average size of the household in Kirehe District (around 4.6) is below the national average and the lowest among all the districts of Eastern Province.

Poverty levels

In the Eastern Province, the current poverty rate is at ~32%[36]. The poverty line is defined as the level of household consumption per adult below which a household is deemed to be poor. The poverty line

[35] According to the 4th national Census
[36] GoR. 2018. The Fifth Integrated Household Living Conditions Survey.

used here refers to a minimum food consumption basket, which was judged to offer the number of calories required for a Rwandan who was likely to be involved in physically demanding work, along with an allowance for non-food consumption. An extreme poverty line was also set as the cost of buying the food consumption basket if nothing was spent on non-food at all; this line corresponds to RWF 83,000 (~US$83) and the poverty line corresponds to RWF 118,000. Kirehe District is ranked second in Eastern Province by percentage of extremely poor (after Bugesera District). About 52% of the population in Kirehe District is identified as non-poor, 44.6% as poor (excluding extremely poor) and 18.5% as extremely poor. Moreover, Kirehe District has one of the highest percentages of the population identified as poor[37].

In terms of vulnerability, groups that are considered particularly vulnerable by the GoR are children under five years old, elderly people aged 60 and over, and people with disabilities. According to the official statistics on percentage distribution of persons with a major disability by district[38], 3.8% of people in Kirehe have a major disability, which is below the national average of 4.5%. In addition, the percentage distribution of orphans by district — including those with one parent or both parents deceased — among the population aged 0–20, indicate that Kirehe District has 2.3% of orphans with both parents deceased and 14.3% of orphans with one parent deceased. The first of these indicators is below the national average (2.7%) and the second is above the national average (14%).

Education levels of the Kirehe District population amount to:
- no education: ~71%;
- primary: ~20%;
- post-primary: ~2.2%;
- lower secondary: ~3.5%;
- upper secondary: ~2.7%; and
- university: ~0.5%[39].

Livelihoods

In the areas surrounding the Ibanda-Makera Natural Forest, crop and livestock agriculture are the primary sources of livelihood for local communities, with 88.3% of the population aged 16 and above participating[40]. This is followed by trade with 4.9%, manufacturing at 1.8%, and 0.7% for both transport and communication and other services (including utilities and financial services). Around the Ibanda-Makera forest, farmers mainly grow banana and other seasonal crops such as maize, beans and sorghum. Agriculture is mainly rainfed, although some farmers have introduced small-scale irrigation to grow vegetables. The Rwanda Agriculture Board has identified the land surrounding Ibanda-Makera for irrigation projects, the feasibility of which is currently being studied. Water for these projects will primarily be sourced from the Akagera River and its corresponding wetlands[41]. During site visits it was noted that near the forest there are bee-keeping activities using traditional beehives, as well as fishing in the wetlands and in the Akagera River. The overall employment rate of the population aged 16 and above in Kirehe District is 87.2% (84% nationally), while the unemployment rate is 0.2% (0.9% nationally) and the economic inactivity rate is 12.6% (15% nationally). In addition, the district has the highest unemployment rate in the Eastern Province.

A recent increase in the migration of people to the Eastern Province of Rwanda in search of agricultural land has placed additional pressure on the region’s natural resources, including those

[37] GoR. 2017. Economic Activity Report. EICV5: The Fifth Integrated Household Living Conditions Survey 2016/2017. https://www.statistics.gov.rw/publication/eicv5thematic-reporteconomic-activity-thematic-reportpdf.
[38] EICV3.
[39] GoR. 2017. Economic Activity Report. EICV5: The Fifth Integrated Household Living Conditions Survey 2016/2017. https://www.statistics.gov.rw/publication/eicv5thematic-reporteconomic-activity-thematic-reportpdf.
[40] ACNR. 2009. Eastern Gallery Forest Conservation Project: Biodiversity Survey. *Research report to the Rufford Small Grant Foundation, UK*.
[41] The New Times. 2017. RAB plans irrigation studies. Available at: https://www.newtimes.co.rw/section/read/209665.

provided by the forest. Increasingly dry climatic conditions in the region over the last decade caused by climate change have resulted in declines of agricultural productivity of up to 70%[42]. Since 1992, the eastern region of Rwanda has been experiencing below average rainfall relative to the historical mean. Accordingly, in the last two decades only the years 2001, 2007, 2011, and 2013 have experienced average or above average rainfall levels, indicating a general decrease in precipitation over this period[43]. Under future climate change scenarios, the dry season in the east of the country is expected to increase in length. This will compound agricultural declines, forcing local communities to encroach further into natural ecosystems to maintain food production and livelihoods. As a result, degradation of the forest will intensify, reducing its capacity to supply ecosystems services (such as food, wood and water), which will exacerbate the effects of dry conditions on the area. Without the implementation of adequate climate change adaptation solutions, the Ibanda-Makera Natural Forest may become completely degraded, which will increase the vulnerability of the surrounding communities.

Land tenure arrangements

Within the Kirehe District there are three types of land tenure, namely customary, statuary and informal tenure[44]. For statutory tenure, land was allocated by the government based on the cattle size of families being resettled after 1994 instead of a standard size. Within the informal tenure group, people either privately-own land without permission or use state-owned land without permission.

Local community representatives raised concerns about the LDCF project's proposed establishment of a buffer zone around the forest, specifically regarding its size and location. Local communities own the land around the forest, with land titles extending right to the forest's edge. As detailed in the detailed description of interventions section, the enrichment planting buffer zone will be located in the forest area itself, while the re-established road will be placed on land already occupied by the previous, degraded road. The proposed interventions will therefore not impact the location and size of community-owned land.

Ibanda-Makera is a remnant forest that is not included in the country's list of protected forests. As a result, it is subject to considerable encroachment by the surrounding agricultural communities, with illegal activities such as poaching, grazing, medicinal plant collection and wood cutting. According to Rwanda's 2016 National Biodiversity Strategy and Action Plan, by 2020 Ibanda-Makera is to be become a protected area through its establishment as an extension of the Akagera National Park[45].

Access to resources

The population in Kirehe District live in grouped villages which facilitates access to the key social economic infrastructure. These villages are accessed via unpaved roads around 45 km from the District Head Office. Two settlement sites are less than 500 m from the forest (see Figure 10) and a second one is near Mpanda Sector, were there is a trading centre. The area is connected to the national grid and the primary sources of energy used for lighting by households are electricity, oil lamps, firewood, candles, paraffin lamps, battery-operated lights, and other unspecified sources. The recent "African Improved Cookstoves and Clean Water Programme: Ibanda – Makera Forest Cook Stove Project III" provided 6,000 improved cookstoves to households around the forest, which is contributing to reducing their reliance on woodfuel and in turn is reducing the degradative impact of its collection (additional details on this project is provided in Section 4).

[42] According to local stakeholders consulted during the proposed project's PPG phase.
[43] GoR. 2018. Rwanda's Third National Communication to the UNFCCC. Available: https://unfccc.int/sites/default/files/resource/nc3_Republic_of_Rwanda.pdf
[44] IFAD. 2008. Kirehe Community-based Watershed Management Project (KWAMP) — Final Design. Working Paper 10: Land Tenure Security.
[45] UNEP. 2016. Republic of Rwanda Biodiversity Strategy and Action Plan. Available at: https://www.cbd.int/doc/world/rw/rw-nbsap-v2-en.pdf.

In terms of mean walking distance to a primary school by district, Kirehe is one of five districts with the highest relative mean walking distance to a primary school in the country (within an interval of 33–37.1 minutes). The mean walking distance to a primary school in Kirehe District is 34.6 minutes, and 35.9% of households are between 30 and 60 minutes from a primary school. The distance in Kirehe District is above both the mean distance in rural areas, which is 28.6 minutes, and the national average, which is 27.2 minutes.

With regards to access to water, the main sources of water are the Akagera River and its associated wetland areas, as well as the Nyamporogoma stream which crosses Ibanda-Makera. Groundwater is accessed via boreholes for small-scale irrigation. As the proposed intervention site is close to the Akagera wetlands, there is potential for the use of groundwater for restoration irrigation purposes.

Reliance on ecosystem services of local communities

The Rwanda Agriculture Board has established a research station in Ibanda-Makera which is used to study species in the forest. Many of the woody species inventoried in the Ibanda-Makera forest are valuable for several purposes, including for livestock forage, food (edible fruits) and ornamental uses. Unfortunately, many of these species have disappeared from neighbouring landscapes and remain only in this small gallery forest. Socio-economic benefits derived from the forest also include the many plant species used in traditional medicine by local communities, especially from the species triangle-tops (*Blighia unijugate),* warty donkey-berry *(Grewia forbesii),* common currant-rhus *(Rhus vulgaris), Ficus acuta* and common wild fig (*Ficus thoningii)*.

In terms of its hydrological and climatic importance, the Nyamporogoma stream runs through the forest, making Ibanda-Makera an important water catchment for local communities. Its papyrus swamp in the South extends to the Akagera River and contributes to the reduction of water loss by evaporation. The Akagera River, which is close to the forest and which depends on the health of the Ibanda-Makera forest for hydrological and climate regulation, also provides opportunities for fishing to local community members. Natural gallery forests throughout the Kirehe District also regulate the high temperatures of this dry part of eastern Rwanda[46].

Infrastructure and services available at the site

As previously noted, Ibanda-Makera is accessed via unpaved roads ~45 km from district head office. One of the settlements near the forest is near Mpanda Sector, where there is a trading centre. The area is connected to the national grid, and households rely on electricity as the main source of lighting.

Financial services

With the creation of a Saving and Credit Cooperative (SACCO) in each sector in the country, the percentage of households in Kirehe with at least one savings account has increased from 29.4% in 2012 to 57,4% in 2020. Mpanga SACCO is the only financing institution near the community in Ibanda-Makera forest.

Climate change problems that EbA interventions will address

Under future climate change scenarios, the dry season in the east of the country is expected to increase in length. The difference between the wettest and driest months is also expected to increase by 22 mm between 2040–2059 and 39 mm between 2080–2099 compared with historic values (1986–2005) under a RCP8.5 scenario (Figure 11)[47]. Average temperature will increase by 1.7–2.1°C

[46] https://web.archive.org/web/20160305061619/http://www.ibidukikije.com/2012/03/rwanda-kirehe-districts-characterized-high-temperatures/.
[47] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

between 2040–2059 and 3.4–4.5°C between 2080–2099, resulting in increased evaporation losses (Figure 12 and Figure 13). These longer dry periods and increased evaporation will compound agricultural declines, forcing local communities to encroach further into natural ecosystems to maintain food production and livelihoods. In addition, the resources of natural ecosystems such as the Ibanda-Makera Natural Forest will continue to be overexploited as people search for additional food sources and livelihood options. Without the implementation of adequate climate change adaptation solutions, the Ibanda-Makera Natural Forest may become completely degraded, enhancing the vulnerability of the surrounding communities.

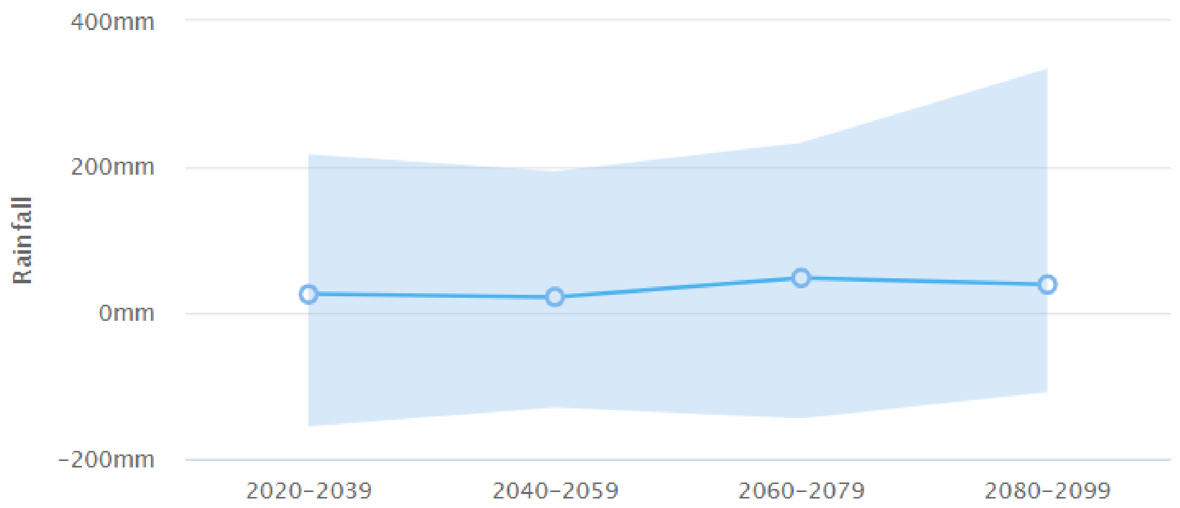


Figure 11. Projected change in annual range in monthly rainfall (mm) for Ibanda-Makera from 2020–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, showing the median and range values for an ensemble of global circulation models[48] (GCMs)[49].

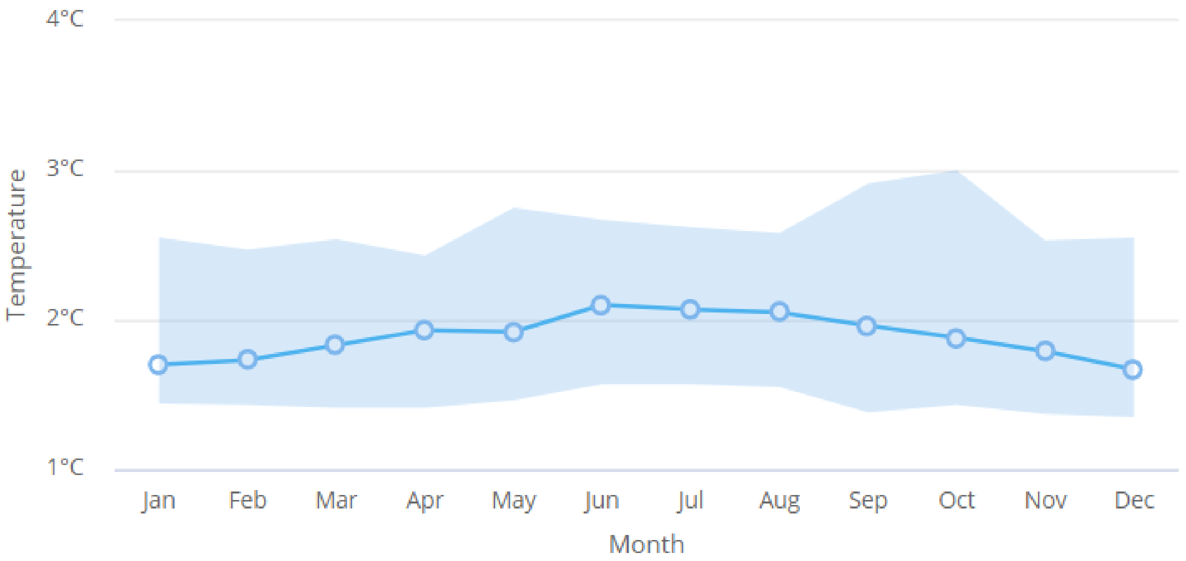


Figure 12. Projected change in monthly temperature (°C) for Ibanda-Makera from 2040–2069 under a RCP8.5 scenario compared with historic values from 1986–2005, showing the median and range values for an ensemble of global circulation models[50] (GCMs)[51].

[48] IPCC. 2014. Fifth Assessment Report.
[49] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#
[50] IPCC. 2014. Fifth Assessment Report.
[51] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

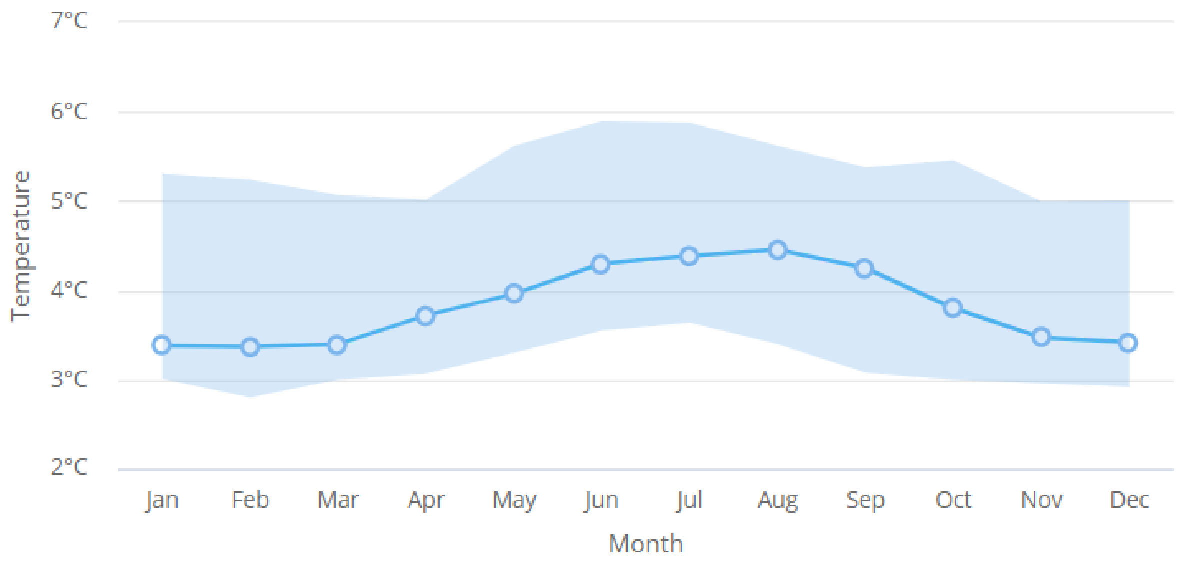
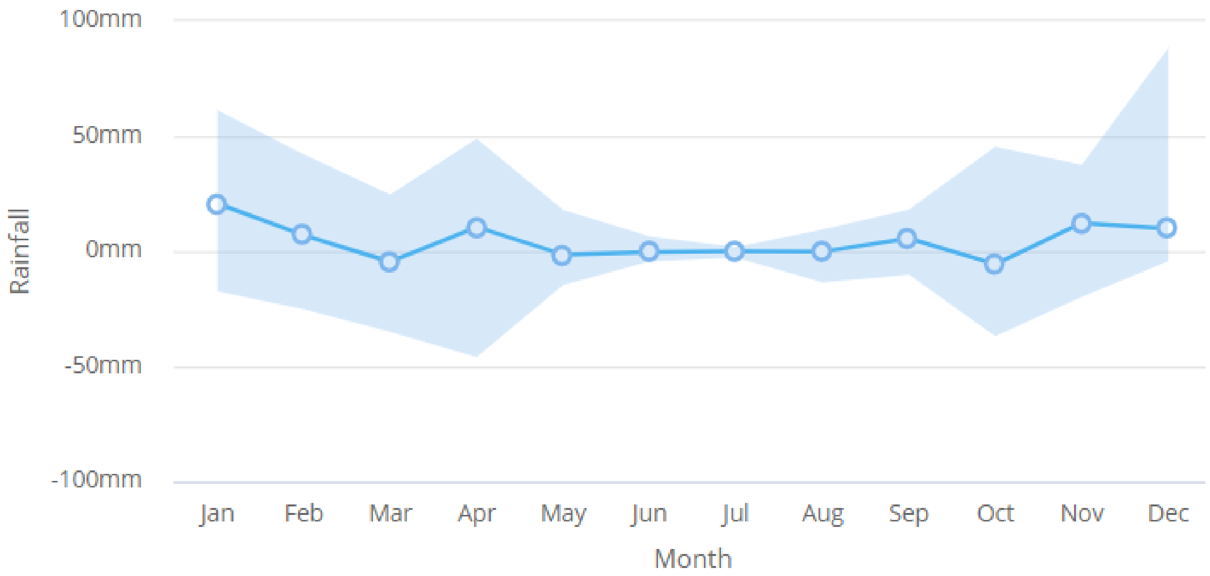


Figure 13. Projected change in monthly temperature (°C) for Ibanda-Makera from 2080–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, showing the median and range values for an ensemble of global circulation models[52] (GCMs)[53].

Droughts are expected to become more severe and rainfall generally more erratic in Rwanda through climate change, and accordingly the intensity and frequency of floods and landslides are predicted to increase. Between 2040–2059, rainfall during the shorter rainy season (March–May) is predicted to increase by 17 mm compared with historic values and by 30 mm during the longer wet season (September–December) (Figure 14)[54]. Rainfall is predicted to increase by 36 mm between 2080–2099 during the shorter wet season and 131 mm in the longer wet season (Figure 15). This increase in the intensity of rainfall during wet seasons and resultant flooding will lead to increased run-off and erosion, causing soil degradation which increases the vulnerability of ecosystems and agricultural lands to drought periods.



[52] IPCC. 2014. Fifth Assessment Report.
[53] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#
[54] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

Figure 14. Projected change in monthly rainfall (mm) for Ibanda-Makera from 2040–2059 under a RCP8.5 scenario compared with historic values from 1986–2005, showing the median and range values for an ensemble of global circulation models[55] (GCMs)[56].

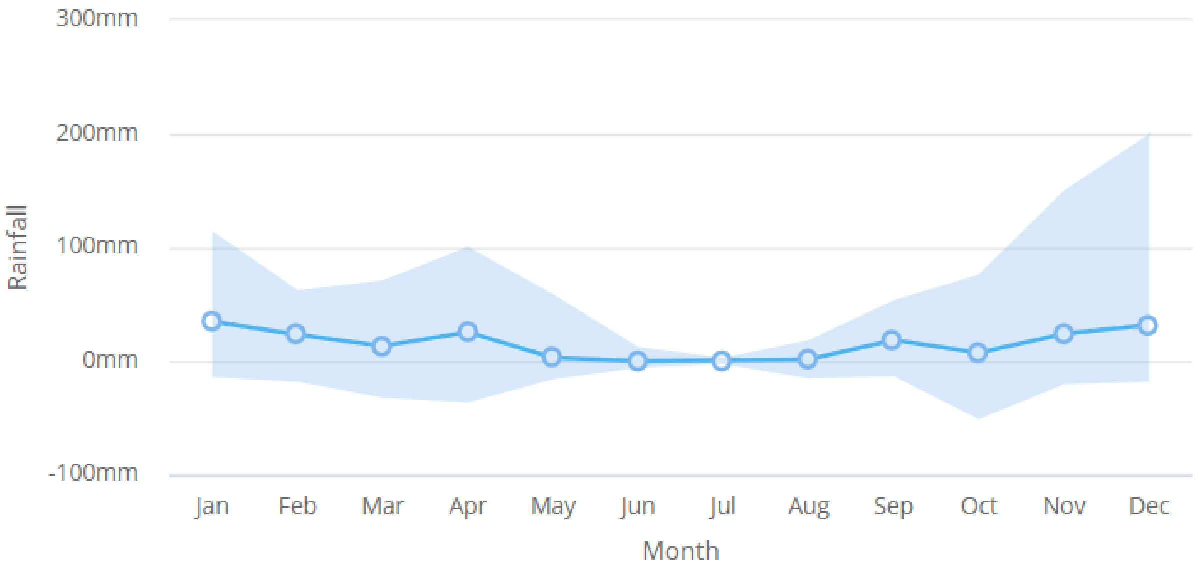


Figure 15. Projected change in monthly rainfall (mm) for Ibanda-Makera from 2080–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, showing the median and range values for an ensemble of global circulation models[57] (GCMs)[58].

Detailed description of interventions

During the project design, recommended EbA interventions to be piloted at Ibanda-Makera Natural Forest included the: i) demarcation and establishment of a buffer zone around the forest; ii) promotion of agroforestry in surrounding agricultural land; and iii) introduction of highly productive drought-resistant crop species. These interventions were discussed with different stakeholders including district officials, local communities and experts from national institutes dealing with the environment and natural forests, such as the Rwanda Development Board, LDCF2 project coordinator, Rwanda Forestry Authority, and Rwanda Agriculture Board. Major outcomes of these discussions and field observations are summarised below.

Consulted stakeholders expressed their support for the proposed EbA interventions. Some farmers, however, expressed the concern that the establishment of a buffer zone around the forest would involve the loss of land that they currently use for agriculture, since farms extend right to the edge of the forest. They proposed that old roads that used to line the perimeter of the forest be re-established, in conjunction with a live fence between the road and the forest, and for this to act as a buffer zone. This road fell into disrepair when traffic along the road reduced with the preferential use of paths and roads through the forest. With this option of re-establishing the road:

- the road will be built in the same location as the degraded road, meaning that no land will be taken from surrounding communities that was not dedicated to the original road; and
- farmers would use these roads to access their rangelands, which would allow the roads and pathways currently used within the forest to regenerate and be restored.

[55] IPCC. 2014. Fifth Assessment Report.
[56] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#
[57] IPCC. 2014. Fifth Assessment Report.
[58] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

In addition to the re-establishment of the road and the planting of a live fence, the district officials and local community members proposed to consider the additional activities described below.

- Planting forestry trees in woodlots on the hills surrounding the forest, which amount to more than 400 ha of state-owned land. This EbA intervention would increase the forest cover while also providing fuelwood for the local communities, which would ease pressure on the Ibanda-Makera forest. While this intervention would help address the baseline driver of the degradation of the remaining Ibanda-Makera forest, it will not be included as an intervention under this project. The agroforestry and introduction of drought-tolerant crop species in the agricultural land around the forest will improve the productivity of these lands, as well as provide wood and NTFPs. The buffer zone and re-establishment of the road around the forest, in conjunction with an awareness-raising campaign and development of a forest management plan, will reduce encroachment into and resource extraction from the Makera forest, as well as provide NTFPs such as fruit and medicine. The introduction of beekeeping as an alternative livelihood option (see below) will also foster support among local communities for the protection of the remaining forest. It was decided that the NAP project's funds could be better spent if focussed on these interventions rather than stretching them to include reforestation or establishment of woodlots on the hills around the Ibanda-Makera forest.
- Supporting community-driven projects such as beekeeping and fish farming around Ibanda-Makera as a way of raising awareness among local community members. While supporting beekeeping was deemed viable, fish farming will not be considered as an additional intervention because of the unreliable water supplies that pose a risk to the sustainability of this option, as well as restrictions imposed by the MoE on fish farming in the Akagera wetland. While beekeeping is not an EbA intervention, the co-benefits arising from the proposed EbA interventions will support the establishment of these livelihood alternatives through the planting of trees that could be used for bee forage. In turn, this alternative livelihood option will reduce pressure on surrounding ecosystems and support the increased resilience of ecosystems. This livelihood option can therefore be a complementary intervention to the EbA activities implemented under the project. The project will provide training to local communities on sustainable bee-keeping, as well as the procurement of apiculture equipment. It emerged during stakeholder consultations that traditional bee-keeping activities already take place near the Ibanda-Makera forest , therefore the training and provision of equipment will build upon techniques already utilised by the communities.
- During consultations, both district officials and local community members mentioned that soil erosion and floods caused by water runoff from surrounding hills are affecting agricultural land and crops around the forest. They suggested that the project should consider other soil erosion control structures such as ditches, terraces and water ponds to control water from surrounding hills. This is not an EbA intervention as it does not directly utilise biodiversity or ecosystem services and was therefore not considered in the MCA for Ibanda-Makera, though these can be implemented in conjunction with the proposed EbA interventions. However, the agroforestry intervention will be designed in a way that planted trees reduce soil erosion and flood impacts on crops.

It was later proposed that this LDCF-funded project also design a pilot proposal for Zero-Budget Natural Farming (ZBNF). Ibanda-Makera was selected as an ideal site for this pilot, given the importance of agriculture at this site and ZBNF's complementarity to the agroforestry interventions. A detailed ZBNF proposal is therefore also provided later in this section, though was not covered in the MCA.

Lastly, in addition to the initially proposed interventions and those recommended by stakeholders, community agreements will be developed to support access to the re-established road, while environmental management committees (EMCs) will be established to assist in fostering agreements that support the construction of the road. The EMCs will also assist in enforcing the sustainable used of the buffer zone and restrict illegal activities within the protected area of the forest, while working with committees to raise awareness of the importance of the forest and the ecosystem services it provides through awareness campaigns.

Results of multi-criteria analysis (MCA) of EbA interventions for Ibanda-Makera Natural Forest

Table 1 below shows the results of the multi-criteria analysis of the EbA interventions proposed for the Ibanda-Makera Natural Forest. The list of interventions includes those proposed in the ProDoc and during stakeholder consultations, as well as additional interventions identified in the rapid options analysis. For more detail, please refer to the scorecards in Annex 2. ZBNF (mentioned above) was not included in the MCA as it was specifically requested to be piloted through this project.

Table 1. Results of the MCA for Ibanda-Makera Natural Forest, based on proposed interventions as well as additional interventions emerging from the Rapid Options Analysis (score: 0 = unfeasible, 1 = perfect intervention).

Intervention assessed	Score
The promotion of agroforestry in surrounding agricultural land	0.76
Introducing highly productive drought-resistant crop species	0.73
Demarcation and establishment of a buffer zone around the forest, using enrichment planting of drought-resilient, multi-use tree species	0.65
Reforest hills surrounding the forest (more than 400 ha)	0.64
Re-establish 5 m wide road along the forest boundary	0.63
Conservation of intact forest and restoration of degraded patches	0.60

Results of the MCA show that the initially proposed EbA interventions — the promotion of agroforestry, introduction of drought-resistant crop species and establishment of a buffer zone around the forest perimeter — are the most viable EbA options at Ibanda-Makera, with the additional interventions of reforesting the hills around the forest and re-establishing a road as part of the forest's buffer zone also ranking relatively high. Agroforestry, the introduction of drought-resilient crop species and

have high potential to complement and strengthen each other and will be included in the final selection of interventions. Similarly, enrichment planted within a 10 m buffer and the re-establishment of the surrounding road complement each other by increasing the potential width of the buffer zone without encroaching on local community land, while discouraging the movement of community members into the core forest area. Although not included in this MCA, beekeeping and the establishment of EMCs and community agreements will be additional, complementary activities to the EbA interventions. Beekeeping will address one of the baseline drivers of degradation (entry into the forests and burning to access honey) while providing awareness raising and forest ownership opportunities for local communities, while EMCs will assist in ensuring the sustainability of interventions through community participation and ownership. The reforestation of surrounding hills and the conservation of intact forest areas will be excluded from the final list of interventions as these activities will be implemented by the LDCF2 project and will complement the chosen interventions for the NAP project. Figure 16 below illustrates the spatial layout of the proposed interventions. Details of these interventions are provided in the sections that follow.

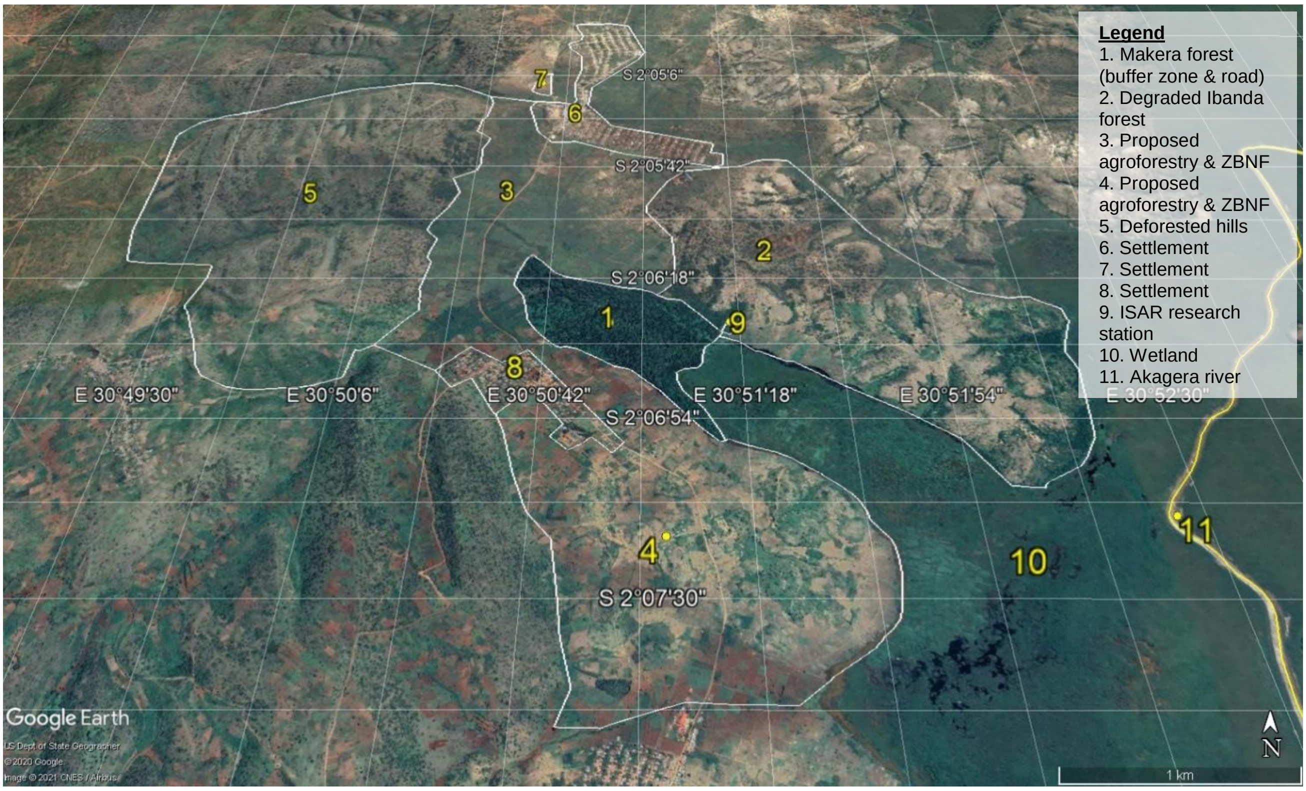


Figure 16. Locations of proposed interventions for Ibanda-Makera. Note that the buffer zone and road will be established around the Makera forest (1), and the Ibanda forest (2) is targeted for reforestation under the LDCF2 project. Map created in Google Earth Pro. Extents of interventions and other locations provided by Theogene Habakubaho.

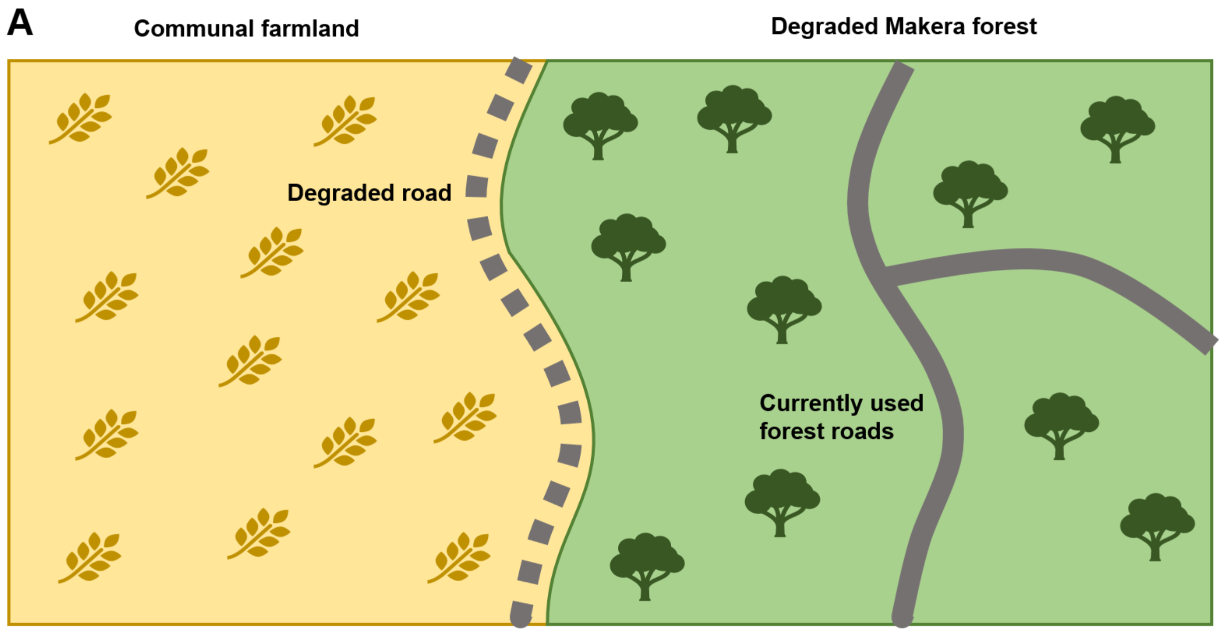
Demarcation and establishment of a buffer zone around the forest

The first intervention proposed at the Ibanda-Makera forest is the demarcation and establishment of a 10 m buffer zone around the forest. A buffer zone is a strip of land with a specific use, function or zoning designed to protect one area of land — such as a protected forest — against the impacts of adjacent areas. This intervention has the potential to reduce pressure and degradation on the Ibanda-Makera forest and thereby strengthen its ability to maintain biodiversity and provide ecosystem services to the surrounding area. For example, reduced forest degradation would improve the forest's ability to control hydrological processes by reducing erosion, increasing infiltration and reducing flooding, allowing for increased water quality and more reliable water availability for local communities within the Nyamporogoma River catchment. Depending on its intended purpose, a buffer zone itself additionally has the potential to provide various biological, social and economic benefits (Table 2). For the proposed buffer zone, enrichment planting using indigenous, drought-resilient, multi-use (fruit, fodder and fuelwood) tree species within the outer degraded 10 m of the remaining forest perimeter will be done to provide communities with additional food and NTFPs. The enrichment buffer, along with the suggested re-establishment of a road along the perimeter of the forest, will discourage the use of paths and resources deeper in the forest by communities (Figure 17). This will alleviate pressure on the natural forest, allowing for regeneration through restoration activities such as those planned under LDCF2. The intervention was well received by consulted stakeholders, including community members, however there was also some reservation, specifically regarding buffer placement and size (more details are provided in the following sub-section).

Table 2. Potential biological, social and economic benefits of the buffer zone[59].

[59] Ebregt A & de Greve P. 2000. Buffer zones and their management: Policy and best practices for terrestrial ecosystems in developing countries. Theme Studies Series 5, Forests, Forestry and Biological Diversity Support Group.

Benefit category	Type of benefit
Biological	Filter or barrier against human access and the undesirable use of the conservation area.
	Protection of the conservation area from invasive plants and animals.
	Additional protection from storm damage, drought, erosion and other forms of damage to ecosystems through vegetative enrichment.
	Enhancement of ecosystem services provided by the conservation area.
Social	Flexible mechanism for resolving conflicts between the interests of conservation and those of adjacent local communities.
	Improved earning potential and quality of the environment for local people.
	Strengthened local and regional support for conservation programmes.
	Provision of plant and animal goods for local communities while supporting the restoration of species, populations and ecological processes in conservation areas.
Economic benefits	Compensation to local communities for the loss of access to the conservation area.
	Increased benefits from the conservation areas for direct users, such as increased income from tourism.
	Increased value of the conservation area from indirect use, such as improved hydrological services.
	Direct benefits from income generation and livelihoods within the buffer zone.



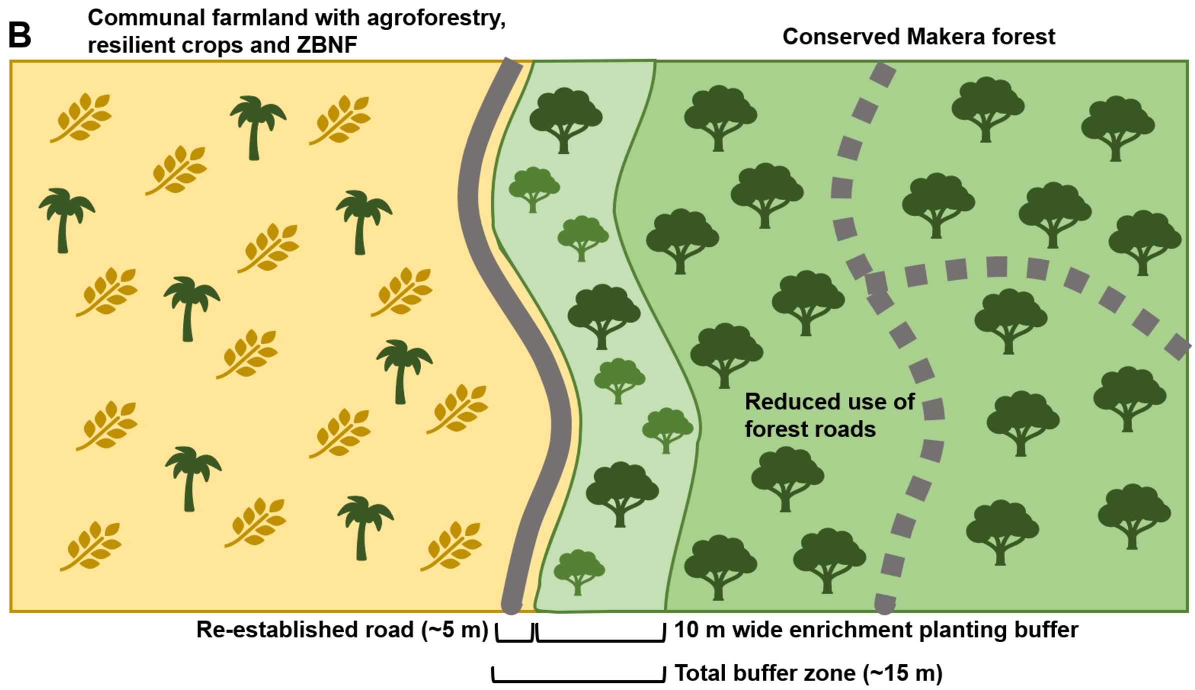


Figure 17. Schematics illustrating (A) the baseline scenario and (B) the placement of the buffer zone and other interventions.

This intervention will consider numerous ecological, physical, socio-economic, institutional and managerial guidelines and points of attention during its final development, implementation and appraisal. These are summarised in Table 3.

Table 3. Guidelines and points of attention that should be considered during the development, implementation and appraisal of buffer zones[60].

Aspect	Points of attention	Remarks
Ecological	General	It is crucial to know exactly what should be conserved and protected. This will require the collection of data and inventories from the buffer zone and conservation area.
	Flora and fauna	Inventories should be made and species lists prepared. It is not necessary to have all species covered, but at least the most important species and vegetation types.
		An assessment of the species composition and classification by rare, endangered, vulnerable etc. categories should be made.
		Spatial distribution by species and by vegetation type should be prepared.
		Identify exotic species that could become invasive.
		Identify fire hazard areas and vegetation types.
		Does the vegetation consist of natural vegetation or does it include plantations or degraded and secondary vegetation as well?
		Are vegetation resources exploited? If so, by what means?
		Vulnerable (sensitive) areas should be identified.
		Identify species (such as crop raiders and livestock predators) harmful to the surroundings, but also threats to wildlife from domesticated species such as cattle.
		Areas of particular importance to wildlife, such as salt licks, have to be identified.
	Ecosystem	The ecosystem approach in buffer zone management is essential.

[60] Ebregt A & de Greve P. 2000. Buffer zones and their management: Policy and best practices for terrestrial ecosystems in developing countries. Theme Studies Series 5, Forests, Forestry and Biological Diversity Support Group.

	Constraints	To be able to assess the need for a buffer zone, threats to the ecology of an area must be clearly identified (also with participation from local people).
Physical	Landscape	Zoning of an area should take into account sensitive areas such as steep slopes, river valleys and cliffs.
		Natural barriers which could be of use as a demarcation line or physical buffer should be identified.
	Soil	Good, bad and erosion-prone soils have to be identified. If agriculture is accepted as an activity, the quality of the soil is important.
	Hydrology	River systems and hydrology should be identified and mapped, as these are important features in zoning.
		The hydrology, in combination with soil type, texture and vegetation cover, determines the sensitivity of a site in relation to impacts such as erosion.
		The hydrology of an area also determines the limitations and opportunities for various land-use systems, including agriculture and infrastructural works.
		Water sources are also important for human habitation.
Socio-economic	Indigenous people	It is important to use local knowledge available from the indigenous people.
		The buffer zone should be a size that will allow indigenous people to maintain reasonable extraction levels (if access to core area is restricted).
	Migration	Economic incentives may attract unwanted migration into the buffer zone. Incentive schemes should include strict targeting of existing resource users.
	Population pressure	A high population pressure may lead to overexploitation of the natural resources. An increase in population might require other approaches in the future.
	Land-use systems	An assessment of existing and potential land-use systems and practices should be made, notably slash-and-burn agriculture.
		Establish buffer zones of a feasible size to support specific land-use systems.
		Land-use systems under communal ownership in buffer zones require informal management arrangements between local users and park authorities
		Access to resources, such as water, is a major concern.
		Analysis (including economic) of different land-use systems and technologies (diversification, product choice, mixed vs. monoculture, plantation, agroforestry) should be considered.
		Invest in establishing an enabling environment for investment in new technology (including streamline credit, input supply, and marketing infrastructure) rather than unsustainable direct financial incentives (such as price supports and subsidies).
	Land rights	Where possible, long-term land rights and title deeds must be established to stimulate long-term investment by land users.
		Investigate intra-household consequences of transition to new land-use and land access regulations and approaches
	Local organisations	A SWOT analysis of existing local institutional setup and organisations will be useful.
		Local resource user groups should be involved in buffer zone development.
		NGOs can play a useful role in establishing (informal) management arrangements for buffer zones.
	Gender aspects	Intra-household differences in access to and use of natural resource base should be considered
		Integrate different social groups (e.g. nomads, landless) into the process of buffer zone development.
		Integrate gender issues into policy development and implementation.

		Mainstream gender issues within project organisation, local government and NGOs.
		Ensure equal participation by women in decision-making.
	Marketing aspects	Analyse existing marketing arrangements, identifying strengths and weaknesses.
		Carry out market research to seek new opportunities in terms of products, processing, market niches and distribution channels.
		Look into possibilities of alternative sources of income generation that are compatible with buffer zone development: eco-tourism, non-traditional natural products, services for park management, etc.
		Invest in marketing infrastructure instead of providing direct price support.
	Constraints	An emphasis on nature conservation could be a major constraint in economic development, leading to a loss of traditional rights of access and use of the resource base. If such restrictions cannot sufficiently be compensated in a feasible and sustainable way, quality of livelihood of local population may decline.
Institutional	National legislation	It is important to identify the shortcomings in national legislation where it addresses protected areas and buffer zones. If buffer zones cannot be supported by legal instruments, it will be advisable to include the buffer zone within the conservation area's boundaries.
		Assessment of National Action Plans and Programmes to identify gaps in relation to buffer zone management.
		Identify legal instruments through which buffer zone management could be optimised and legalised, in particular in relation to biodiversity conservation and rural development.
		National legislation dealing with land rights and decentralisation should be scrutinised.
		If the country has guidelines for sustainable exploitation of natural resources, they could be an asset.
		It is important to assess the capability and dedication of the responsible authorities.
	Local legislation	In countries where decentralisation has progressed, local laws and by-laws often fill the gaps in national legislation.
		It is important to know the mechanisms and major players in the process of preparing and approving by-laws.
		Identify partners and key players dealing with conservation and rural development.
	Monitoring	Has a monitoring system been developed, preferably at the stakeholder level (including participatory monitoring mechanisms)?
	Collaboration	Identify authorities involved.
		Determine the feasibility of collaboration between various authorities, notably park and rural development authorities.
	Staffing	How are the responsible government authorities dealing with nature conservation and rural development organised?
		What is the level of training and capacity of these authorities?
		Are park staff trained in participatory approaches?
		Assessments of constraints in staffing, and how to solve them, should be made.
Size and location	Availability of land	Land availability depends on the population density and pressure on the natural resources.
		The bigger the buffer zone, the better, up to the point where marginal cost of further enlargement equals its marginal benefit.
		Stakeholders should agree on size and location of the buffer zone.
		A link between land-use systems and the possible size of buffer zone should be established, including a consideration for acceptable alternative land-use systems.

	Location	The size of the protected area, the population pressure and national and/or local legislation may determine the location of the buffer zone: inside or outside the boundaries of the conservation area.
		If it is necessary to have the buffer zone under the same jurisdiction as the conservation area, preference should be given to have the buffer zone located inside the conservation area. This is the case when buffer zones outside conservation areas do not have a special status.
Management	Structure	It is important that the stakeholders be directly involved in the management of the buffer zone.
		Can the management structure continue after termination of external assistance?
		Policy development and implementation — who is in charge of what aspect? How to monitor the implementation of the buffer zone?
		Communication between stakeholders for monitoring and management purposes should be considered.
	Financial aspects	Has a system been developed to sustain the management system?
		Under what circumstances will financial incentives still be necessary for buffer zone development — who is paying, what should their purpose be, how is it organised, who is eligible, how long can and should direct financial support be maintained, how can it be phased out and by what will it be replaced (if at all)?
		Ascertain financial feasibility of economic components of the buffer zone development programme.

Buffer zone size and placement

The preferred size of a buffer zone is variable and dependent on the intervention's objectives, the availability of land, traditional land-use systems, threats and opportunities[61]. Ecologically, a larger buffer zone is beneficial as it extends the size of the protected area, however this is not always socially or economically feasible. Indeed, the size and placement of the buffer zone was highlighted as a concern by local communities who own the land around the Ibanda-Makera forest as existing land titles extend to the edge of the forest. Therefore, if the buffer zone is to be established, the project will either need to compensate the landowners around the forest or establish the buffer zone inside the forest boundaries, in which case a core zone (area of focussed conservation) will need to be established. Of those two options, the former is not recommended as it has the potential to adversely affect existing community livelihoods and subsequently presents the risk of communities not supporting the sustainability of the intervention. Another consideration with regards to the size of the buffer zone is that — since it will include multi-use species that communities will be able to access for resources and livelihoods — the zone will have to be large enough to sustainably support the needs of the community[62]. If the buffer zone degrades from unsustainable use and can no longer provide services to local communities, its effectiveness with regards to offering a protective buffer to the forest will be reduced. Based on best practices for buffer size within Rwanda, the width of the enrichment planting buffer zone within the forest area will be 10 m. This — in conjunction with additional resources from the agroforestry and zero-budget natural farming interventions — will be large enough to fulfil community resource needs and maintain a large enough core conservation area. The buffer zone will only be implemented around the Makera section of the forest, as Ibanda is being targeted for restoration under the LDCF2 project. The Makera section covers 76.65 ha. A 10-m buffer zone around the forest would therefore cover ~7.7 ha.

Local community members suggested that re-establishing a road around the perimeter of the forest will add to the sustainability of the buffer zone, and it will prevent further trampling and degradation of trails within the forest. For this reason, a road will form the outer boundary of the buffer zone and

[61] Ebregt A & de Greve P. 2000. Buffer zones and their management: Policy and best practices for terrestrial ecosystems in developing countries. Theme Studies Series 5, Forests, Forestry and Biological Diversity Support Group.

[62] Ebregt A & de Greve P. 2000. Buffer zones and their management: Policy and best practices for terrestrial ecosystems in developing countries. Theme Studies Series 5, Forests, Forestry and Biological Diversity Support Group.

extend the buffer zone width by a further 5 m. Because this intervention was raised by community members themselves, it is expected to be supported by farmers surrounding the forest, and will therefore improve the overall effectiveness and sustainability of the whole buffer zone. The road will be a gravel road, and should be designed using best practice principles for gravel roads in tropical areas, including having a slightly raised crown down its centre and having drainage channels on its edges to prevent flooding, potholing and deterioration of the road[63] (Figure 18). It is also important to use a high-quality gravel, where the gravel size is not too large and is able to absorb some moisture. This will reduce long-term maintenance costs of the road. These best practices regarding road material and design will ensure the long-term sustainability of the road to climate threats. Protection of the Ibanda-Makera forest beyond the buffer zone will also be encouraged, to promote the continuous use of the re-established road rather than the trails within the forest, thereby ensuring the renewed road does not become overgrown with vegetation and fall into disrepair again. Minimising traffic within the forest will also improve the forest's long term climate resilience by reducing the spread of invasive weeds that are associated with roadsides[64] into the forest's core area. Although entry into the forest is already officially regulated by district authorities, in practice use of the forest is not effectively controlled. The project will therefore also provide conservation awareness-raising activities within the surrounding communities, focussing on the importance of the Ibanda-Makera forest to climate change resilience of local communities. Together with the multi-use buffer zone, this activity will ensure the protection of the remaining forest, as well as the new restored forest patches planned under LDCF2.

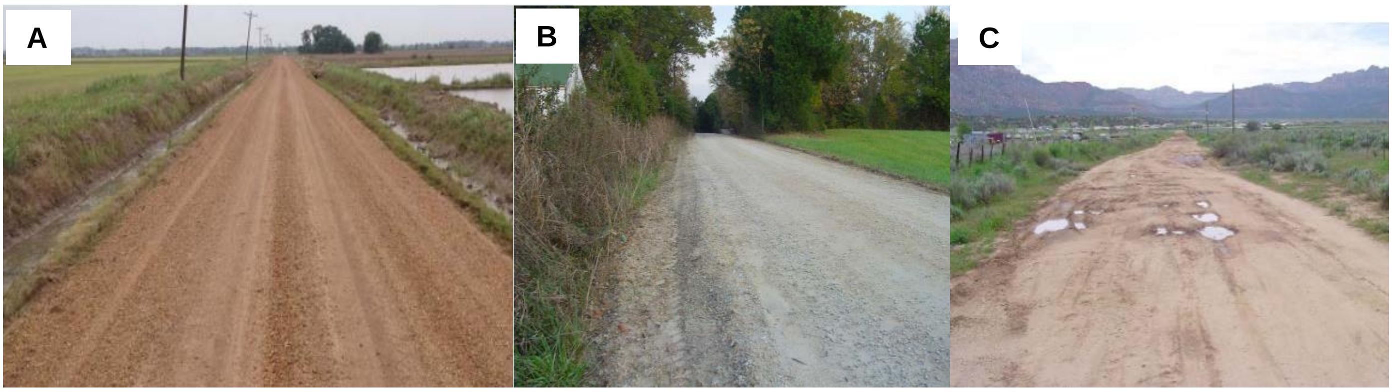


Figure 18. A well-made gravel road should have an adequately high crown, a sloping shoulder and ditches along its edges to ensure proper drainage and avoid damage from heavy rains. Panel A is an example of an ideal gravel road. Panel B is an example of a road with little space for a shoulder, which will likely be the case for the Ibanda-Makera road where space is limited, but one that still has a well-designed ditch along its edge. Panel C is an example of a poorly constructed gravel road with no crown and no ditches at the edge of the roadway. Source: US Department of Transportation. 2015. *Gravel Roads: Construction & Maintenance Guide.*

Species selection for the buffer zone

Buffer zones not only provide benefits to local communities, but are most effective when they utilise species that mirror those found within the conservation area. Based on case studies within the Ibanda-Makera forest, several indigenous, climate-resilient species have the potential to be used in the establishment of a buffer zone that provide climate resilience and livelihood benefits. These species are listed in Table 4 below.

[63] US Department of Transportation. 2015. *Gravel Roads: Construction & Maintenance Guide*. Available: https://www.fhwa.dot.gov/construction/pubs/ots15002.pdf

[64] Mortensen DA, Rauschert ES, Nord AN & Jones BP. 2009. Forest roads facilitate the spread of invasive plants. Invasive *Plant Science and Management* 2: 191–199.

Table 4. Suitable indigenous species for use within a buffer zone around Ibanda-Makera forest and their potential benefits[65].

Scientific name	Local name	Climate resilience role	Livelihood impact role
Acacia polyacantha	Umugu	Soil fertility, slope protection, soil stabilisation	Bee forage, construction material, fuel wood, edible fruits, timber
Allophylus africanus	Umutete	Slope protection, soil stabilisation	Bee forage, handicraft, edible fruits
Macaranga kilimanscharica	Umusekera	Slope protection, soil stabilisation	Handicraft, fuel wood, shading, traditional medicine
Phoenix reclinata	Umukindo	Slope protection, soil stabilisation	Handicraft, ornamental
Polyscias fulva	Umwungo	Slope protection, soil stabilisation	Bee forage, handicraft, ornamental
Pterygota mildbraedii	Umuguruka	Shading, soil stabilisation	Bee forage, ornamental, timber
Vernonia amygdalina	Umubirizi	Live fence, soil fertility	Bee forage, handicraft, fuel wood, timber

Acacia polyacantha can be propagated from seeds, which require pre-treatment by immersing them in boiling water and allowing them to soak overnight to soften their hard outer seed coats[66]. The seeds should then be germinated in well-drained pots for 1–4 weeks, while the saplings require full sun and watering for 2–4 years before planting. *Mazaranga kilimandscharica* regenerates quickly and requires little management once grown, however saplings require interventions to protect them against physical damage or drought conditions[67]. *Phoenix reclinata* is tolerant of dry and nutrient-poor soils, however their planted saplings require watering until they are established[68]. This species can be readily germinated in nurseries, with germination occurring within 2–3 months. Male and female plants exist, requiring both to be planted for restoration purposes. *Polyscias fulva* can be germinated in nurseries within 5–7 weeks from seeds acquired from existing fruits[69]. Their seedlings can be transplanted 4–6 months after germination. *Pterogota mildbraedii* seeds can similarly be collected from existing fruits and require no pre-treatment before germination[70]. *Vernonia amygdalina* can be grown from seeds or propagated from cuttings — the latter method being faster[71]. Seeds germinate after 2–3 weeks and can be transplanted within 4–6 weeks after emergence, before which they require regular irrigation. Cuttings can be planted erect or at an angle of 45 degrees which allows for more side shoots to develop. The establishment of community nurseries will increase the potential success of tree seedlings, particularly those that are less viable when sown or planted as cuttings in the field. This will require irrigation mechanisms to be established within the nurseries to promote seedling growth until they are ready to be transplanted. Seeds or seedlings should be planted early in the wet season to eliminate or reduce watering requirements in the field, however follow-up and monitoring should still be done to ensure the survival of planted seedlings. With regards to watering requirements, groundwater provides a potential water source and the project will additionally engage with the planned Export Targeted Irrigated Agriculture Project in the area for other possible irrigation options. In addition, the project will work with the Rwanda Forest Authority to establish a mechanism for monitoring and following up on interventions.

Development of a forest management plan

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[65] Rwanda Environment Management Authority. 2019. Ecosystem-based adaptation guidelines for climate resilient restoration of savannah, wetland and forest ecosystems of Rwanda.
[66] Available at: http://pza.sanbi.org/senegalia-polyacantha-subsp-campylacantha
[67] World Agroforestry. N.d. Macarange kilimandscharica. Available at: http://apps.worldagroforestry.org/treedb2/AFTPDFS/Macaranga_kilimandscharica.PDF.
[68] Plants for a Future. N.d. Available at: https://pfaf.org/user/Plant.aspx?LatinName=Phoenix+reclinata.
[69] Useful Tropical Plants. 2019. Polyscias fulva. Available at: http://tropical.theferns.info/viewtropical.php?id=Polyscias+fulva.
[70] Pl@ntUse. 2016. Pterygota mildbraedii. Available at: https://uses.plantnet-project.org/en/Pterygota_mildbraedii_(PROTA).
[71] PROTA4U. n.d. Vernonia amygdalina Delile. Available at: https://www.prota4u.org/database/protav8.asp?g=pe&p=Vernonia+amygdalina+Delile..

For the successful protection of the Ibanda-Makera forest and its surrounding buffer zone, a forest management plan should be developed by local authorities. This can be a joint activity between District and Sector authorities, Nasho Cell and Kirehe District environmental committees, Rwanda Environmental Management Authority (REMA), Rwanda Forest Authority (RWFA), Rwanda Agricultural Board (RAB) and Rwanda Agricultural Research Institute (ISAR). The plan should address the regulation of entry into, and use of, Ibanda-Makera forest resources, as well as the sustainable management of the buffer zone and re-established road around the Makera forest boundary.

The promotion of agroforestry in surrounding agricultural land

Overview

The promotion of agroforestry in agricultural land surrounding the Ibanda-Makera forest (through the planting of drought-resilient, multi-use tree species as described above) will complement farming activities and provide additional food and livelihood resources. This intervention is aligned with the Ministry of Environment's aim of planting over 200,000 fruit trees across the Eastern Province as part of a broader effort to address malnutrition[72]. Agroforestry is considered an EbA intervention within agricultural landscapes as it: i) is based on sustainable management practices that promote ecological functions and processes; ii) provides adaptation benefits by increasing crop yields; and iii) improves the livelihoods of local communities by increasing food security and providing an additional source of income through the production of fruit and other resources (Table 5)[73].

Table 5. Summary of the three major dimensions and underlying criteria that agricultural practices need to satisfy to be considered EbA practices[74].

[72] Nkurunziza, M. 2018. Over 200,000 fruit trees to be planted as govt steps up anti-malnutrition effort. *The New Times.* Available at: https://www.newtimes.co.rw/news/over-200000-fruit-trees-be-planted-govt-steps-anti-malnutrition-effort

[73] Vignola R, Harvey CA, Bautista-Solis P, Avelino J, Rapidel B, Donatti C & Martinez R. 2015. Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints. Agriculture, Ecosystems and Environment, 211: 126–132.

[74] Vignola R, Harvey CA, Bautista-Solis P, Avelino J, Rapidel B, Donatti C & Martinez R. 2015. Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints. Agriculture, Ecosystems and Environment, 211: 126–132.

Dimension 1: **Based on Ecosystem Services**	Dimension 2: **Provides adaptation benefits**	Dimension 3: **Improves the livelihoods of smallholder farmers**
• Is based on the conservation, restoration and sustainable management of biodiversity (e.g., genetic, species and ecosystem diversity) • Is based on the conservation, restoration and sustainable management of ecological functions and processes	• Maintains or improves crop, animal or farm productivity in face of climate variability and climate change • Reduces the biophysical impacts of extreme weather events (heavy rainfall, strong winds, etc.) and high temperatures on crops, animals or farming systems • Reduces pest and disease outbreaks due to climate change	• Increases food security of smallholder households • Increases or diversifies income generation • Takes advantage of local or traditional knowledge of smallholder farmers • Uses local, available and renewable inputs • Has affordable labor and implementation costs

Stakeholders who were consulted were appreciative of this activity's potential to contribute to food provision and soil erosion control. These stakeholders indicated strong interest in implementing agroforestry on their land. One point raised by stakeholders during consultation is that there is an irrigation project under preparation that is also targeting the area surrounding the Ibanda-Makera forest (the 'Export Targeted Irrigated Agriculture Project' funded by India's Exim Bank, which is targeting various farms in the Kirehe District[75]). It has been proposed that fruit trees be planted outside the irrigated area or in areas where they will not interfere with the proposed centre-pivot irrigation system. Implementation of the proposed agroforestry intervention will therefore need to be closely coordinated with the activities implemented under the irrigation project. Potential water sources for the irrigation of agroforestry trees — as well as potentially the watering of plants used in the buffer zone until they are established — is ground water and the Akagera River.

Agroforestry uses an integrated, EbA approach of combining trees and shrubs with crops and/or livestock, drawing on the resultant interactive benefits. It combines agricultural and forestry technologies to create more diverse, productive, profitable, healthy and sustainable land-use systems. In agroforestry systems, trees or shrubs are intentionally used within agricultural systems, or non-timber forest products (NTFPs) are cultured in forest settings. Knowledge, careful selection of species (see 'Species selection for agroforestry' subsection below) and good management of trees and crops are required to optimise the production and positive effects within the system and to minimise negative competitive effects[76].

Alley cropping of agroforestry trees in terraces is a form of intercropping, and can be applied by farmers as a strategy to, among other integrated benefits: i) combat soil erosion; ii) improve the fertility of soil through nitrogen fixation and mulch provided by leaves; iii) diversify croplands; and iv) provide shade and windbreaks for crops. In this practice, crops are planted in strips in the terraces between rows of trees and/or shrubs. The potential benefits of this design include the provision of shade, retention of soil moisture, and increases in the structural diversity of the site for wildlife habitat. The

[75] https://www.newtimes.co.rw/section/read/207103
[76] Rwanda Environment Management Authority. 2010. Tool and Guideline #6: Practical Tools on Agroforestry.

woody perennials in these systems can produce fruit, fuel wood, fodder and other benefits indicated in Table 7 below.

Many trees used in agroforestry are multipurpose and provide a range of benefits. Agroforestry provides many livelihood and environmental benefits, including:

- Enriching the asset base of poor households with farm-grown trees;
- Enhancing soil fertility and livestock productivity on farms;
- Providing accessible fuel wood for farmers, protecting other areas from deforestation or depleted woodlands, and also releasing the burden of long-distance collection of wood for energy by women and children;
- Linking poor households to markets for high-value fruits, oils, cash crops and medicines;
- Balancing improved productivity with the sustainable management of natural resources; and
- Maintaining or enhancing the supply of environmental services in agricultural landscapes, for water, soil health, carbon sequestration and biodiversity[77].

Best practices and protocols for agroforestry

Agroforestry systems maximise the use of available land. Every part of the land is considered suitable for useful plants. Emphasis is placed on perennial, multi-purpose crops and trees that are planted once and yield benefits over a long period of time. In addition, well-designed systems of agroforestry maximise beneficial interactions of the crop plants while minimising unfavourable interactions. The most common interaction is competition, which may be for light, water, or soil nutrients. Competition invariably reduces the growth and yield of any crop. Yet competition occurs in monoculture as well, and this need not be more deleterious in agroforestry than monoculture systems. Interactions between components of an agroforestry system are often complementary. In a system with trees and pasture, with foraging animals, the trees provide shade and/or forage while the animals provide manure. To reduce competition for solar radiation between crops and agroforestry trees, the canopy of agroforestry trees should be pruned and thinned annually, and the trees should also be planted at distance with their final size in mind[78]. Figure 19[79] below provides a schematic representation of an agroforestry system under runoff conditions, and could be followed as a protocol for farms around Ibanda-Makera that are at the bases of hill slopes.

[77] Rwanda Environment Management Authority. 2010. Tool and Guideline #6: Practical Tools on Agroforestry.
[78] Caron BO, Pinheiro MVM, Korcelski C, Schwerz F, Elli EF, Sgarbossa J. & Tibolla LB. 2019. Agroforestry systems and understory harvest management: the impact on growth and productivity of dual-purpose wheat. *Anais da Academia Brasileira de Ciências* 91.
[79] Rwanda Environment Management Authority. 2010. Tool and Guideline #6: Practical Tools on Agroforestry.

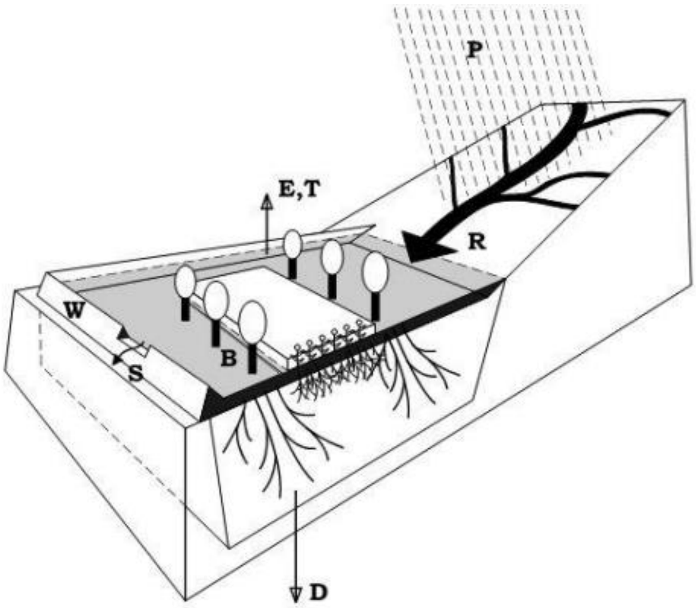

Figure 19. Schematic representation of an agroforestry system under runoff conditions[80]. Precipitation (P) generates surface runoff (R) on hill slopes, which accumulates into natural tributaries feeding a level runoff basin (B). The collected runoff water is trapped by a retaining wall (W) allowing the water to percolate into the soil profile (D). The stored water is transpired (T) by deep rooting trees and shallow rooting annuals, while losses by evaporation (E) and deep percolation are minimised. The built-in spillway (S) controls surplus water.

Where possible, agroforestry on hillsides should include the use of terraces, as these reduce soil erosion and flooding[81]. As part of the agroforestry and introduction of drought-tolerant crop interventions at the Ibanda-Makera site, training will be provided to local community members on the construction and maintenance of climate-resilient terraces.

The components of agroforestry systems include woody perennials (forest and fruit trees) and agricultural crops (such as maize and vegetables) with grass in fallow areas. Woody perennials are raised in farm forests/tree farms on the upper slopes, along farm boundaries, within the home lots, or on the edges of terraces, bunds or alleys. Agricultural crops are planted on the terraces or bunds found on level areas and along the lower to middle slopes.

The trees and shrubs should be managed to reduce competition with crops for nutrients, water and light. The management methods differ from one species to another, though for many of the species suggested below, management guidelines are available online (for example, the Tropical Forages Tool[82]). Generally, shrubs and trees are cut at 20–50 cm from the ground level and will rejuvenate every six months. The cut products can serve many purposes such as:

- stakes are used for climbing beans;
- leaves are used as fodder for livestock;
- leaf biomass are used as green manure; and
- wood biomass is used for firewood[83].

The fuel wood and bean stakes provided by the agroforestry trees are particularly important to communities around Ibanda-Makera, as deforestation for wood is a baseline driver of the forest's degradation. The provision of sturdy bean stakes by these trees will also reduce encroachment of

[80] Rwanda Environment Management Authority. 2010. Tool and Guideline #6: Practical Tools on Agroforestry.
[81] https://www.thegef.org/project/building-resilience-communities-living-degraded-forests-savannahs-and-wetlands-rwanda
[82] https://www.tropicalforages.info/text/entities/index.htm#index_C
[83] Rwanda Environment Management Authority. 2010. Tool and Guideline #6: Practical Tools on Agroforestry.

farms into the forest, because climbing beans require substantially less space to grow than bush beans, as has been shown in other parts of Rwanda through the World Agroforestry-led 'Trees For Food Security 2' project[84].

Steps are required to plan and provide landowners and farmers with knowledge on how to successfully integrate an agroforestry practice into their farms. The planning process will help develop a familiarity with the management that is required to reach the goals, objectives, benefits and economics that are desired. The development of a plan for integrating agroforestry practices to the farm system is as important as the actual establishment of the practice itself. Planning — and the development of a timeline — will help maximise the chances of success for the agroforestry practice. Planning will not only assist in communities' understanding of how the practice and its placement on the landscape can accomplish specific on-farm goals, but will provide assistance in identifying market opportunities for products that may be grown in the practice. Below are the main planning process questions that are required to plan an effective agroforestry system.

- Plan the proportion of the permanent fruit and timber trees on the basis of relative importance to the farmer.
- Plan the spacing of long-term trees on the basis of final space requirements.
- Plan succession of annual and perennial understory crops.
- Plan protection and soil enrichment strategies.
- As large permanent trees grow, adjust planting plan to place shade-tolerant crops in most shady areas.
- Always keep the ground covered, using various crops or mulch, to protect soil from evaporation and erosion.
- Try the system on a small scale first.
- Measure the inputs and outputs of the system.
- Evaluate whether the benefits expected have been achieved.
- Expand or extend any new system cautiously[85].

Training on the best practices and protocols for the establishment of sustainable agroforestry have been budgeted for in the Ibanda-Makera's budget, and will include the training and planning of the above steps. Once adequate planning for the establishment of agroforestry has taken place, and species have been selected, community nurseries will need to be established. Numerous resources[86, 87] are available detailing best practices for community nurseries for agroforestry.

Other best practices that crop farmers around Ibanda-Makera forest should integrate into their current farming practices (if they do not already) to increase their farms' climate resilience include basic sustainable agricultural practices, such as using push-pull pest control methods[88], establishing soil erosion measures in addition to the aforementioned terracing (such as bunds), reducing input of fertilisers and pesticides, mulching using leaves from the agroforestry trees, applying livestock manure to soil, and priming seeds (soaking the seed overnight in water before planting)[89].

Species selection for agroforestry

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[84] https://worldagroforestry.org/blog/2020/04/03/more-stakes-more-climbing-beans-less-malnutrition-rwanda-finds-solution
[85] Rwanda Environment Management Authority. 2010. Tool and Guideline #6: Practical Tools on Agroforestry.
[86] Wightman KE. 1999. Good Tree Nursery Practices: Practical Guidelines for Community Nurseries. International Centre for Research in Agroforestry. Available: http://apps.worldagroforestry.org/downloads/Publications/PDFS/B10715.pdf
[87] https://cisp.cachefly.net/assets/articles/attachments/79966_wwf_community_nursery_guide_english_web_sep19.pdf
[88] Push-pull pest control is a natural, low impact method to reducing pest damage on crops, through the planting of plant species that are poisonous or deterrents to pests within croplands (push) and that attract pests outside of the crop area (pull).
[89] REMA. 2010. Tool and Guideline #4: Practical Tools on Sustainable Agriculture. Available: https://www.rema.gov.rw/~remagov/fileadmin/templates/Documents/rema_doc/Environmental%20Managemnent%20Plractical%20Tools/4-%20Practical%20Tools%20on%20Sustainable%20Agriculture%20_Final%20Version_%2016-07-2010%20%23%20Paper%20A4.pdf.

One of the purposes of the agroforestry intervention is to provide an alternative source of climate-resilient livelihoods to local communities, so that the baseline drivers of degradation in the Ibanda-Makera forest are halted or reduced. The baseline drivers of forest degradation include the: i) harvesting of forest trees for fuel wood, which the agroforestry intervention will address by providing a steady source of fuel wood and other livelihood benefits within the existing agricultural lands; and ii) encroachment of agriculture into the forest as a result of limited land availability, which the agroforestry intervention will address by increasing the productivity, climate resilience and range of use of existing agricultural land.

Several indigenous, drought-resistant tree species have been identified that are resilient to current and future climate change threats in the Ibanda-Makera forest, and have been suggested for agroforestry interventions in the region. These are presented in Table 6 below.

Table 6. Suitable indigenous species for agroforestry use in agricultural land around Ibanda-Makera forest and their potential benefits[90].

Scientific name	Local name	Climate resilience role	Livelihood impact role
Macaranga kilimandscharica	Umusekera	Slope protection, soil stabilisation	Handicraft, fuel wood, shading, traditional medicine
Polyscias fulva	Umwungo	Slope protection, soil stabilisation	Bee forage, handicraft, ornamental
Vernonia amygdalina	Umubirizi	Live fence, soil fertility	Bee forage, handicraft, fuel wood, timber

An additional 13 tree species suitable for agroforestry in the Ibanda-Makera forest are presented in Table 7 below. They are all fast-growing species that are grown among crops in the Bugesera District in the Eastern Province, which is geographically close to Ibanda-Makera and experiences similar climatic conditions. Out of the species listed in Table 7, native, non-invasive species including *F. ovata*, *F. thonningii*, *M. lutea*, *M. obtusifolia* and *S. mannii* should be prioritised. Of these, *F. ovata*, *F. thonningii* and *M. lutea* are drought tolerant, can be sown easily or propagated through cuttings and provide multiple ecosystem services. Following these, secondary priority should be given to exotic species that are not known to be invasive in Rwanda, including *C. calothyrus, G. sepium, J. mimosifolia, J. curcas, L. trichandra, M. nigra* and *S. sesban*. Most of these species are tolerant of dry conditions and can be planted relatively easily as cuttings or sown as seeds *in situ*. Caution should be used for *P. americana*, which has the potential to outcompete crops for nutrients and overshade certain species.

Table 7. Suitable indigenous and non-invasive exotic species for agroforestry use in agricultural land around Ibanda-Makera forest and their potential benefits and planting requirements[91].

Scientific name	Local name	Exotic or indigenous	Climate resilience role	Livelihood impact role	Planting requirements and characteristics[92]
Calliandra calothyrsus	Kariyandara	Exotic	Soil erosion control, soil fertility (mulch and N-fixing), shade, windbreak	Bee forage, fuel wood, timber, fodder, ornamental	Scarified[93] seeds can be sown directly or grown in nurseries. Evergreen tree that can survive

[90] Rwanda Environment Management Authority. 2019. Ecosystem-based adaptation guidelines for climate resilient restoration of savannah, wetland and forest ecosystems of Rwanda.
[91] Kuria A, Uwase Y, Mukuralinda A, Iiyama M, Twagirayezu D, Njenga M, Muriuki J, Mutaganda A, Muthuri C, Kind R, Betemariam E, Cronin M, Kinuthia R, Migambi F, Lamond G, Pagella T & Sinclair F. 2017. Suitable tree species selection and management tool for Rwanda. [Database]. World Agroforestry Centre (ICRAF). http://apps.worldagroforestry.org/suitable-tree/
[92] Useful Tropical Plants. N.d. Available at: http://tropical.theferns.info/c.
[93] Scarification refers to the treatment of seeds before planting by boiling or scraping to remove the hard outer casing and improve germination yields.

					long dry spells and nutrient-poor soils.
Ficus ovata	Umurehe	Indigenous	Soil erosion control, shade, windbreak	Fuel wood, edible fruits, medicine, fodder, ornamental	The planting of cuttings is the fastest propagation method, but seeds can also be harvested from fruit.
Ficus thonningii	Umuvumu	Indigenous	Soil erosion control, shade, windbreak, live fence	Fuel wood, medicine, bean stakes, gums/resins, fibre, ornamental	Can be grown from seeds but more commonly through cuttings which can either be planted directly or first grown in a nursery. A relatively drought-resilient tree.
Gliricidia sepium	Gereveriya	Exotic	Soil erosion control, soil fertility (N-fixing), shade, windbreak	Fuel wood, charcoal, timber, medicine, bee forage, bean stakes, fodder, ornamental	Can be propagated from cuttings in good soils, otherwise seeds can be planted directly after land preparation or grown in a nursery. A deciduous tree that is tolerant of long dry seasons.
Jacaranda mimosifolia	Jacaranda	Exotic	Soil erosion control, soil fertility (mulch), shade, live fence	Fuel wood, timber, bee forage, farm tools	For planting from seeds, no pre-treatment is needed but should be soaked for 24 hours. Branch cuttings can also be used. Deciduous tree that can tolerate long dry seasons.
Jatropha curcas	Umubira/ Icyomoro	Exotic	Live fence, soil erosion control	Medicine, bean stakes	Seedlings can be germinated in moist conditions from fresh seeds. Alternatively, cuttings of half-ripe wood can be used in-situ. A deciduous tree that is tolerant of arid areas with nutrient-poor soils.
Leucaena trichandra	Resena	Exotic	Live fence, soil fertility (mulch and N-fixing), soil erosion control	Edible food parts, fuel wood, timber, fodder	Can be grown from scarified seeds or cuttings of semi-ripe wood.
Markhamia lutea	Umusave	Indigenous	Soil fertility (mulch and N-fixing); shade	Fuel wood, timber, charcoal, medicinal uses, bee forage, bean stakes, ornamental	Can germinate from direct sowing in sunny areas. Evergreen tree that can tolerate distinct dry seasons and tolerates drought

					conditions once established.
Markhamia obtusifolia	Umukundambazo	Indigenous	Shade	Fuel wood, timber (furniture and construction), medicinal uses, fodder, ornamental	Can be cultivated from seeds.
Morus nigra	Iboberi/umukeri	Exotic	Live fence	Edible fruits, fuel wood, fodder, bee forage, ornamental	Grown from stratified seeds in nurseries or cuttings of half-ripe wood. A semi-deciduous species favoured in areas with extended drought conditions.
Persea americana	Avoka	Exotic — can compete for nutrients and overshades neighbouring plants	Shade, soil erosion control	Edible fruits, fuel wood, fodder, timber (construction), charcoal	Propagated through seeds grown in a nursery and prefers warm, moist conditions. Evergreen tree that can tolerate high temperatures and poor soils .
Sesbania sesban	Umunyegenyege	Exotic	Live fence, shade, soil fertility (mulch), wind break	Fuel wood, charcoal, timber (construction), medicinal uses, fodder, bee forage, gums and resins	Scarified seeds can be cultivated in nurseries. Deciduous species that can tolerate low rainfall and poor soils.
Solanecio mannii	Umutagara	Indigenous	Shade	Fuel wood, bean stakes, medicinal uses, tannins (dyes), ornamental	Fast growing evergreen tree.

Mangos are another drought-tolerant horticultural species that could be encouraged among the communities around Ibanda-Makera. Currently, mango farming occurs in all four provinces of Rwanda. However, it is best suited for the Eastern Province, as mangos require hot, low altitude climates with rainfall ranging from about 500 to 2,500 mm — which are conditions that exist in the Kirehe District. Most importantly, the Eastern Province is characterised by dry periods of three months, a prerequisite for successful mango production[94].

Introducing highly productive drought-resistant crop species

Introducing highly productive drought-resistant crop species represents a means of improving agricultural output by improving the land-use efficiency of agriculture without the need to increase the the size of cultivated areas — a necessary approach in a country limited by land availability. This approach fulfils the definition of agricultural EbA by increasing sustainable management through genetic and crop species diversity, while increasing the adaptive capacity of local communities through increased food security and income generation despite changes in climate (Table 5). In addition, when used in conjunction with zero-budget natural farming (further discussed below) and agroforestry in Ibanda-Makera — which will improve the climate resilience of existing crops grown

[94] REMA. 2010. Tool and Guideline #4: Practical Tools on Sustainable Agriculture.

around the forest by increasing soil fertility, controlling soil erosion and providing shade — crop diversification will also minimise the risk of local communities to the effects of climate change by reducing the losses experienced by farmers during periods with limited rainfall or prolonged dry seasons. The Ibanda-Makera area is predicted to experience more erratic rainfall and increased frequency of droughts under future climate conditions, which indicates the necessity of this intervention for increasing the overall climate resilience of the communities surrounding the forest.

Existing drought-tolerant crops that are grown in the Kirehe District include maize[95] and Jatropha (*Jatropha curcas*)[96,97]. Jatropha is grown for biofuel production, but its large-scale cultivation is currently not economically feasible as a result of low seed yields, low seed price and high production costs. Jatropha cultivation is, however, feasible for smallholder farmers when it is planted as a live fence around crops (given the low investment risks and opportunity costs for land when planted in this manner), and when hired labour is replaced by family labour[98]. When Jatropha is planted as a live fence, it is a valuable drought-tolerant crop species to communities around Ibanda-Makera that can contribute to the benefits provided by trees detailed in the agroforestry intervention section above.

Another minor drought-tolerant food crop that is already grown in the Kirehe District[99,100], is amaranth (*Amaranthus* spp.)[101]. Amaranth can be used as livestock feed and has been proven to increase digestibility of other livestock feed[102]. Amaranth can also be intercropped with maize and other crop species already grown by local communities at the site to increase forage yield for livestock in the dry season, as done successfully in drought-prone areas of Nigeria[103]. Amaranth is also part of the diets of many people in Rwanda and is considered highly nutritious[104]. The nutritional composition of amaranth may also form the foundation to help meet nutritional requirements of communities around Ibanda-Makera[105]. In addition to these benefits, amaranth can also be utilised as a fuel source and address one of the baseline drivers of land degradation in Ibanda-Makera forest (i.e. deforestation of trees for fuel wood). The species *Amaranthus retroflexus* in particular has been found to possess 75–90% of the calorific value of wood[106]. Production of amaranth in the communities around the forest should be increased. Some farmers at the site already grow amaranth, which indicates that the procurement and distribution of seeds should be accessible and cost-effective.

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[95] The Rufford Small Grants Foundation. 2009. Eastern Gallery Forest Conservation Project: Biodiversity survey.

[96] Ntaribi T & Paul DI. 2019. The economic feasibility of Jatropha cultivation for biodiesel production in Rwanda: A case study of Kirehe district. *Energy for Sustainable Development* 50: 27–37.

[97] Sapeta H, Costa JM, Lourenco T, Maroco J, Van der Linde P & Oliveira MM. 2013. Drought stress response in Jatropha curcas: growth and physiology. *Environmental and Experimental Botany* 85: 76–84.

[98] Ntaribi T & Paul DI. 2019. The economic feasibility of Jatropha cultivation for biodiesel production in Rwanda: A case study of Kirehe district. *Energy for Sustainable Development* 50: 27–37.

[99] Alemayehu FR, Bendevis MA & Jacobsen SE. 2015. The potential for utilizing the seed crop amaranth (Amaranthus spp.) in East Africa as an alternative crop to support food security and climate change mitigation. *Journal of Agronomy and Crop Science*, 201: 321–329.

[100] Lenné JM & Ward AF. 2010. Improving the efficiency of domestic vegetable marketing systems in East Africa: Constraints and opportunities. *Outlook on Agriculture*, 39: 31–40.

[101] REMA. 2010. Tool and Guideline #4: Practical Tools on Sustainable Agriculture.

[102] Olorunnisomo OA & Ayodele OJ. 2009. Effects of intercropping and fertilizer application on the yield and nutritive value of maize and amaranth forages in Nigeria. *Grass and Forage Science*, 64: 413–420.

[103] Olorunnisomo OA & Ayodele OJ. 2009. Effects of intercropping and fertilizer application on the yield and nutritive value of maize and amaranth forages in Nigeria. *Grass and Forage Science*, 64: 413–420.

[104] GAIN. 2016. The Marketplace for Nutritious Foods: Rwanda Landscape Report. Available at: https://www.gainhealth.org/sites/default/files/publications/documents/the-marketplace-for-nutritious-foods-rwanda-landscape-report-2016.pdf

[105] Alemayehu FR, Bendevis MA & Jacobsen SE. 2015. The potential for utilizing the seed crop amaranth (Amaranthus spp.) in East Africa as an alternative crop to support food security and climate change mitigation. *Journal of Agronomy and Crop Science*, 201: 321–329.

[106] Alemayehu FR, Bendevis MA & Jacobsen SE. 2015. The potential for utilizing the seed crop amaranth (Amaranthus spp.) in East Africa as an alternative crop to support food security and climate change mitigation. *Journal of Agronomy and Crop Science*, 201: 321–329.

Additional drought-tolerant crops that could be introduced to communities around the Ibanda-Makera forest include cowpea and rice. These two crops, along with maize, have been targeted for drought tolerance research because of their importance to the diets of many people globally. Through selective breeding and biotechnology techniques, drought-resistant cultivars of these crops have been developed[107] that could be introduced to the local communities at this site. The Drought Tolerant Maize for Africa (DTMA project) has developed and released over 160 drought-tolerant maize varieties to farmers in 13 African countries, including some in East Africa such as Tanzania, Uganda, Malawi and Zambia[108], and could be used as a source for such cultivars to be used in this intervention.

There are numerous other crops that can be grown in Rwanda to improve yields under future climate conditions. Many of these crops are already staple foods for the population of the country. This includes drought-tolerant crops such as peat millet[109] and cassava, as well as short-cycle crops such as beans and sweet potatoes[110].

Zero-Budget Natural Farming proposal

Zero Budget Natural Farming (ZBNF) is a scalable model of low-input/high-output agriculture that eliminates the use of synthetic external inputs by utilising local farm-based inputs, and which regenerates soil health[111]. ZBNF can address multiple issues facing current 'Business as Usual' (BAU) agricultural practices, including: diminishing soil fertility as a result of erosion and floods, increasing pest loads in landscapes dominated by monoculture, pollution of water resources from high fertiliser and pesticide use, overuse of water resources, high amounts of greenhouse gas emissions, and loss of biodiversity and ecosystem services. Together these problems threaten the resilience of the food system as a whole, making it susceptible to stresses and shocks.

The Theory of Change of ZBNF is rooted in the science of ecology. ZBNF's central concept is that it is possible to harness the power of nature in such a way that people can harvest agricultural products and at the same time benefit from ecosystem services while supporting regenerative processes in soils — particularly replenishing soil organic carbon — as well as above ground to make up for any exports of nutrients. ZBNF also has the objective of strengthening and mobilising social capital of groups, especially farmers' and women's groups.

The benefits of ZBNF can be broken down into seven broad categories:

1. Reduction in carbon emissions and carbon sequestration

ZBNF reduces the CO_2 emissions released from agricultural systems by returning carbon stored in plant tissue, leaves and roots to the soil through composting and mulch.

2. Increased climate resilience

ZBNF practices improve microbial content and water retention capacity in soils which enables drought-prone areas to provide consistent yields. Reduction in chemical fertilisers reduces runoff into rivers and wetlands ensuring water quality and availability during extreme weather events.

3. Social impact

[107] https://reliefweb.int/report/world/becoming-drought-resilient-why-african-farmers-must-consider-drought-tolerant-crops#:~:text=Drought%20tolerant%20crops%20%E2%80%94%20like%20maize,produce%20even%20when%20rains%20fail

[108] Fisher M, Abate T, Lunduka RW, Asnake W, Alemayehu Y & Madulu RB. 2015. Drought tolerant maize for farmer adaptation to drought in sub-Saharan Africa: Determinants of adoption in eastern and southern Africa. *Climatic Change*, 133: 283–299.

[109] FortuneofAgrica. No date. Millet Growing in Rwanda. Available at: https://fortuneofafrica.com/rwanda/millet/

[110] De Dieu Nsabimana, J. 2019. Kirehe: Farmers adviced to plant drought resistant crops. *The New Times*. Available at: https://www.newtimes.co.rw/news/kirehe-farmers-advised-plant-drought-resistant-crops

[111] https://wedocs.unep.org/bitstream/handle/20.500.11822/28895/Zero_budget.pdf?sequence=1&isAllowed=y

Reduced cost of cultivation as a result of low-cost inputs and stable yields enables farmers to have consistent quantities of crops to sell, making their livelihoods more secure. Preservation of ecosystems on the farms lessens drudgery of women who have easier access to clean water, fuel wood and feed for livestock as well as reducing illnesses caused by chemicals in food, especially among children.

4. Net economic impact
Every US$1 invested on a farmer to adopt ZBNF results in direct benefits equalling US$13. The direct benefits include, *inter alia*: reduction in costs of cultivation, higher yields, lower costs of borrowing, income from inter crops, and a slight premium on selling price. ZBNF can also create new jobs on rural farms.

5. Impact on realisation of the 2030 Agenda for Sustainable Development
ZBNF could help make significant progress towards achieving almost a quarter of the 169 Sustainable Development Goal (SDG) targets. ZBNF reduces poverty by recognising vulnerable farmers and improving their incomes (SDG 1 and 10), diversifying crops for better nutrition (SDG 2), reducing health risks from chemicals (SDG 3), training women as farming guides (SDG 5), decreasing runoff into water bodies (SDG 6), creating green value chains (SDG 9), conserving nature (SDG 11), generating awareness about conscious consumption (SDG 12) and promoting collaborative efforts across stakeholders (SDG 17).

6. Food security
Across ZBNF crops, yields are more consistent regardless of seasonal changes and extreme weather events (prolonged dry spells or sudden heavy rains). Poly-cropping practices provide diverse nutrition sources for households which are affordable.

7. Minimising species extinction and ecological losses and fostering an increase of biodiversity
There are observable increases in the numbers and types of wild species (insects, snakes, mongoose, etc.) that have returned to farms in India where ZBNF has been implemented. An increase in birds is evident in addition to the fact that they are nesting amongst the crops. Bees are also visible through a rise in beehives in ZBNF crop fields.

A few generic principles that should be followed in ZBNF are provided below:

- A healthy soil microbiome is critical for optimal soil health and plant health, and thereby animal health and human health.
- Soil should always be covered with crops (the living roots principle[112]), throughout the year. Soil should not be bare. In those months where cropping is not possible, there should be at least crop residue mulch cover.
- Each farm should have a diversity of crops.
- Minimal disturbance of soils is critical, therefore no till farming or shallow tillage is recommended.
- Animals should be incorporated into farming. Integrated farming systems are critical for promoting natural farming.
- Healthy soil microbiome is the key to retaining and enhancing soil organic matter. Bio-stimulants[113] are necessary to catalyse this process. There are different ways of making bio-stimulants, including the fermentation of animal dung and urine.
- Increasing the amount and diversity of organic residues returned to the soil is very important. These include crop residues, cow-dung, compost, etc.

[112] Roots nourish microbes by providing a food source or by releasing nutrient-rich compounds into the soil. It is estimated that plants release 10–40% of the carbon fixed by photosynthesis through the roots. This carbon increases soil organic matter. Source: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/pa/soils/health/?cid=nrcseprd1200408
[113] Bio-stimulants are substances containing micro-organisms whose function when applied to soil is to stimulate natural processes to enhance nutrient uptake and tolerance to abiotic stress. Source: https://emergence.fbn.com/inputs/what-are-biostimulants

- Pest management should be done through better agronomic practices (such as push-pull pest control) and through botanical pesticides (only when necessary).
- Use of synthetic fertilisers and other biocides is harmful to this process of regeneration and is not allowed.

ZBNF is recommended as a sustainable intervention for Ibanda-Makera to improve the resilience of farms around the forest. It will enhance the success and sustainability of the agroforestry and drought-tolerant crop interventions, through the various benefits it generates (described above). World Agroforestry (ICRAF) will lead the implementation of ZBNF at the Ibanda-Makera site, as recommended by REMA. ICRAF will be supported by agricultural officers from the Kirehe District, and will also work with other ZBNF actors such as Bridge2Rwanda. ICRAF's approach to ZBNF focuses on the planting of trees to increase the biomass of soils thereby improving agricultural productivity. This will reduce the need to expand agricultural into surrounding natural areas such as the Ibanda-Makera Natural Forest, reducing degradation. Diverse tree species will be planted as part of ICRAF's approach, with the aim of not only improving agricultural productivity but also to provide NTFPs to local farmers. ICRAF has conducted a pre-assessment of the Ibanda-Makera site and have also identified relevant tree species for the implementation of ZBNF (these details were not provided by ICRAF for inclusion in this Feasibility Study). In addition to overseeing the implementation of ZBNF, ICRAF will also contribute to building the capacity of district officials and local farmers to implement and maintain ZBNF interventions.

Intervention risks and mitigation measures

Table 8. Potential risks and mitigation measures of each proposed intervention for the Ibanda-Makera site.

Intervention	Risk category	Risk	Mitigation measure
Forest buffer zone	Social	Displacement of land owned by local communities	No land will be taken from surrounding communities. Local community members consulted supported the re-establishment of the road, so if the road intersects any farmland there should not be conflict
	Sustainability	Re-established road falling into disrepair	A grader will be hired annually to maintain the road. Road will also be designed using best practices for gravel roads in the tropics, including designing for optimal drainage
	Environmental	Degradation of, or encroachment into buffer zone/ live fence	Road will act as a strong boundary between communities and forest. Communities will be targeted for conservation awareness-raising campaigns. Species selected for buffer zone have been selected based on the numerous benefits they provide
Agroforestry	Social	Displacement of land that could be used for crop farming	Selection of trees that provide shade and that have roots that bind soil and reduce erosion will increase the overall productivity of farm plots
	Social	Limited knowledge on forestry practices among crop farmers	Training on agroforestry best practices will be provided to all champion farmers who pilot agroforestry interventions

	Environmental	Vulnerability of tree seedlings to drought	Only drought-tolerant tree species will be planted
	Environmental	Vulnerability of water sources for irrigation to drought and other pressures	Creation of buffer zone around Ibanda-Makera forest will increase the resilience of the forest and its water resources to climate change by reducing erosion and sedimentation of rivers and streams
	Environmental; Sustainability	Agroforestry trees shading out crops and reducing productivity	Tree canopies will be pruned and thinned to allow sufficient solar radiation to reach crops. They will also not be planted too close together
	Environmental	Irrigation and fertiliser applied to crops may draw tree roots closer to the surface than normal, making trees less resistant to strong winds	Introduction of drought-tolerant crop species requiring less irrigation, as well as introduction of ZBNF to limit fertiliser use will mitigate this effect
Introducing drought-tolerant crop species	Capacity	Limited knowledge of farmers on how to grow new crop species	Training on the cultivation of new species will be provided to farmers
	Capacity	Procurement of drought-tolerant crop species and cultivars if they are not readily available in the Kirehe District	Project management will work with national agricultural agencies and institutes (RAB, MINAGRI, ISAR) to procure these seedlings
Establishing ZBNF	Capacity	Limited knowledge of farmers to incorporate ZBNF techniques	Training on ZBNF techniques will be provided to pilot farmers during the implementation of this intervention
Supporting bee-keeping livelihoods	Social	Beneficiaries are the same as those benefiting from LDCF2 bee-keeping activities	Consultations revealed there is widespread interest among community members in developing this livelihood, which means more people can be targeted for this intervention
All	Institutional	Limited capacity of environmental committees on which success of interventions will depend	Coordination with REMA, Ministry of Environment and Rwanda Agriculture Board will be encouraged to maximise institutional, knowledge and financial capacity of regional environmental committees

Summary budget

The total budget for interventions at the Ibanda-Makera forest is US$834,000. Below is an approximate breakdown of how the budget for the Ibanda-Makera site could be spent, based on values of costs obtained from the 'LDCF2 project' ('*Building resilience of communities living in degraded forests, savannas and wetlands of Rwanda through an ecosystem-based adaptation approach*') (Table 9)[114]. Detailed budgets are provided in Annex 7.

Table 9. Summary budget for interventions at Ibanda-Makera Natural Forest.

Intervention	Input/activity	Estimated cost (US$)

[114] https://www.thegef.org/project/building-resilience-communities-living-degraded-forests-savannahs-and-wetlands-rwanda

Demarcation and establishment of a buffer zone around the forest	Labour for clearing 5-m area around forest for road	14,200
	Hand tools for clearing 5-m area around forest for road	6,000
	Grader to make a road around forest	15,000 initial (500 per day for 30 days; followed by 500 per day for 10 days a year for maintenance)
	Establishment (including maintenance) of 10-m vegetative buffer zone with multi-use tree species[115] between the forest and the road (8 ha)	16,000 (2,000 per ha)
Promotion of agroforestry in surrounding agricultural land	Establishment of agroforestry in 200 ha of agricultural land around the forest[116]	100,000 (500 per ha)
	Training on agroforestry best practices	6,000
Introduction of highly productive drought-resistant crop species	Procurement and establishment of new drought-tolerant crop species	100,000
	Training on the establishment and growing of new drought-tolerant crop species	6,000
Establishment of Zero Budget Natural Farming (ZBNF)	Training by ICRAF on use of ZBNF techniques (including use of natural bio-stimulants, natural pest control methods, planting a diversity of crops)	10,000
	Establishing ZBNF on farms around the forest by ICRAF	190,000
All EbA interventions	One-day workshop with local communities to develop a nursery management system	3,000
	Establishment and management of nursery for plants used in agroforestry and forest buffer zone[117]	139,000 (500 per ha of buffer zone and agroforestry)
Additional interventions addressing baseline drivers of degradation (complementary to EbA)	Training on bee-keeping (100 individuals)	6,000
	Provision of bee-keeping equipment (100 individuals)	40,000
	Awareness-raising campaign on the climate change adaptation benefits of the forest and its continued protection from degradation	10,000
	Support (including training) provided to establish and equip environment committees to maintain and implement interventions during the project period	20,000
Total		**681,200**

[115] US$2,000 per ha is allocated to the establishment of a multi-use buffer zone around the Makera forest. Assuming a buffer zone of width 10 m all around this ~77-ha forest, the buffer zone would cover ~8 ha.
[116] US$5,00 per ha is allocated to the development of agroforestry in the agricultural areas around the forest.
[117] 1,500 trees will be planted per hectare of forest. A mortality rate of 40% is accounted for. Therefore, 2,200 seedlings will be planted in nurseries for each hectare of restored forest. An average of US$500 per hectare is allocated to purchase the seeds and build the nurseries for forest restoration and agroforestry.

Implementation timetables

Implementation timetables for the selected interventions are presented in Annex 3.

Implementation arrangements

Most of the interventions proposed in Ibanda-Makera are related to tree planting. Given the difficulties associated with tree planting in Rwanda's Eastern Province as a result of limited rainfall, stakeholders recommended to have a contractor who will be responsible for implementing the project's tree planting activities and follow up for at least two years to ensure that tree survival rate is optimised. The contractor will be requested to use local labour to ensure community ownership of the intervention, as well as to provide employment to local community members. During the implementation local communities will also be trained on the EbA approach and a follow-up agreement will be signed with the community where interventions will be implemented on their lands.

Stakeholders identified for the Ibanda-Makera interventions also include:

- District-, Sector- and Cell-level authorities that will be involved in project implementation on the ground, as well as coordinating with the local communities to raise awareness among local farmers;
- Rwanda Forest Authority (RWFA), World Agroforestry (ICRAF) which will provide technical expertise in final selection and procurement of appropriate tree species;
- Rwanda Agriculture Board and Rwanda Agricultural Research Institute (ISAR), which will assist the project managers in procuring highly productive drought-resistant crop species to be introduced in the area; and
- ICRAF will lead the implementation of ZBNF at the Ibanda-Makera site, as recommended by REMA. ICRAF will be supported by agricultural officers from the Kirehe District, and will also work with other ZBNF actors such as Bridge2Rwanda. ICRAF has conducted a pre-assessment of the Ibanda-Makera site and have also identified relevant tree species for the implementation of ZBNF (these details were not provided by ICRAF for inclusion in this Feasibility Study). In addition to overseeing the implementation of ZBNF, ICRAF will also contribute to building the capacity of district officials and local farmers to implement and maintain ZBNF interventions.

Upon the new Ministerial Order[118] to establish Environment Committees, it was recommended by district officials that the project supports the establishment of these committees in the intervention area and provide them with training on implementing EbA interventions. The involvement of these committees in project implementation will ensure sustainability beyond the project period. According to the ministerial order, Environment Committees will be responsible for: i) ensuring the implementation of the laws, policies, programmes and plans relating to the protection, conservation and promotion of the environment in Rwanda; ii) monitoring challenges related to awareness-raising of the population on environmental protection and appropriate land use; and iii) ensuring that persons who destroy the environment are pursued by the relevant institutions.

Committees will be established at Provincial, District, Sector and Cell level. At Cell level — which is closest to the community — the committee will comprise the following:

- a representative of National Women Council at Cell level;
- a representative of National Youth Council at Cell level;
- a representative of the private sector at Cell level;
- two experts in environmental matters approved by the Council of the Cell;

[118]https://rema.gov.rw/fileadmin/templates/Documents/rema_doc/Laws%20and%20Regulations_Updated/Ministerial%20Orders/Prime%20Minister's%20order%20%20for%20Committees%20in%20charge%20of%20the%20Environment%20conservation%20and%20protection.pdf

- a representative of non-government organisations dealing with environmental matters who is elected by his/her peers;
- persons in charge of environment in the Executive Committees of the Villages; and
- persons in charge of social affairs in the Executive Committees of the Villages.

In terms of the monitoring of interventions at Ibanda-Makera, the Provincial, District, Sector and Cell Environmental Committees will have different responsibilities. According to the Ministerial Order[119], the Committee for the Eastern Province will coordinate activities aimed at conserving and protecting the environment in the province, which includes regulating the protection of the Ibanda-Makera Natural Forest. The Kirehe District Environmental Committee will be responsible for caring for the protected forest and its species, as well as monitoring the proper management thereof, making this Committee an integral part of the activity to develop a forest management plan for Ibanda-Makera. The Environmental Committee established for the Mpanga Sector will be responsible for monitoring the management of tree nurseries set up under the project, and also ensure soil erosion measures are being correctly implemented. It will also ensure the monitoring and evaluation of the execution of the project's interventions. At the Cell level, the Nasho Cell Environmental Committee will ensure the proper use and management of the road established around the Makera forest, and assist the Sector Environmental Committee in monitoring soil erosion and tree-planting measures in the communities around the forest.

[119] https://rema.gov.rw/fileadmin/templates/Documents/rema_doc/Laws%20and%20Regulations_Updated/Ministerial%20Orders/Prime%20Minister's%20order%20%20for%20Committees%20in%20charge%20of%20the%20Environment%20conservation%20and%20protection.pdf

2.2 *Site 2: Muvumba River, Nyagatare District, Eastern Province*

<u>Site description</u>

Administrative location

The section of the Muvumba River targeted for EbA interventions by the NAP project is located in the Nyagatare District of the Eastern Province. The stretch of river is shared between eight sectors: Matimba and Musheri for the upstream interventions, and Rwempasha, Nyagatare, Tabagwe, Karama, Rukomo and Gatunda for the downstream interventions (Figure 20). The difference between “upstream” and “downstream” interventions is described in further detail in the ‘Detailed description of interventions’ section for the Muvumba River site. The river enters Rwanda at the Kagitumba border post in the country’s northeastern corner (on Rwanda’s border with Uganda), and then shares a border on its northern side with Uganda until it enters the Rwempasha Sector.

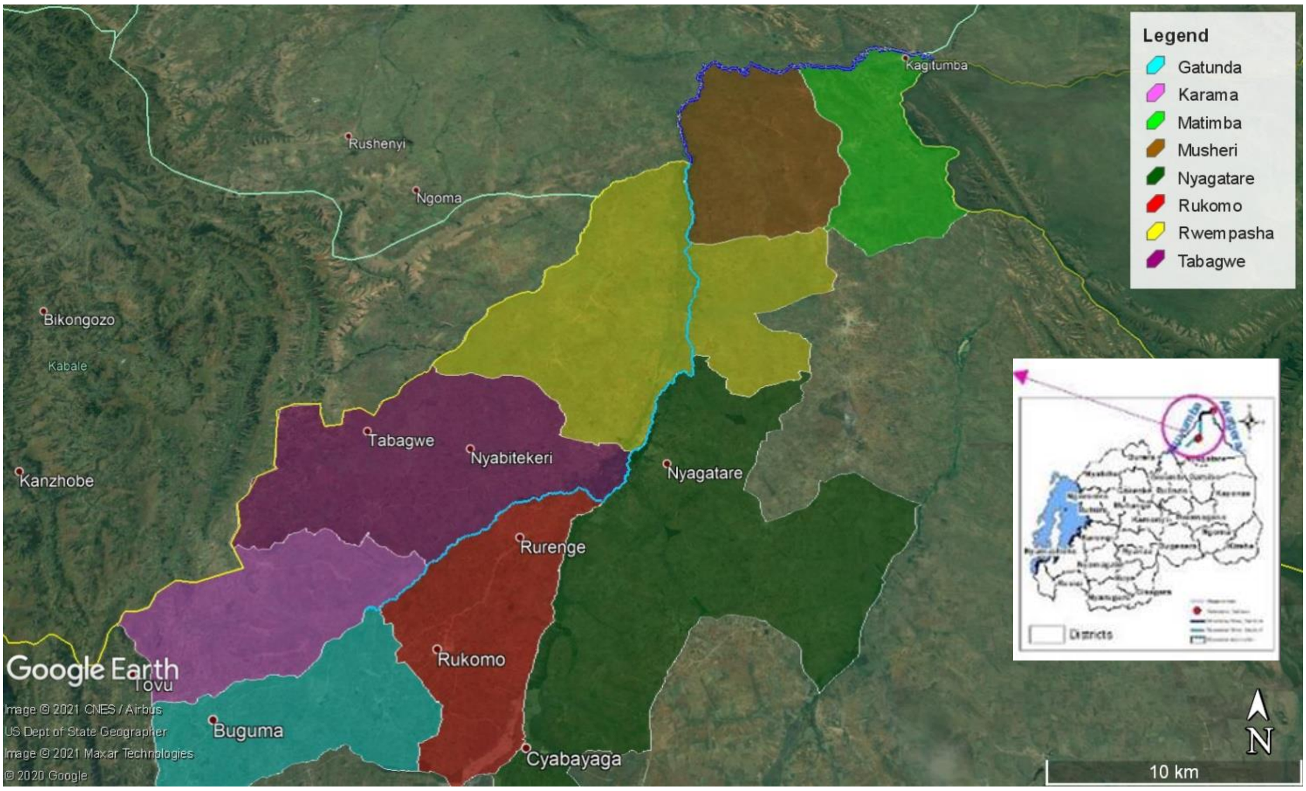


Figure 20. Sectors of the Nyagatare District that the targeted stretch of the Muvumba River flows through. The yellow line represents the Rwanda-Uganda border, which follows the river’s course in the two northern-most Sectors. The dark blue line represents the “upstream” section of the Muvumba River, while the light blue line represents the “downstream” section, in terms of this project’s proposed interventions. Map created using Google Earth Pro. Sector borders downloaded from a World Bank database[120]. Muvumba River location provided by Theogene Habakubaho.

The cells and villages along the downstream section of the Muvumba River are provided in Table 10 below. In total this section of the river crosses 12 cells and 23 villages.

Table 10. Cells and villages intersected by the downstream section of the Muvumba River.

No	Cell	Village
1	Nyamirembe	Huriro

[120] https://datacatalog.worldbank.org/dataset/rwanda-admin-boundaries-and-villages

2	Bushara	Bushara Centre
3		Uruyenzi
4	Cyenkwanzi	Kabeza
5	Gikundamvura	Gikundamvura I
6		Umutara
7		Mirama II
8	Nyagatare	Nyagatare I
9		Nyagatare II
10		Amizero
11		Isangano
12	Nyakagarama	Kayenzi
13		Nyakagarama
14		Nyamworoma
15	Rurenge	Akajuka
16		Benishyaka
17	Rutare	Rutare
18	Gitengure	Gitengure
19		Nshuri
20	Nkoma	Ibare
21		Kabeza
22	Nyabitekeri	Kabirizi
23	Nyagatoma	Akajevuba

The cells and villages along the upstream section of the Muvumba River are provided in Table 11 below. In total this section of the river crosses 7 cells and 15 villages.

Table 11. Cells and Villages intersected by the upstream section of the Muvumba River.

No	Cell	Village
1	Cyembogo	Kamahoro
2		Kagitumba
3		Munini
4	Kagitumba	Musenyi
5		Muvumba
6		Nziranziza
7	Rwentanga	Kagezi II
8		Mitayayo II
9	Kibirizi	Nyamenge
10		Gikunyu
11	Nyagatabire	Mushorerwa
12		Nyagatabire
13	Nyamiyonga	Cyenombe
14		Nyamiyonga
15	Kazaza	Gakindo

Climate and climate threats

The Muvumba River falls in the hot and dry lowland agro-climatic zone, which has an average annual rainfall of ~864 mm (ranging from 827 mm to 900 mm). Within the Rwembasha Sector — which is centrally located to the pilot area and incorporates a large section of the Muvumba River — the average annual rainfall is 745 mm (Figure 21). Rainfall in the pilot area is low compared with the majority of the country — and mostly occurs during the short and long wet seasons (270 mm and 337 mm respectively) (Figure 22). This limited rainfall is furthermore unpredictable, negatively affecting water availability for agriculture and livestock. Although the overall trend in rainfall during the shorter wet season has stayed relatively constant from 1981–2017 (Figure 23), rainfall in the longer wet season has indicated an increasing trend over this period (Figure 24).

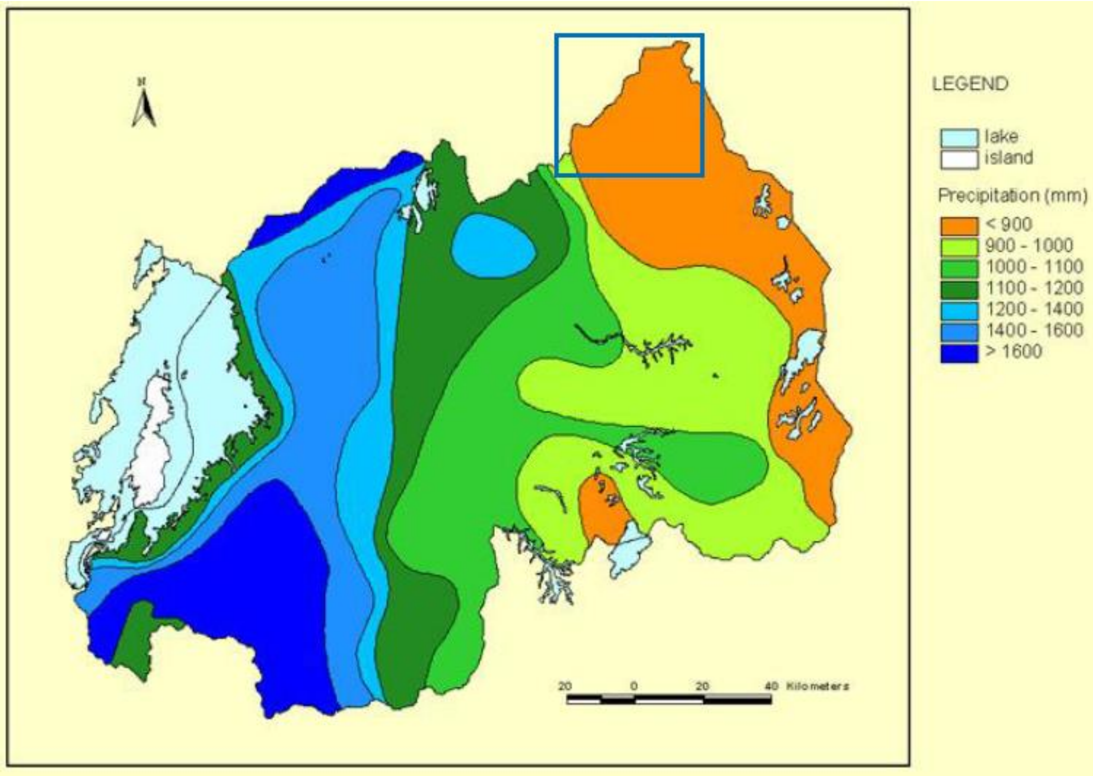


Figure 21. Annual average rainfall for Rwanda[121]. The Muvumba pilot site is indicated with a blue square.

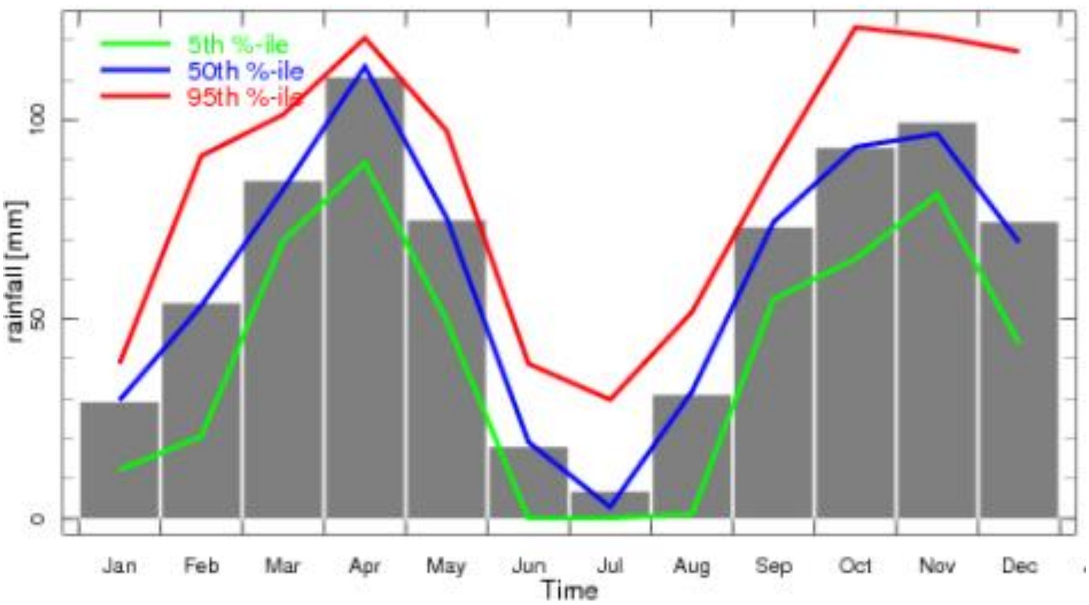


Figure 22. Average monthly rainfall (mm) for the Muvumba pilot site[122].

[121] Verdoodt A & van Ranst E. 2003. Land evaluation for agricultural production in the tropics. A large-scale land suitability classification for Rwanda.
[122] Meteo Rwanda. 2020. Climate Summary for Local Governments: Rwempasha Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405212%3Ads#tabs-1

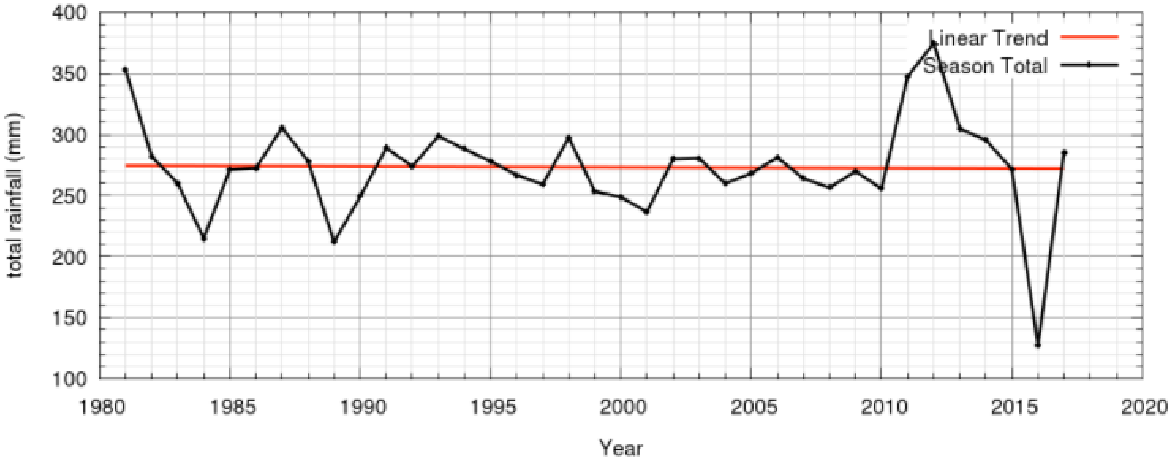


Figure 23. Trend in total seasonal rainfall from March–May for the Muvumba pilot site[123].

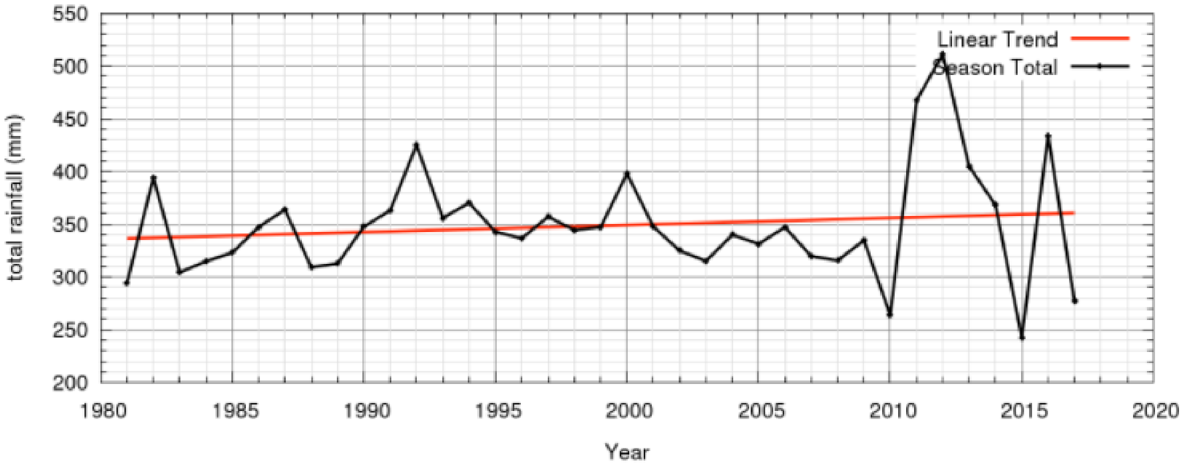


Figure 24. Trend in total seasonal rainfall from September–December for the Muvumba pilot site[124].

Along with having relatively low rainfall compared with most of Rwanda, average annual temperatures in the eastern portion of the country — including where the Muvumba pilot site is situated — are hotter than most of the country (Figure 25). The average annual temperature is 20–22°C, with an average maximum temperature of 24°C (Figure 26) and an average minimum temperature of 14°C (Figure 27).

[123] Meteo Rwanda. 2020. Climate Summary for Local Governments: Rwempasha Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405212%3Ads#tabs-1

[124] Meteo Rwanda. 2020. Climate Summary for Local Governments: Rwempasha Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405212%3Ads#tabs-1

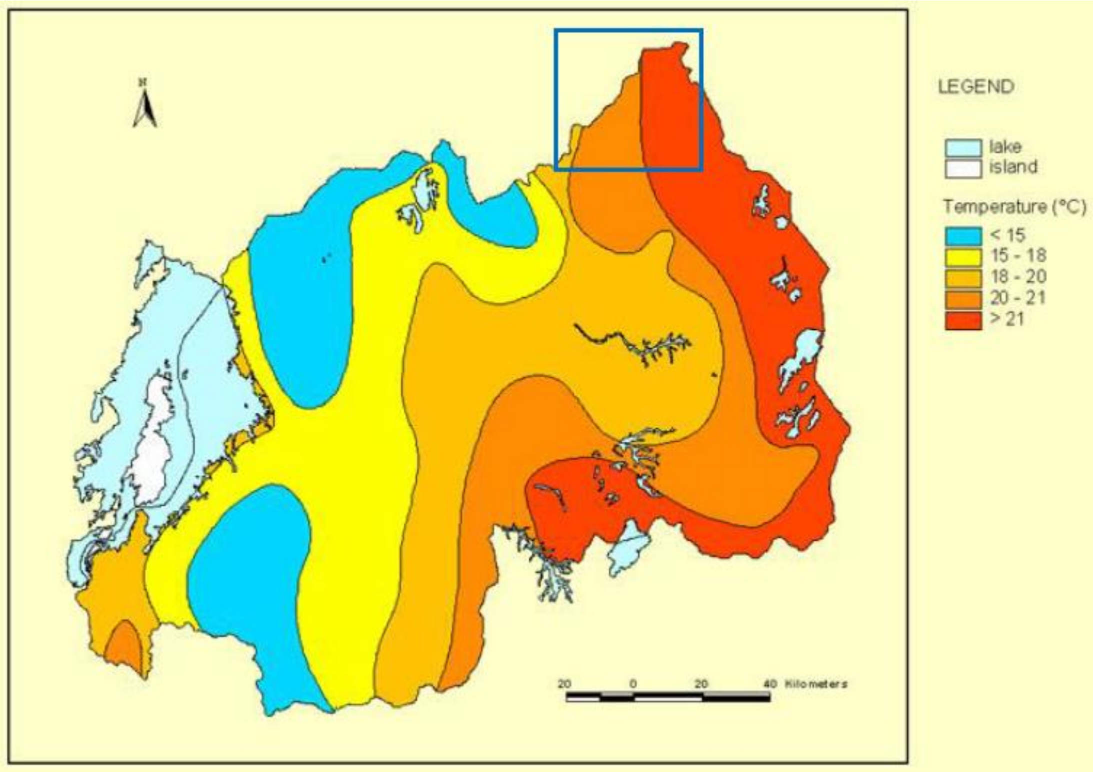


Figure 25. Annual average temperature for Rwanda[125]. The Muvumba pilot site is indicated with a blue square.

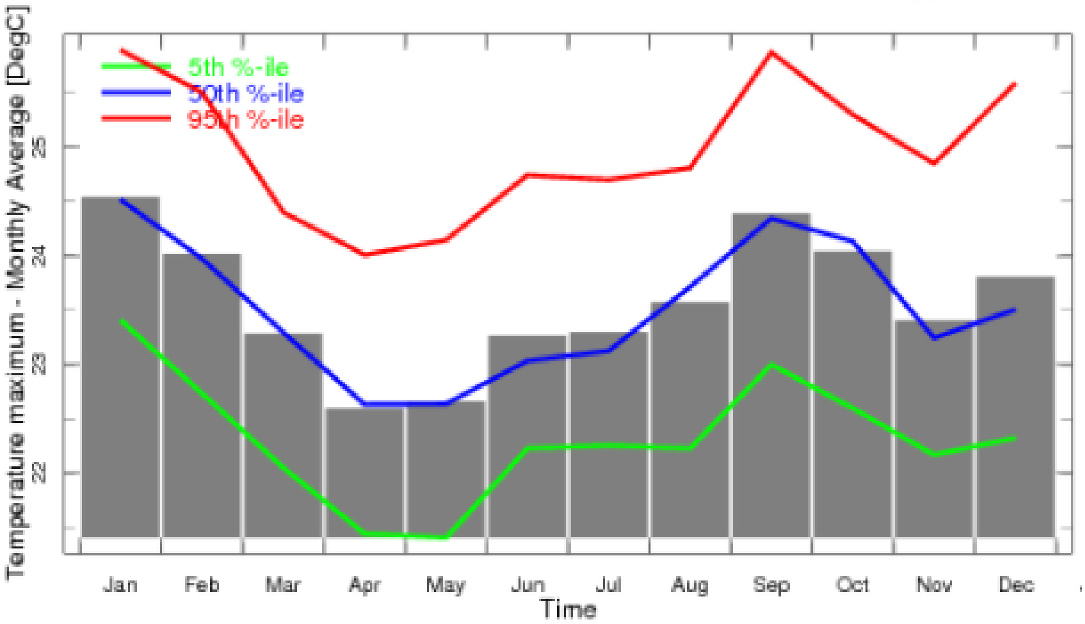


Figure 26. Average monthly maximum temperature (°C) for the Muvumba pilot site[126].

[125] Verdoodt A & van Ranst E. 2003. Land evaluation for agricultural production in the tropics. A large-scale land suitability classification for Rwanda.
[126] Meteo Rwanda. 2020. Climate Summary for Local Governments: Rwimiyaga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405213%3Ads#tabs-1

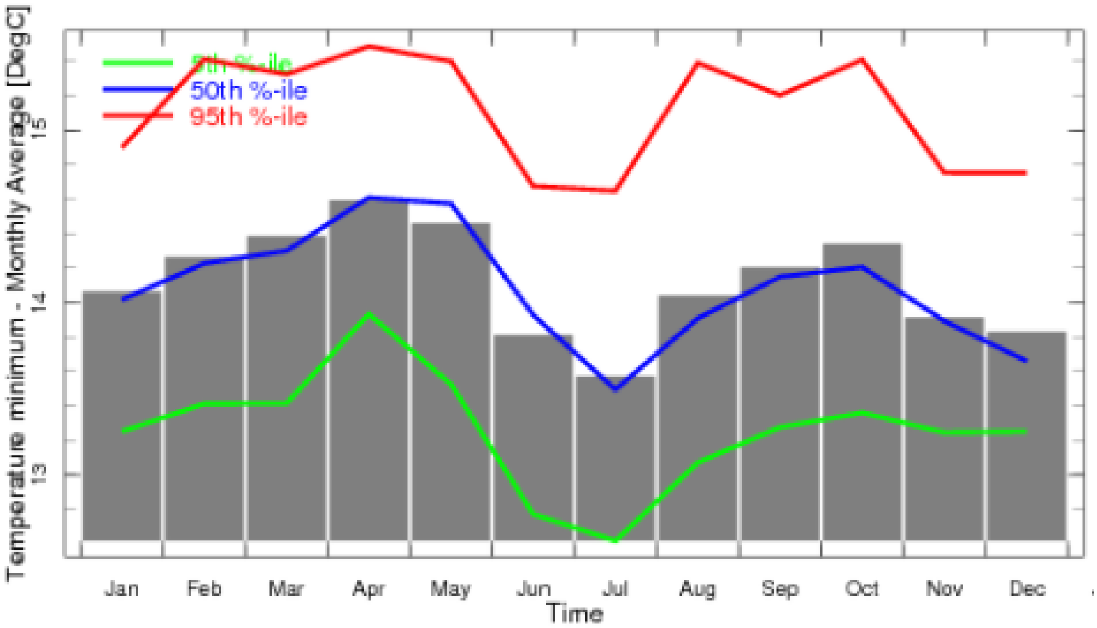


Figure 27. Average monthly minimum temperature (°C) for the Muvumba pilot site[127].

Relevant climate threats in this site include droughts, windstorms and flooding. Drought conditions in the Muvumba catchment results in reduced water availability for surrounding communities during the dry season, leading to increased costs of vendor-supplied water in urban areas, increased time spent searching for and collecting water, as well as increased reliance on groundwater reserves[128].

Increased flooding during heavy rainfall events occurs along riparian areas of the river, particularly in the Mulindi marshlands — which contains poorly drained tea plantations — and along areas surrounding rivers[129]. Flooding in the Muvumba catchment is increased by the presence of mountainous terrain, resulting in the erosion of exposed riparian areas and riverbanks. The loss of fertile soils leads to reduced soil fertility and poor agricultural productivity in higher parts of the watershed. The section of the Muvumba River in the vicinity of the city of Nyagatare is regularly affected by floods that cause substantive losses to farmers. This flooding increases siltation within the river, which decreases the water intake capacity of water supply stations that service local communities. Siltation negatively affects water supplies to surrounding communities and increases maintenance costs. Productivity at water treatment plants found on the river is also reduced when water turbidity (associated with siltation) increases during the wet seasons. As water becomes more turbid, the treatment costs increase. Once turbidity rises over the upper limit of 10,000 Nephelometric Turbidity Units (NTU), production is halted as the costs and volume of the necessary treatment chemicals are too high[130].

Ecosystem profile

Patches of relict gallery forest[131] exist along much of the Muvumba River's banks (Figure 28). These forest patches are currently threatened by degradation and habitat loss from expanding agricultural areas. The most notable forest tree species in this regard is *Vachellia kirkii* (formerly *Acacia kirkii;* known locally as Umunyaryera or Umukinga), which is important because, *inter alia*: i) it is a

[127] Meteo Rwanda. 2020. Climate Summary for Local Governments: Rwimiyaga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405213%3Ads#tabs-1
[128] Nzeyimana I & Philliper K. N.d. Drought conditions and management strategies in Rwanda.
[129] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[130] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[131] Relict gallery forests refer to forests which retain species and characteristics from a period before external degradation or change.

threatened species that has experienced a declining habitat range in the Great Lakes Region, with the forests along the Muvumba being one of its last remaining strongholds; ii) it can tolerate frequent flooding; and iii) it provides habitat for many bird, amphibian and mammal species.

Figure 28. Gallery forest patches along the Muvumba River. Photos taken by Theogene Habakubao during his site visit, September 2020.

The Muvumba Catchment Management Plan (2018–2024)[132] includes suggested interventions for restoration of the catchment, mainly involving the intensification and diversification of agroforestry techniques such as: i) extending the diversity and intensity of agroforestry trees already used to stabilise the slopes of terraces and improve soil fertility; ii) promotion of perennials and tree-crops (including tea, shade coffee, and fruit trees); iii) intercropping; and iv) planting of in-field trees, shelter-belts or live-fences. Plant species are to be selected in relation to the local conditions in coordination with farmers to adapt to their needs. The local tree species suggested for agroforestry and restoration in the Muvumba Catchment Management Plan include conifers (*Podocarpus*), the parasol tree (*Polyscias fulva*), *Entandrophragma,* Kenya croton (*Croton megalocarpus*), Nile tulip (*Markhamia lutea*), bitter leaf (*Vernonia amygdalina*), *Mitragyna*, and *Syzygium*. Exotic commercial species that are suggested for the purpose of generating additional revenue include alder (*Alnus acuminate*), Arabic gum (*Vachellia nilotica*), Australian blackwood (*Acacia melanoxylon*), as well as bamboo species.

Baseline drivers and extent of ecosystem degradation

The Muvumba catchment experiences two primary types of ecosystem degradation: deforestation and pollution of water sources. Deforestation has occurred largely as a result of a dependency of 82% of households in the catchment on wood for energy/fuel, particularly for cooking[133], but has also resulted from encroachment of settlements and agricultural lands. Deforestation has in turn led to soil erosion and the sedimentation/siltation of the Muvumba River. This siltation occurs because the catchment is characterised by fragmented, small farms on mountainous terrain as well as abundant rainfall, which result in high levels of runoff over exposed slopes. The Muvumba catchment lost 767,857 tonnes of soil in 2015, compared to 430,996 tons in 1990 — a ~78% increase in soil loss[134]. The loss of fertile soils in turn leads to reduced soil fertility and poor agricultural productivity in higher parts of the watershed. In addition to agriculture, overgrazing and collection of fuelwood have

[132] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[133] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[134] World Bank. 2019. Rwanda Natural Capital Accounts — Ecosystems.

contributed to high rates of deforestation particularly in the upland watersheds (Figure 29). Another negative impact of high rainfall runoff and soil erosion is the formation of gullies along the Muvumba River's banks (Figure 30).

Figure 29. Tree cutting for fuelwood and clearing of land for agriculture along the banks of the Muvumba River. Source: Theogene Habakubaho, September 2020.

Figure 30. Gullies along the sloped banks of the Muvumba River as a result of intense rainfall runoff and soil erosion and low vegetation cover. Source: Theogene Habakubaho, September 2020.

While soil erosion resulting from deforestation in the catchment has reduced the water quality of the Muvumba River, other factors also contribute to its poor quality. The emerging urban centres, including Byumba, Gatuna, Yaramba, Miyove, Rukomo and Nyagatare, lack solid waste, storm water and sewerage facilities and most waste flows into rudimentary drainage systems that pollute main watercourses. Other sources of water pollution are attributed to industries, Gicumbi informal settlements and mining activities — with particularly limited environmental regulation in the mining sector. Pollution arising from the application of fertilisers and pesticides from irrigation schemes is also a major cause of poor water quality in downstream river sections. In addition, agricultural irrigation is the largest user of water from the Muvumba River, accounting for 6% of total water use[135]. While current water levels are adequate to support water demand within the catchment, current water use is unregulated and inefficient, and given a business-as-usual scenario with increased population numbers and economic growth, demand will exceed water availability by ~50 million cubic meters per year (MCM/yr) by 2024 and ~100MCM/yr by 2050[136].

Additional drivers of ecosystem degradation/pressures on ecosystems in the catchment include population pressure and widespread poverty. The population of Muvumba catchment is ~600,000 people, mainly living in the emerging urban areas of Gatsibo, Byumba and Nyagatare. In these areas,

[135] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[136] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

population densities are as high as 500 inhabitants/km^2. As a result of population pressure, cultivation of food crops has been extended from upland areas down into valley wetlands. Large drainage channels have been constructed to drain excess water from these areas to reclaim them for cultivation, with ~71% of wetlands having been converted into several types of agricultural lands. These irrigated systems are however often poorly developed and characterised by inefficient water use. Rapid population growth has also led to the encroachment of agriculture into forest ecosystems, leading to further deforestation. Along with declining soil fertility and recurring droughts in a largely agrarian-based economy, the population growth has led to high poverty rates in the catchment, with ~60% of the Nyagatare District's inhabitants classified as "poor".

Urbanisation and rapid population growth have also resulted in the concentration of rainwater in built-up areas, leading to soil erosion and the formation of gullies. The movement of communities into the wetlands and riverbank ecosystems in the Muvumba catchment has caused overgrazing and trampling of riparian vegetation by livestock, as well as further deterioration of the river water quality (specifically with regards to increased concentrations of E. coli[137]) as cattle stand in and drink the water.

Currently, a substantial proportion of the catchment is not sufficiently managed or protected against soil erosion. Current farming methods, such as frequent intensive tillage of soil, combined with an absence of anti-erosion measures, such as terraces, swales, contour markers and trenches, lead to high levels of soil erosion and loss of soil fertility. Rapid runoff on such soils leads to gully formation and, in extreme cases, landslides. Poor mining practices in active mine sites, both formally licensed and informally unlicensed mines, lead to the runoff of large quantities of sediment into rivers and watercourses. Even when no longer active, and despite regulations requiring post-closure rehabilitation, many abandoned mines continue to contribute large amounts of sediment to the downstream environment.

The influx of large quantities of sediment to rivers leads to high turbidity levels, often rendering water physically unsuitable for irrigation, water supply or hydropower generation without prior treatment. In addition — although data on chemical and biological water quality are scarce or absent — it is highly likely that there are also potentially high levels of contaminants, such as heavy metals, resulting from mining, and eutrophication, resulting from ingress of fertiliser from agriculture.

Topography

Similar to the Nyagatare savannas, the Muyumba River site is located in the eastern lowlands. Steep slopes within the project area are moderately covered in vegetation, while the valley bottoms and adjacent hillsides — especially along the right bank of the Muvumba River — are moderately cultivated with crops such as banana, maize and beans. The river does not have a well-defined course and as a result a large area of the valley in the river's vicinity becomes inundated during heavy rainfall periods.

The western part of the Muvumba River catchment, which drains into Uganda through the Mulindi River, is characterised by alternating schist and quartzite layers with moderate groundwater holding potential (Figure 31)[138]. In the eastern portion of the catchment, granite is the dominant basement aquifer. The most extensive soil types within the low-lying, northeastern section of the catchment are Ferralsols. In the southwestern uplands on steep slopes are Cambisols and Alisols, which are moderately deep and more fertile than Ferralsols since they possess a higher Cation Exchange Capacity (CEC). Given their location on steep slopes they are particularly susceptible to erosion.

[137] Escherichia coli (E. coli) is a bacteria commonly found in water or food contaminated with fecal matter that can cause potentially severe stomach cramping, bloody diarrhea and vomiting.
[138] Ministry of Agriculture and Animal Resources. 2009. Land husbandry, water harvesting and hillside irrigation (LWH) project.

Furthermore, along the river valley bottoms and associated with swamps, are the clay soils characterised by moderate fertility and low infiltration capacity.

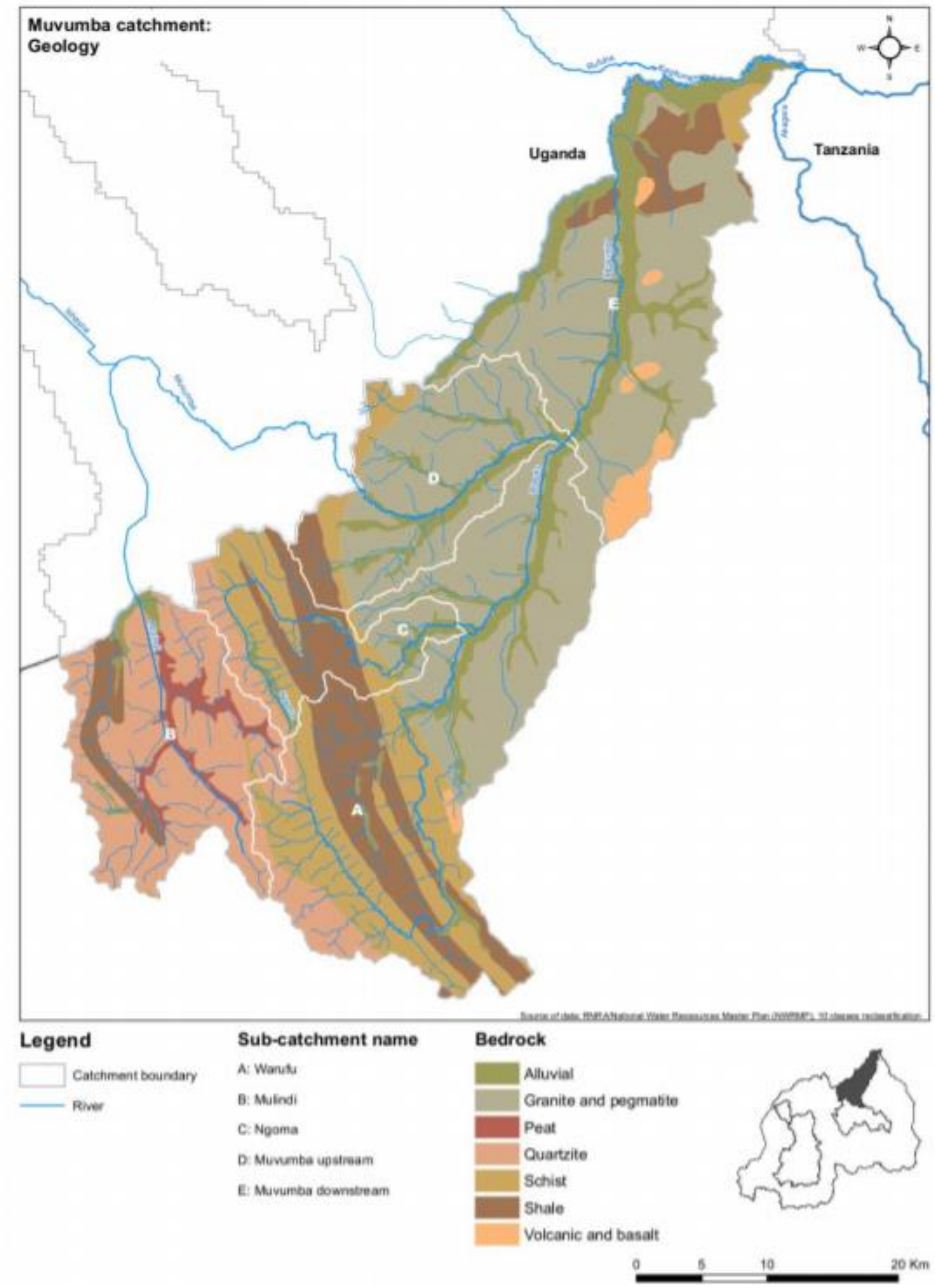


Figure 31. Geology of Muvumba catchment[139].

Hydrological profile

The Muvumba River's total catchment area is 3,714 km^2 (Figure 32**Error! Reference source not found.**), of which 1,568 km^2 is located within Rwandan borders and another 2146 km^2 in Uganda. Within Rwanda, the length of the Muvumba River is approximately 56 km[140]. The source of the Muvumba catchment is the Mulindi River located in the mountainous Buberuka highlands which have

[139] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[140] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

an altitude of ~2,500 masl. Other larger rivers that contribute to the Muvumba River are the Ngoma, Kizinga and Warufu Rivers[141]. The Eastern Lowlands has gentle slopes and includes numerous lakes and wide areas covered by marshes extending along the Akagera River, into which the Muvumba River discharges[142].

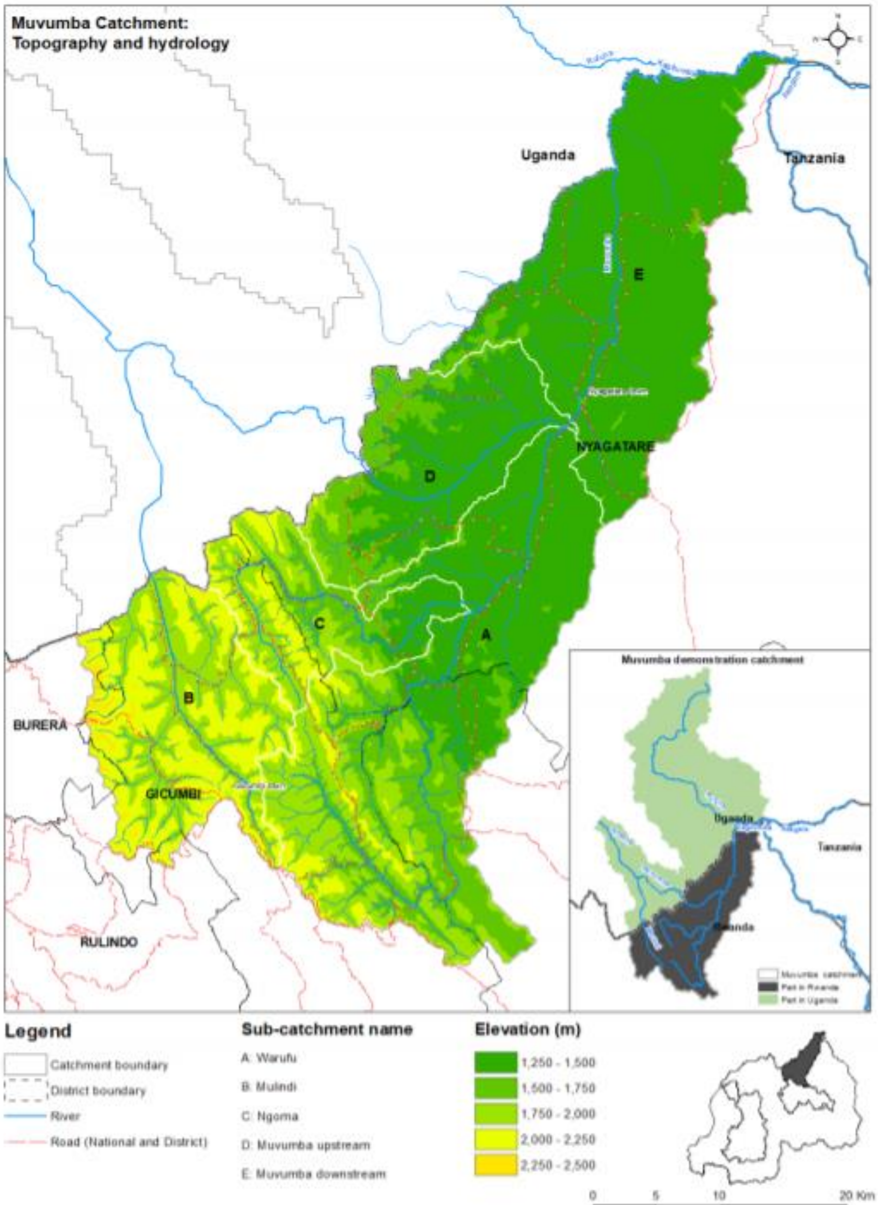


Figure 32. Transboundary Muvumba catchment elevation, waterbodies and waterways[143].

Long-term river flow observations are available for the confluence of the Muvumba River with the Akagera River at Kagitumba, the location where Rwanda, Uganda, and Tanzania meet. The seasonal distribution of discharge intensity is depicted in **Error! Reference source not found.**, indicating an annual average flow of about 14 m^3/s (Figure 33)[144].

[141] Dusabe MC, Wronski T, Gomes-Silva G, Plah M, Albrecht C & Apio A. 2019. Biological water quality assessment in the degraded Mutara rangelands, northeastern Rwanda. Environmental Monitoring and Assessments, 191: 139.
[142] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[143] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[144] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

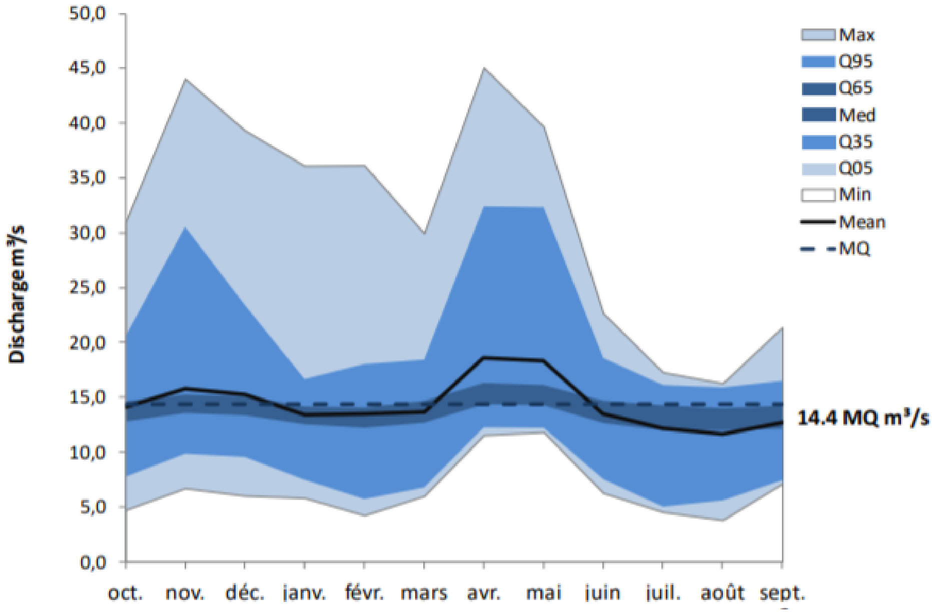


Figure 33. Muvumba River flow regime curves (m³/s) at Kagitumba[145]. Q95 is the average monthly flow exceeding 95% of monthly flow events in m³/s; similarly, Q65 is the flow exceeding 65% of events.

Catchment-wide green and blue water balances[146] reveal that ~65% of all precipitation is used by vegetation (rainfed agriculture, forests, and nature), or lost to evaporation (Table 12**Error! Reference source not found.**). Only 2% of all precipitation is eventually abstracted for domestic, industrial, irrigation or livestock use. Outflows from the catchment and groundwater recharge are other important components of the Muvumba River's water budget, accounting for 28% and 12% of the catchment's outputs respectively[147]. Of these last catchment outputs, groundwater recharge indirectly contributes to water security through the long-term storage of water in aquifers that can potentially be accessed with boreholes.

Table 12. Green and blue water balances for the Muvumba River catchment[148].

Inputs	MCM/yr	Outputs	MCM/yr
Green water			
Precipitation	1,543	Evapotranspiration	995
Return flows	10	Withdrawals for human use	32
Storage change	0.7	Outflow	469
Inflow	148	Groundwater recharge	206
Total	1,702	Total	1,702
Blue water			
Runoff	39	Domestic	2
Baseflow	303	Industry	0.2
Groundwater	0	Irrigation	29
Return flows	10	Livestock	0.7
Inflow	148	Outflow	469
Total	501	Total	501

Land uses

[145] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[146] 'Blue' water is the manageable water in surface water bodies and groundwater. The 'Green' water balance incorporates 'blue' water, but also all precipitation that never reaches surface water bodies or accessible groundwater bodies and instead is lost from the catchment through evapotranspiration or via recharge of inaccessible, deep groundwater layers.
[147] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[148] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

Irrigated and agricultural wetlands (mainly for rice production) occupy considerable areas alongside the Muvumba River, particularly in the central and north eastern parts. The southern part of the catchment area is dominated by fields and numerous forest plantations. In the Nyagatare District, numerous villages are also located along the Muvumba River's banks. Many communities also use the river as a source of water for their livestock. Figure 34 below illustrates the proximity of agriculture to the Muvumba River.

Figure 34. Agricultural land use around in within the Muvumba River. Many communities use the river as a source of drinking water for their livestock (A). Crop farms extend right up to the border of the river in much of the river's stretch (B and C), while in some patches relict gallery forest remains along the river's edge (C). Source: Theogene Habakubaho.

Almost all economic growth in the catchment is linked to water use, whether agricultural, livestock, industrial, or related to providing drinking water to urban and rural areas. The transboundary nature of the catchment necessitates careful planning and close collaboration with Uganda, where a management plan is already in place for the Muvumba catchment through the Ugandan Ministry of Water and Environment[149].Uganda's catchment management plan aims to provide a long-term strategy for the sustainable development and utilisation of water and related resources in Muyumba and other major water catchments in the country by adopting an integrated water resources management paradigm. Currently there is informal cooperation between Rwanda and Uganda with regards to catchment management within the Muvumba catchment, with limited formal cooperation. However, the Muvumba Catchment Management Plan highlights potential projects within the 2018–2024 period aimed at facilitating catchment dialogue between the Gicumbi and Nyagatare districts of Rwanda and the Kabale and Ntungamo districts in Uganda[150]. Although formal coordination with Ugandan officials will most likely not be necessary with regards to the NAP EbA project interventions, the Uganda catchment management plan has the potential to provide multiple best practices and will complement the project's interventions by continuing river management along larger sections of the Muvumba River's length.

The total forested area covers 10% of the Muvumba catchment area (Figure 35 and Table 13 below), which is below the national average and below the national target of 30%. Of this, about 20% is considered sparse forest, showing signs of tree felling or other forms of degradation. Approximately 90% of land use in the Muvumba catchment is related to agriculture (both seasonal and perennial crop farming, and livestock grazing represented by "bare soils" in Table 13 below). Other economic activities in the catchment include artisanal mining of tungsten, cassiterite and coltan, as well as quarrying[151]. The predominance of agricultural land use, along with bare soils resulting from mining and quarrying, reflects the large impact of dense rural populations on the land, and, combined with high soil erosion risks associated with steep slopes, strongly contributes to sediment ingress into rivers such as the Muvumba.

[149] Ministry of Water and Environment. 2019. Catchment Management Plans. Available at: https://mwe.go.ug/library/catchment-management-plans-0.
[150] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[151] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

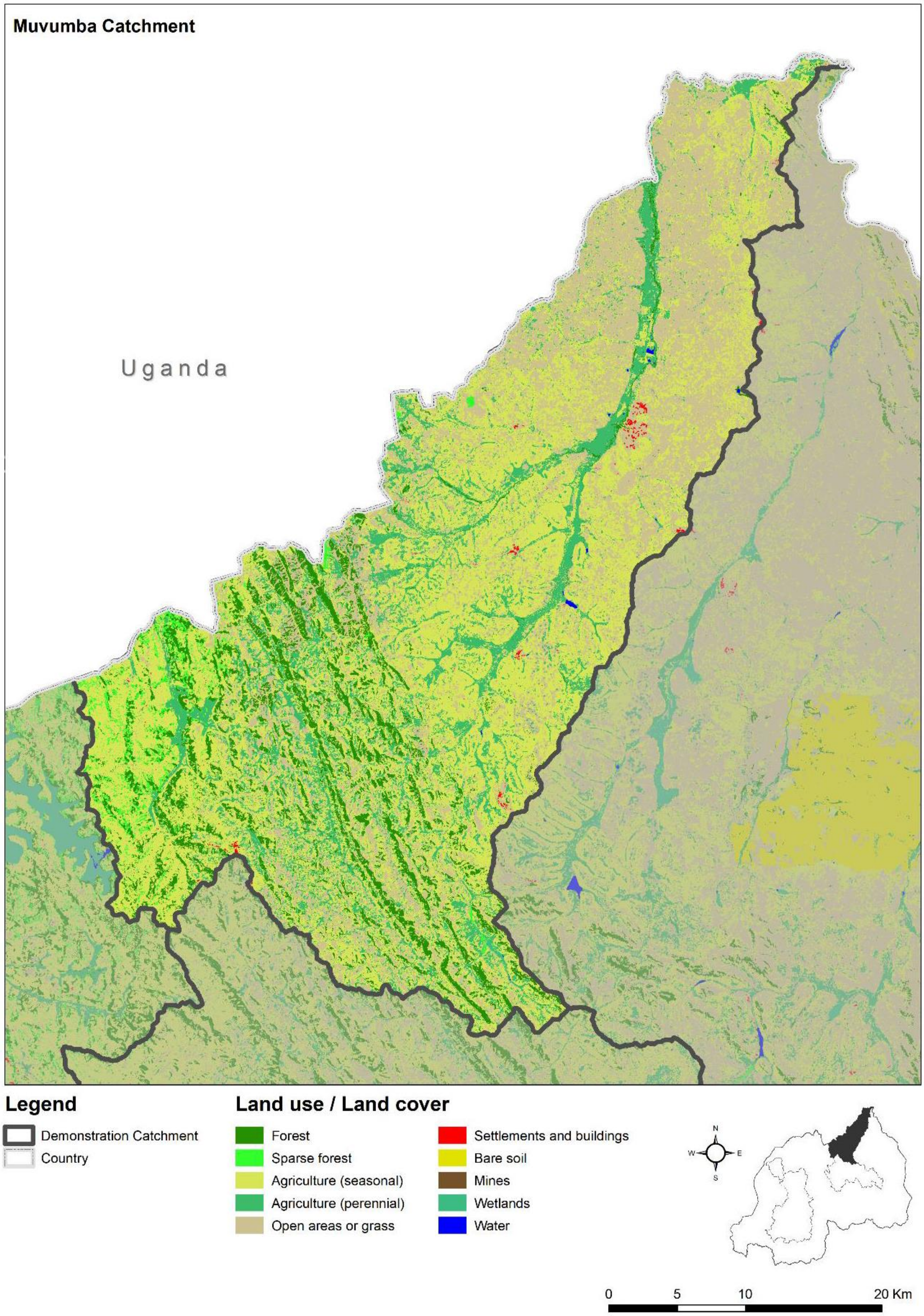


Figure 35. Land use/cover in the Muvumba River catchment[152].

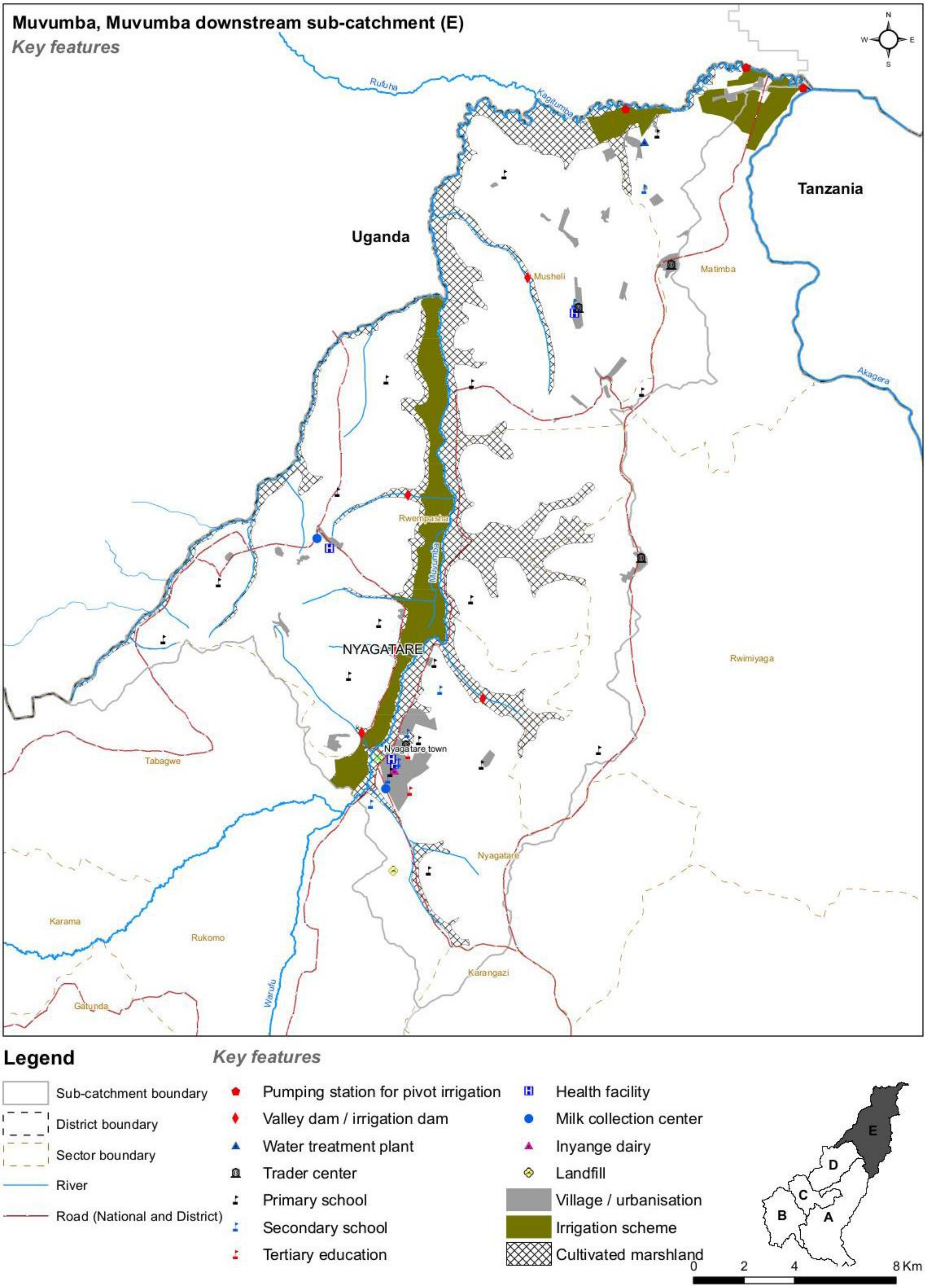
152 From: Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

Table 13. Land use/ land cover classification for the Muvumba catchment[153].

Class	Area (ha)	Percentage (%)
Agriculture (seasonal)	75,286	48
Open areas or grass	44,147	28
Agriculture (perennial)	22,235	14
Forest	12,233	8
Sparse forest	2,475	2
Bare soil	3	0
Settlements and buildings	261	0
Water	75	0
Wetlands	63	0
TOTAL	**156,779**	**100**

Figure 36 below, from the Muvumba Catchment Management Plan, provides further detail on the primary land uses as well as key infrastructure in the downstream section of the Muvumba River where the buffer zone intervention of the NAP project (described in the 'Detailed description of interventions' section for this site) will be implemented.

[153] From: Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).



Muvumba, Muvumba downstream sub-catchment (E)
Key features
N
W
E
S
Rufuha
Kagitumba
Uganda
Tanzania
Musheli
Matimba
Akagera
Rwempasha
Muvumba
NYAGATARE
Rwimiyaga
Nyagatare town
Tabagwe
Nyagatare
Karama
Rukomo
Karangazi
Gatunda
Warufu
Legend
Sub-catchment boundary
District boundary
Sector boundary
River
Road (National and District)
Key features
Pumping station for pivot irrigation
Valley dam / irrigation dam
Water treatment plant
Trader center
Primary school
Secondary school
Tertiary education
Health facility
Milk collection center
Inyange dairy
Landfill
Village / urbanisation
Irrigation scheme
Cultivated marshland
A
B
C
D
E
0
2
4
8 Km

Figure 36. Key geographic features of the downstream section of the Muvumba Catchment. Source: Muvumba Catchment Management Plan (2018–2024).

Local communities

As mentioned above, in the Nyagatare District, numerous villages are located alongside the Muvumba River. Apart from the Akagera and Umuyanja Rivers bordering the district in the east and north respectively, the Muvumba is the only river in the Eastern Province that can be accessed by the population of Nyagatare. The Muvumba catchment, like many areas in Rwanda, is very densely populated. In the emerging urban areas of Gatsibo, Byumba and Nyagatare, population densities are as high as 500 inhabitants/km^2.

Demographics

With a total population of ~466,000 people, the Nyagatare District is the second most populous district in Rwanda[154]. Despite this relatively high population number compared with other districts, the average population density in the area is ~241 people/km^2, which is lower than the average of the Eastern Province (274 people/km^2) and the national average of 415 people/km^2.[155] In addition, annual population growth in Nyagatare District is ~6.2%, which is higher than the national average of 2.6%[156].

The 2012 national population and housing census indicated that 600,000 people live in Muvumba catchment[157], with 7.7% in urban areas, and 92.3% in rural areas. Approximately 52% of the population is female and 54% (both men and women) are younger than 20. The highest population densities (536–767 persons/km^2) in the central area of the catchment were in Rukomo, Katabagemu and Mimuli, in Gatsibo in the southeast area, and in Nyankenke, Byumba, Manyagiro, Cyumba, Bungwe, Rubaya in the southwest, with Kageyo at the highest density (768–998 persons/km^2).

Poverty levels

Poverty rates within the Muvumba catchment area are very high, with approximately 20% of the Muvumba catchment population living below the poverty line (see Table 14 below). Levels of poverty in Household Living Surveys (EICV4, 2014) are defined on the basis of food consumption figures. The ‘poor’ poverty classification is related to a consumption level of a basket of food and non-food items defined as 159,375 RWF per capita per year. The ‘extremely poor’ poverty level classification is defined on the basis of consumption related to the cost of the basket of food items costed at 105,064 RWF per capita per year. The cause of poverty in the region has been linked to high population growth and declining crop yields attributable to poor soil fertility in a largely agrarian-based economy dependent on crop production and livestock rearing[158].

[154] Ministry of Environment. 2017. Rwanda Water and Forestry Authority Muvumba Multipurpose Dam Development Project. Available at: https://esa.afdb.org/sites/default/files/RWANDA-MUVUMBA%20MULTIPURPOSE%20WATER%20RESOURCES%20DEVELOPMENT%20PROGRAM%20PHASE1-ESIA-P-RW-EA0-015.pdf

[155] GoR. 2014. Kagera River Basin Management Project: Muvumba Irrigation and Watershed Development Project (Nyagatare District, Kagera Basin).

[156] MINAGRI. 2016. Environmental and Social Impact Assessment & Environmental and Social Management Plan For Indicative Feeder Roads. Available at: http://documents1.worldbank.org/curated/en/182831489645025406/pdf/SFG3153-V1-EA-P158092-Box402895B-PUBLIC-Disclosed-3-13-2016.pdf

[157] This number includes people living in the Ugandan sections of the catchment, hence the fact that the number is higher than the total mentioned for Nyagatare district (mentioned above)

[158] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

Table 14. Population % identified as poor and extremely poor for the Muvumba catchment (EICV4) **[159]**. The percentage of the poor population comprises the percentage of the extreme poor population.

District	% poor (district population)	% extremely poor (district population)
Nyagatare	44	20
Gicumbi	55	25
Gatsibo	44	19

Although education statistics for the entire Muvumba catchment are not available, education levels of the Nyagatare District population are as follows:

- no education: ~73%;
- primary: ~18%;
- post-primary: ~1.7%;
- lower secondary: ~3.8%;
- upper secondary: ~2.7%; and
- university: ~1.0%[160].

Livelihoods

The principal economic activity in the Muvumba catchment is agriculture, and specifically crop production and livestock rearing[161]. See ‘Land uses’ and ‘Baseline drivers and extent of ecosystem degradation’ sections above for additional detail on livelihood activities in the catchment.

Land tenure arrangements

Within the densely populated Muvumba catchment, ~29% of Nyagatare’s households own agricultural land with a size of less than 0.3 ha per household. This shortage of land constitutes a big challenge to the agriculture and agro-production development in the Nyagatare District.

Land distribution in the Nyagatare District is managed by the district authorities and other government institutions to protect the Muvumba River — mainly through environmental impact assessments — for a rice production project and licensed mines. This has contributed to limiting encroachment threats, which increases the potential for the trends in the reduction of natural vegetation to decline in the future. However, despite these efforts to conserve natural vegetation, increasing population growth will continue to put pressure on ecosystems in the Muvumba catchment.

Access to resources

At present, ~20% of the population in Nyagatare District in northeastern Rwanda has no access to clean drinking water and sanitation. In addition, a biological water quality assessment conducted in 2018 found the overall quality of water in the Muvumba River to be poor[162] (Figure 37), which means communities in the region are consuming and utilising contaminated water. According to Rwanda’s Water and Sanitation Corporation’s (WASAC) figures at district level, access to safe water is low at 49% and 53% among the populations of the Gatsibo and Nyagatare Districts, respectively[163]. Accordingly, about half the population uses dirty water from streams, dams, valleys or swamps and does not have access to safe and reliable supplies of water for productive and domestic uses. Regarding sanitation facilities, pit latrines are the most common form and are used by ~89% of the Muvumba catchment population, while ~65% of the population uses compost dumping for other waste

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[159] GoR. EICV4 2013/2014.
[160] Government of Rwanda. 2017. Economic Activity Report. EICV5: The Fifth Integrated Household Living Conditions Survey 2016/2017. https://www.statistics.gov.rw/publication/eicv5thematic-reporteconomic-activity-thematic-reportpdf.
[161] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[162] Dusabe MC, Wronski T, Gomes-Silva G, Plath M, Albrecht C & Apio A. 2019. Biological water quality assessment in the degraded Mutara rangelands, northeastern Rwanda. *Environmental Monitoring and Assessment*. 191: 139.
[163] 2012

disposal. There are no sewerage systems in the large towns of Byumba and Nyagatare in the catchment.

Figure 37. Poor water quality and high sedimentation of the Muvumba River. Source: Kevin Emslie, 14 February 2018 (left and centre photos) and Theogene Habakubaho, September 2020 (right photo).

WASAC, under the Lake Victoria Water Supply and Sanitation (LVWATSAN II) project[164], has set up raw water intake stations on the banks of the Muvumba River to supply local communities with clean water (Figure 38). Water is then pumped from the intake stations to water treatment plants (operated by WASAC; Figure 38) and treated for use by local communities. During the rainy seasons (both short and long), however, siltation of the river related to erosion of exposed riparian areas and riverbanks decreases water intake of the stations through the clogging of pumps and the reduced intake capacity during the necessary cleaning. This negatively affects the supply to surrounding communities and increases maintenance costs of the water treatment plants. Productivity at these plants is also reduced when water turbidity (associated with siltation) increases during the rainy seasons. As water becomes more turbid, its treatment costs (the cost of chemicals in particular) increases[165], with production halting if turbidity rises above the upper limit of 10,000 NTU (Nephelometric Turbidity Units).

Figure 38. Raw water intake station (left) and water treatment plant (right), established by WASAC, along the banks of the Muvumba River in Nyagatare District. Source: Kevin Emslie, 14 February 2018.

[164] https://www.lvbcom.org/node/49.
[165] A 1% increase in turbidity increases water treatment cost by ~0.2%. Warziniack, T., Sham, C.H., Morgan, R. and Feferholtz, Y., 2017. Effect of forest cover on water treatment costs. *Water Economics and Policy*, *3*(04), p.1750006.

The water resources of the Muvumba River are insufficient to cater for all demand during the dry season. This, along with the fact that the lower Muvumba is a transboundary river, increases the likelihood of cross-border disputes developing in the future. Establishing contact for local cooperation with Uganda is necessary for the management of the shared waters, particularly over the lower reach of the Muvumba.

In terms of power supply, the Muvumba River region remains significantly below the national average, with access per household under 12.4% compared with 20% nationally. This leads to an over-dependence on forest resources for energy, with 82% of households using firewood to cook meals. The use of alternative energy sources, such as biogas and improved cooking stoves, remains limited.

According to WASAC figures at district level, access to safe water is low at between 40% and 50% on average in Rwanda, with 49.2% in Gatsibo and 52.8% in Nyagatare. This means that about half the population uses unsanitary water from streams, dams, valleys or swamps and therefore do not have access to safe and reliable supplies of water for productive and domestic uses.

Reliance on ecosystem services of local communities

As mentioned under the "Access to resources" section above, water security of communities along the Muvumba River is directly dependent on the quality of river water entering WASAC's water treatment plant. Riparian vegetation also allows for the filtering of water by reducing the speed of the river's flow, resulting in the accumulation of sediment that enters the river rather than its continued suspension in the water column, which improves the water quality. Riparian vegetation also aids in flood mitigation during extreme rainfall events.

Plant species found in the marshlands around the Muvumba River have numerous uses to local communities, including: improvement of soil fertility, soil stabilisation, construction and carpentry, fuel wood and charcoal, crafts, support hives, forage, mulch for farming, live fences for edges of properties, shade for livestock and coffee plantations, and mats and basket-weaving (using reed species)[166].

Community organisations and structures

The Nyagatare District is divided into 14 sectors comprising 106 cells and 630 villages. Many of these villages were established under the '*Imidugud'u* programme, a government settlement policy that were implemented after the 1994 Genocide and which saw the regrouping of rural populations into villages.

Infrastructure and services available at the site

The World Bank's ongoing "Muvumba Multipurpose Dam Development Project (2020–2027)[167] will result in the construction of an artificial dam along the Muvumba River in the Karama and Gatunda Sectors of the Nyagatare District. The dam will have a maximum height of 40 m and a storage capacity of 191 million m^3. The project's goals are to: i) improve water security for communities in the Nyagatare District that are prone to drought; ii) provide flood and water flow regulation; iii) provide alternative livelihood opportunities for local communities, including aquaculture and tourism; and iv)

[166] Ministry of Environment. 2017. Rwanda Water and Forestry Authority Muvumba Multipurpose Dam Development Project. Available at: https://esa.afdb.org/sites/default/files/RWANDA-MUVUMBA%20MULTIPURPOSE%20WATER%20RESOURCES%20DEVELOPMENT%20PROGRAM%20PHASE1-ESIA-P-RW-EA0-015.pdf

[167] Ministry of Environment. 2017. Rwanda Water and Forestry Authority Muvumba Multipurpose Dam Development Project. Available at: https://esa.afdb.org/sites/default/files/RWANDA-MUVUMBA%20MULTIPURPOSE%20WATER%20RESOURCES%20DEVELOPMENT%20PROGRAM%20PHASE1-ESIA-P-RW-EA0-015.pdf

provide a supply of hydropower. See the “Access to resources” section above for further details regarding the existing water treatment plant along the river.

Climate change problems that the EbA interventions will address

The intensity and frequency of heavy rainfall events (particularly in upstream catchment areas) is expected to increase under future climate change scenarios. Between 2020–2059 and under RCP8.5, rainfall is expected to increase by 17 mm during the first, short wet season (May–March) and 30 mm in the longer, second wet season (September–December) compared with historic values (1986–2005) (Figure 39)[168]. By 2080–2099, rainfall increases by 36 mm in the shorter wet season and 131 mm in the longer wet season by 2080–2099 (Figure 40). The amount of rainfall during very wet days[169] will increase by 4% between 2040–2059 and by 33% between 2080–2099 compared with historic values[170] (Figure 41).

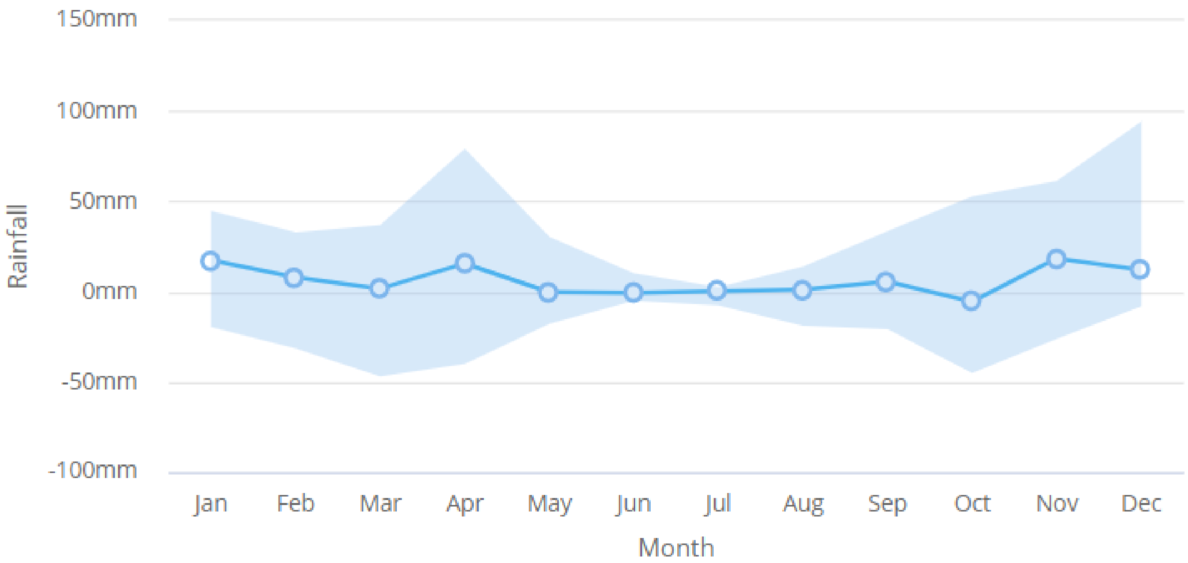


Figure 39. Projected change in monthly precipitation (mm) for the Nyagatare pilot sites from 2040–2059 under a RCP8.5 scenario compared with historic values from 1986–2005, showing the median and range values for an ensemble of global circulation models[171] (GCMs)[172].

[168] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

[169] Very wet days are days that have the fall within the top 5% of wet day precipitation amounts.

[170] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

[171] IPCC. 2014. Fifth Assessment Report.

[172] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

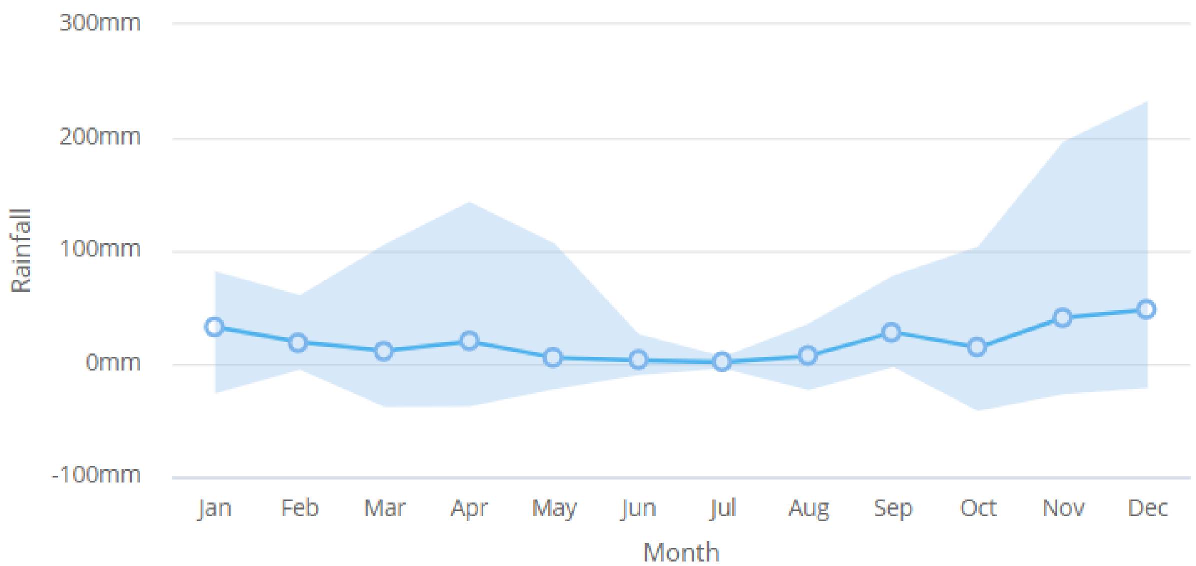


Figure 40. Projected change in monthly precipitation (mm) for the Nyagatare pilot sites from 2080–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, showing the median and range values for an ensemble of global circulation models[173] (GCMs)[174].

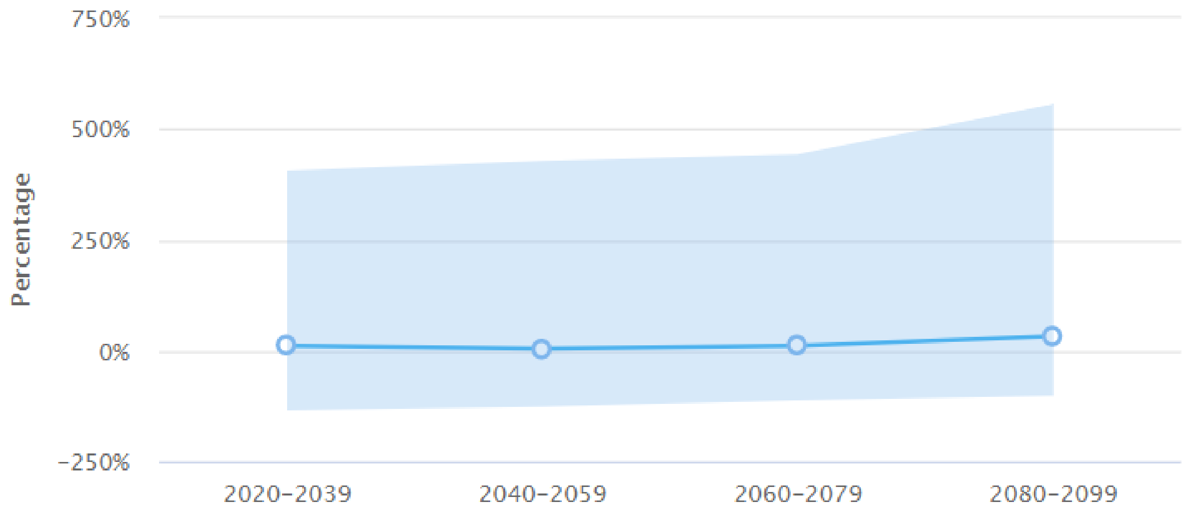


Figure 41. Projected change in rainfall of very wet days (%) for the Nyagatare pilot sites from 2020–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, showing the median and range values for an ensemble of global circulation models[175] (GCMs)[176].

The predicted increase in rainfall and the frequency of heavy rainfall events resulting from climate change will exacerbate current levels of erosion and siltation in the Muvumba River. This will subsequently negatively impact the capacity of raw water intake stations and treatment plants to supply water to surrounding communities efficiently. Without the implementation of climate change adaptation activities, the current and future supply of water to communities for domestic use and irrigation will be compromised.

<u>Detailed description of interventions</u>

[173] IPCC. 2014. Fifth Assessment Report.
[174] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#
[175] IPCC. 2014. Fifth Assessment Report.
[176] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

The interventions initially proposed during the project's design for the Muvumba River site are provided below.

- The demarcation of a buffer zone, which will prevent agricultural and settlement encroachment. Within the buffer zone, riparian vegetation will be restored using species with strong soil binding properties such as bamboo. This will decrease the exposure and consequent erosion of riparian and riverbank areas, reducing siltation.
- Reforestation of catchment areas upstream of water intake and treatment plants, as well as irrigation projects (planned by the Ministry of Agriculture and Animal Resources (MINAGRI)) with drought-resistant tree species to reduce runoff and erosion, ultimately reducing the effects of flooding and siltation further downstream.

These interventions were discussed with different stakeholders including district officials, local communities and experts from national institutes dealing with water management, agriculture, environment and natural forests, such as the Rwanda Water Resource Board, Rwanda Agriculture Board and the Ministry of Agriculture. The major outcomes of the discussions and field observations are summarised below.

Stakeholders were supportive of establishing a buffer zone along the river, though they expressed hesitation regarding the planting of bamboo. They mentioned that riparian restoration should consider the other land uses along the river, such as rice cultivation. They proposed including the planting of agroforestry trees within the buffer zone, including fruit trees and sugar cane. Regarding the intervention to reforest the Muvumba catchment upstream of water intake and treatment plants, stakeholders were fully supportive. They mentioned that it should be aligned with existing initiatives and suggested implementing the intervention between the Muvumba Multipurpose Dam and the water treatment plant.

Two additional EbA activities were suggested by local community representatives during the consultation process: i) in addition to reforestation of the catchment, establish other soil erosion control structures such as ditches with grasses; and ii) extend the buffer zone beyond 10 metres in areas where gallery forests remain, such as in the Karama, Gatunda, Tabagwe, Nyagatare, Rwempasha, Musheri and Matimba Sectors, so that these forests can be protected from degradation. These interventions were also assessed in the MCA for the Muvumba River site.

Results of multi-criteria analysis (MCA)

Table 15 below summarises the results of the multi-criteria analysis of EbA interventions for Muvumba River. The list of interventions includes those proposed in the ProDoc and during stakeholder consultations. For more detail, please refer to the scorecard in Annex 2.

Table 15. Results of the MCA for Muvumba River (score: 0 = unfeasible, 1 = perfect intervention).

Intervention assessed	Score
Reforestation of catchment areas upstream from water intake and treatment plants	0.75
Using ditches and grasses for soil erosion control in the catchment	0.74
Planting fodder and fruit trees adjacent to the river buffer zone	0.71
Demarcation and establishment of a buffer zone along river, using riparian vegetation restoration	0.66
Expansion of buffer zone to include remaining Gallery Forest outside of 10-m riparian zone in Karama, Gatunda, Tabagwe, Nyagatare, Rwempasha, Musheri and Matimba	0.64

The MCA results indicate that the riparian buffer zone is most feasible if it includes a combination of indigenous, soil-binding vegetation and more multi-purpose agroforestry trees, such as fruit and fodder trees. While the extension of this buffer zone to include gallery forests also scored reasonably well, it will need to be implemented on a case-by-case basis. Details about each gallery forest will need to be collected and assessed before a final decision can be made by project managers. The reforestation of the catchment area upstream of the water intake and treatment plants scored well in the MCA, as did the establishment of erosion control structures — these will therefore be implemented in conjunction with each other. Further details about the proposed EbA interventions are provided below.

Demarcation and establishment of a buffer zone

The demarcation of a buffer zone will assist in preventing the encroachment of agricultural land and settlements onto the riverbank. This EbA intervention will allow riparian areas and the river itself to maintain biological diversity and provide ecosystem services to local communities such as flood and erosion control, improved water quality and availability, food sources and NTFPs. This intervention will draw on guidelines and points of attention for buffer zone development and placement as provided in Table 2, Section 2.1.2. Riparian buffer zones are already being used within Rwanda, with bamboo often being the preferred crop for demarcating the buffer zone and providing protection from agricultural intrusion[177]. Bamboo is a cash crop that can be used for a number of applications, depending on the selected variety. Moreover, bamboo is listed along with fruit trees and elephant grass as part of agroforestry by the Muvumba Catchment Management Plan[178] as a suitable species for revegetation within buffer zones along the Muvumba River. In terms of watershed protection and riparian restoration, *Bambusa vulgaris, Arundinaria alpine,* and possibly *Yushania alpine*, have been identified as suitable bamboo species[179] — additional details on the use of bamboo in riparian buffer zones is presented in Annex 7. This intervention was positively received by stakeholders, but the proposed use of bamboo will need to take into consideration the current land use. For example, farmers appealed against having bamboo in the area where they are growing rice. In these areas, farmers are proposing to have other economically useful species like fodder plants, agroforestry trees, fruit trees and sugar cane that do not have negative impacts on river ecosystems. A few farmers have already started planting some fruit trees along the buffer zone. Indigenous species to this riparian vegetation type that also provide resources such as fruit, fodder, fuel wood and medicine, include wild date palm (*Phoenix reclinate*), water berry (*Syzygium cordatum*), swamp hibiscus (*Hibiscus diversifolius*) and Egyptian riverhemp (*Sesbania sesban*)[180].

Potential riparian buffer widths vary depending on the intended impact of the intervention. For example, an effective buffer width for bank stabilisation can be as narrow as 3 m, whereas a buffer zone with an objective of providing a habitat for wildlife may be as wide as 100 m[181]. For erosion control and stream stabilisation, vegetated riparian buffers with a width of 10–20 m are recommended (Table 16). The proposed approach is therefore to have a strong live fence at 10 m from the river as required by the country's environmental regulations to allow natural vegetation to regenerate. It is worth noting, however, that in different areas of the Muvumba River remaining sections of natural forest are under considerable pressure from local communities who are encroaching on the forest for agricultural lands or for firewood. These forest sections extend into the Karama, Gatunda, Tabagwe, Nyagatare, Rwempasha, Musheri and Matimba Sectors. In these cases, a variable buffer width approach — that considers site-specific factors such as wetland type, adjacent land use, vegetation, soils, wildlife habitats and slope — may be more appropriate[182]. During consultations with the district, the inclusion of the restoration and protection of these forest areas beyond the 10 m buffer zone along the Muvumba River was proposed. Given budgetary constraints, this will not be feasible under the

[177] Rwanda Water Portal. N.d. Buffer strips and gully erosion control. Available at: https://waterportal.rwb.rw/toolbox/468.
[178] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[179] IUCN. 2015. Rwanda's Green Wall: Opportunities to engage private sector investors in Rwanda's forest landscape restoration.
[180] World Agroforestry Centre. 2015. Useful tree species for astern Africa: Freshwater swamp. Available at: http://maps.vegetationmap4africa.org/docs/X.html.
[181] Hawes E & Smith M. 2005. Riparian buffer zones; Functions and recommended widths. Yale School of Forestry and Environmental Studies.
[182] MacFarlane D & Bredin I. 2017. Buffer zone guidelines for wetlands, rivers and estuaries Part 1: Technical guidelines. Water Research Commission, South Africa.

LDCF-funded NAP project, though the protection of these forests should be a priority for the Nyagatare District authorities and accordingly targeted under future projects. Their conservation will strengthen the overall climate resilience of the landscapes and ecosystems in the Muvumba catchment.

Table 16. Recommended widths for riparian buffer zones based on function[183].

Function	Description	Recommended width
Water quality protection	Buffers, especially dense grassy or herbaceous buffers on gradual slopes, intercept overland runoff, trap sediments, remove pollutants, and promote ground water recharge. For low to moderate slopes, most filtering occurs within the first 10 m, but greater widths are necessary for steeper slopes, buffers comprised of mainly shrubs and trees, where soils have low permeability, or where NPS loads are particularly high.	5–30 m
Stream stabilisation	Riparian vegetation moderates soil moisture conditions in stream banks, and roots provide tensile strength to the soil matrix, enhancing bank stability. Good erosion control may only require that the width of the bank be protected, unless there is active bank erosion, which will require a wider buffer. Excessive bank erosion may require additional bioengineering techniques.	10–20 m
Riparian habitat	Buffers, particularly diverse stands of shrubs and trees, provide food and shelter for a wide variety of riparian and aquatic wildlife.	30–500+ m
Flood attenuation	Riparian buffers promote floodplain storage by intercepting overland flow and increasing travel time, thereby resulting in reduced flood peaks.	20–150 m
Detrital input	Leaves, twigs and branches that fall from riparian forest canopies into the stream are an important source of nutrients and habitat.	3–10 m

The establishment of the 10 m riparian buffer zone will involve two distinct processes: i) patches where some natural riparian vegetation remains will be targeted for assisted natural regeneration, in which existing tree seedlings will be protected and preserved and where necessary new seedlings will be planted; and ii) patches that are fully degraded and where soils are bare will be targeted for the planting of bamboo species (Figure 42). Importantly, some paths will be left unvegetated to allow local farmers to access the river to water their livestock, as well as community members to collect water for commercial and personal use. The placement of these paths will be determined during implementation based on the use of the current locations' community members to access the river, and based on the ease of access. A review of the suitability of bamboo in the establishment of a riparian buffer zone on the banks of the Muvumba River is provided in Annex 7.

[183] Jontos R. 2004. Vegetative buffers for water quality protection: an introduction and guidance document. Connecticut Association of Wetland Scientists White Paper on Vegetative Buffers.

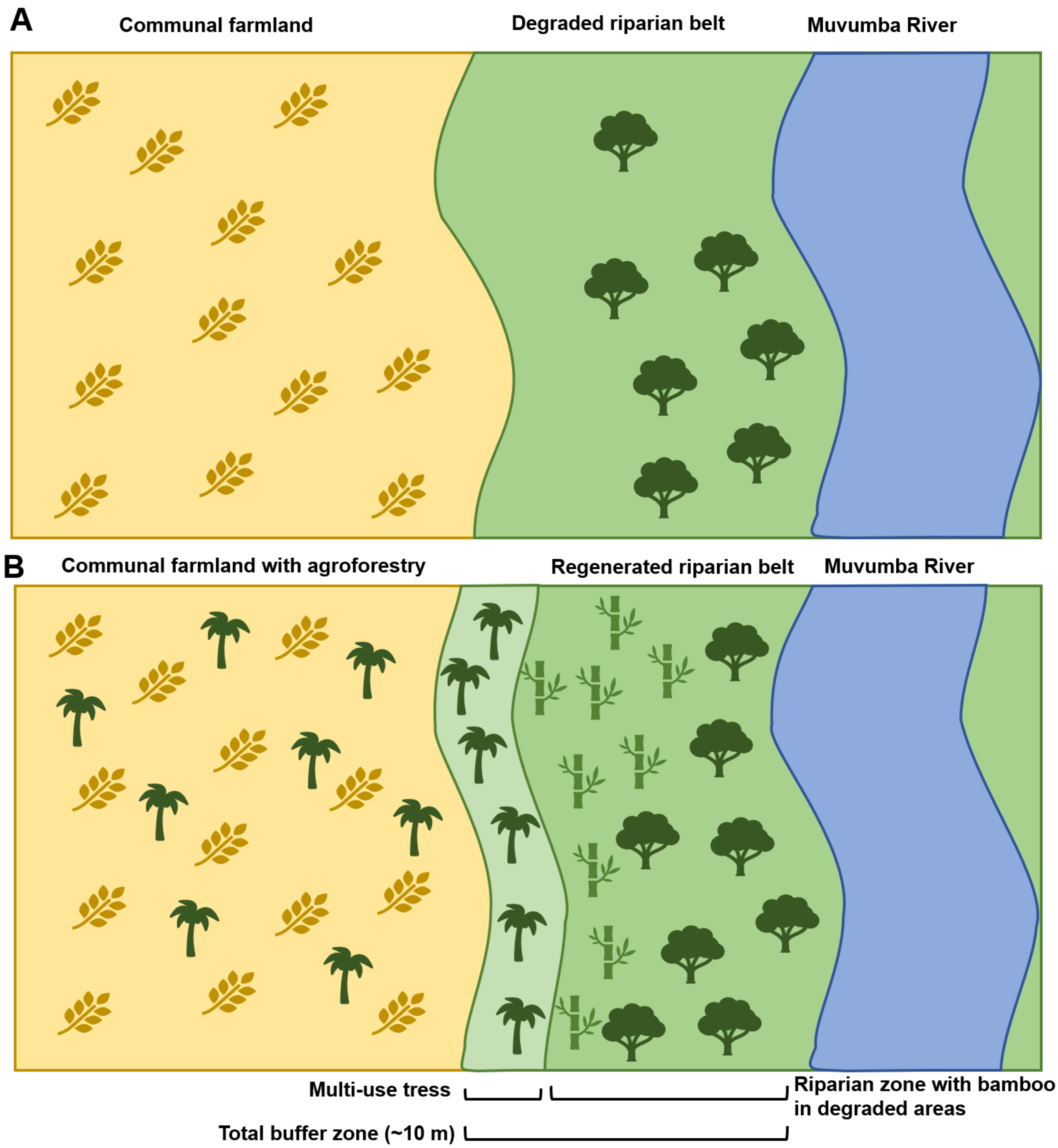


Figure 42. Schematics illustrating (A) the baseline scenario and (B) the placement of the buffer zone along the Muvumba River.

Assisted natural regeneration (ANR) is a simple, low-cost restoration method that can effectively convert degraded ecosystems to more productive systems[184]. The aim of the method is to accelerate, rather than replace, natural successional processes by removing or reducing barriers to natural forest regeneration such as soil degradation, competition with weedy species, and recurring disturbances (including livestock grazing, and wood harvesting). Compared to conventional reforestation methods involving planting of tree seedlings, ANR offers significant cost advantages because it reduces the costs associated with propagating, raising, and planting seedlings. For the buffer zone along the

[184] Shono K, Cadaweng EA & Durst PB. 2007. Application of assisted natural regeneration to restore degraded tropical forestlands. *Restoration Ecology 15*: 620–626.

Muvumba River, ANR can be implemented in conjunction with “enrichment planting”, which involves planting a low number of seedlings to increase the rate of vegetation regeneration and thereby reduce the time period for benefits to begin accumulating (Table 17 below).

Table 17. Comparison of forest restoration approaches and their benefits[185]. ANR with enrichment planting is the approach suggested for the downstream section of the Muvumba River.

Reforestation Approach	*Costs (Labor and Capital)*	*Biodiversity*	*Time for Forest Development*	*Research Input Required*
Commercial monoculture plantation	High[a]	Low	Fast	Low
Monoculture of commercial nurse trees	High[b]	Low to medium	Fast[c]	Low
ANR without enrichment planting	Low	Low to medium	Slow to medium	Low
ANR with enrichment planting	Low to medium	Medium	Medium	Low to medium
Framework species method	Medium to high	Medium	Medium	High
High-density planting of forest trees	High	High	Fast	High

[a] The high establishment and operational costs are generally recovered by profits.
[b] Some of the establishment cost may be recovered by harvesting of nurse trees.
[c] Nurse trees grow fast, but understory develops slowly.

Agroforestry in croplands adjacent to buffer zone

To address the baseline driver of deforestation along the downstream sections of the Muvumba River, agroforestry will be implemented in the agricultural areas bordering the 10 m riparian buffer zone. These trees will provide timber, fruit, fodder, medicine and other NTFPs to communities along the river, and will reduce the rate of ecosystem degradation of both the riparian vegetation and the remaining patches of gallery forest in the downstream sections of the Muvumba River. During consultations, community members expressed their preference for fruit and other multi-use trees for the buffer zone. This intervention will therefore address the communities’ livelihood needs while still maintaining the integrity and resilience of the riparian buffer zone by minimising human disturbance within the 10 m riverbank area. Limiting disturbance will be necessary for the optimal functioning of the buffer zone in attenuating floods and soil erosion, which are the main adaptation needs of the downstream communities.

Multi-use tree species suitable for agroforestry in the croplands adjacent to the Muvumba River buffer zone are presented in Table 18 below. These are all fast-growing species that are grown among crops in the Bugesera District in the Eastern Province, which experiences dry climatic conditions — meaning these species are relatively drought tolerant and will require minimal irrigation. Accessing seedlings will also be relatively straightforward given that they are already propagated and planted in the Eastern Province. Out of the species listed in Table 18, native, non-invasive species including *F. ovata, F. thonningii, M. lutea, M. obtusifolia* and *S. mannii* should be prioritised. Of these, *F. ovata, F. thonningii* and *M. lutea* are most drought tolerant, can be sown easily or propagated through cuttings and provide multiple ecosystem services. Following these, secondary priority should be given to exotic species that are known not to be invasive in Rwanda, including *C. calothyrus, G. sepium, J. mimosifolia, J. curcas, L. trichandra, M. nigra* and *S. sesban*. Most of these species are tolerant of dry conditions and can be planted relatively easily as cuttings or sown as seeds *in situ*. Caution should be used for *P. americana*, which has the potential to outcompete crops for nutrients and overshade certain species.

[185] Shono K, Cadaweng EA & Durst PB. 2007. Application of assisted natural regeneration to restore degraded tropical forestlands. *Restoration Ecology 15*: 620–626.

Table 18. Suitable indigenous and non-invasive exotic species for agroforestry in croplands adjacent to the Muvumba River buffer zone and their potential benefits and planting requirements[186].

Scientific name	Local name	Exotic or indigenous	Climate resilience role	Livelihood impact role	Planting requirements and characteristics[187]
Calliandra calothyrsus	Kariyandara	Exotic — non invasive	Soil erosion control, soil fertility (mulch and N-fixing), shade, windbreak	Bee forage, fuel wood, timber, fodder, ornamental	Scarified[188] seeds can be sown directly or grown in nurseries. Evergreen tree that can survive long dry spells and nutrient-poor soils.
Ficus ovata	Umurehe	Indigenous	Soil erosion control, shade, windbreak	Fuel wood, edible fruits, medicine, fodder, ornamental	The planting of cuttings is the fastest propagation method, but seeds can also be harvested from fruit.
Ficus thonningii	Umuvumu	Indigenous	Soil erosion control, shade, windbreak, live fence	Fuel wood, medicine, bean stakes, gums/resins, fibre, ornamental	Can be grown from seeds but more commonly through cuttings which can either be planted directly or first grown in a nursery. A relatively drought-resilient tree.
Gliricidia sepium	Gereveriya	Exotic — non invasive	Soil erosion control, soil fertility (N-fixing), shade, windbreak	Fuel wood, charcoal, timber, medicine, bee forage, bean stakes, fodder, ornamental	Can be propagated from cuttings in good soils, otherwise seeds can be planted directly after land preparation or grown in a nursery. A deciduous tree that is tolerant of long dry seasons.
Jacaranda mimosifolia	Jacaranda	Exotic — non invasive	Soil erosion control, soil fertility (mulch), shade, live fence	Fuel wood, timber, bee forage, farm tools	For planting from seeds, no pre-treatment is needed but should be soaked for 24 hours. Branch cuttings can also be used. Deciduous tree that can tolerate long dry seasons.
Jatropha curcas	Umubira/ Icyomoro	Exotic — non invasive	Live fence, soil erosion control	Medicine, bean stakes	Seedlings can be germinated in moist conditions from fresh seeds. Alternatively, cuttings of half-ripe

[186] Kuria A, Uwase Y, Mukuralinda A, Iiyama M, Twagirayezu D, Njenga M, Muriuki J, Mutaganda A, Muthuri C, Kind R, Betemariam E, Cronin M, Kinuthia R, Migambi F, Lamond G, Pagella T & Sinclair F. 2017. Suitable tree species selection and management tool for Rwanda. [Database]. World Agroforestry Centre (ICRAF). http://apps.worldagroforestry.org/suitable-tree/

[187] Useful Tropical Plants. N.d. Available at: http://tropical.theferns.info/c.

[188] Scarification refers to the treatment of seeds before planting by boiling or scraping to remove the hard outer casing and improve germination yields.

					wood can be used in-situ. A deciduous tree that is tolerant of arid areas with nutrient-poor soils.
Leucaena trichandra	Resena	Exotic — non invasive	Live fence, soil fertility (mulch and N-fixing), soil erosion control	Edible food parts, fuel wood, timber, fodder	Can be grown from scarified seeds or cuttings of semi-ripe wood.
Markhamia lutea	Umusave	Indigenous	Soil fertility (mulch and N-fixing); shade	Fuel wood, timber, charcoal, medicinal uses, bee forage, bean stakes, ornamental	Can germinate from direct sowing in sunny areas. Evergreen tree that can tolerate distinct dry seasons and tolerates drought conditions once established.
Markhamia obtusifolia	Umukundambazo	Indigenous	Shade	Fuel wood, timber (furniture and construction), medicinal uses, fodder, ornamental	Can be cultivated from seeds.
Morus nigra	Iboberi/umukeri	Exotic — non invasive	Live fence	Edible fruits, fuel wood, fodder, bee forage, ornamental	Grown from stratified seeds in nurseries or cuttings of half-ripe wood. A semi-deciduous species favoured in areas with extended drought conditions.
Persea americana	Avoka	Exotic — can compete for nutrients and overshades neighbouring plants	Shade, soil erosion control	Edible fruits, fuel wood, fodder, timber (construction), charcoal	Propagated through seeds grown in a nursery and prefers warm, moist conditions. Evergreen tree that can tolerate high temperatures and poor soils .
Sesbania sesban	Umunyegenyege	Exotic — non invasive	Live fence, shade, soil fertility (mulch), wind break	Fuel wood, charcoal, timber (construction), medicinal uses, fodder, bee forage, gums and resins	Scarified seeds can be cultivated in nurseries. Deciduous species that can tolerate low rainfall and poor soils.
Solanecio mannii	Umutagara	Indigenous	Shade	Fuel wood, bean stakes, medicinal uses, tannins (dyes), ornamental	Fast growing evergreen tree.

Reforestation of upstream catchment areas

The reforestation of catchment areas upstream of water intake and treatment plants, as well as irrigation projects (planned by MINAGRI) with drought-resistant tree species to reduce runoff and erosion, have the potential to ultimately reduce the effects of flooding and siltation further downstream. This EbA intervention was evaluated as viable and feasible. However, the Rwanda Water Board (RWB) indicated that there are other initiatives proposed involving the protection of river catchments, including Muvumba. The RWB has developed the Muvumba Catchment Management Plan and protection activities have started upstream of the proposed Muvumba Multipurpose Dam (Figure 43). Therefore, it was proposed that NAP interventions cover the section between the dam area and water treatment plants towards downstream areas. Another important section is the area near the Kagitumba border with Uganda, which is experiencing riverbank destruction and landslides as a result of agricultural activities.

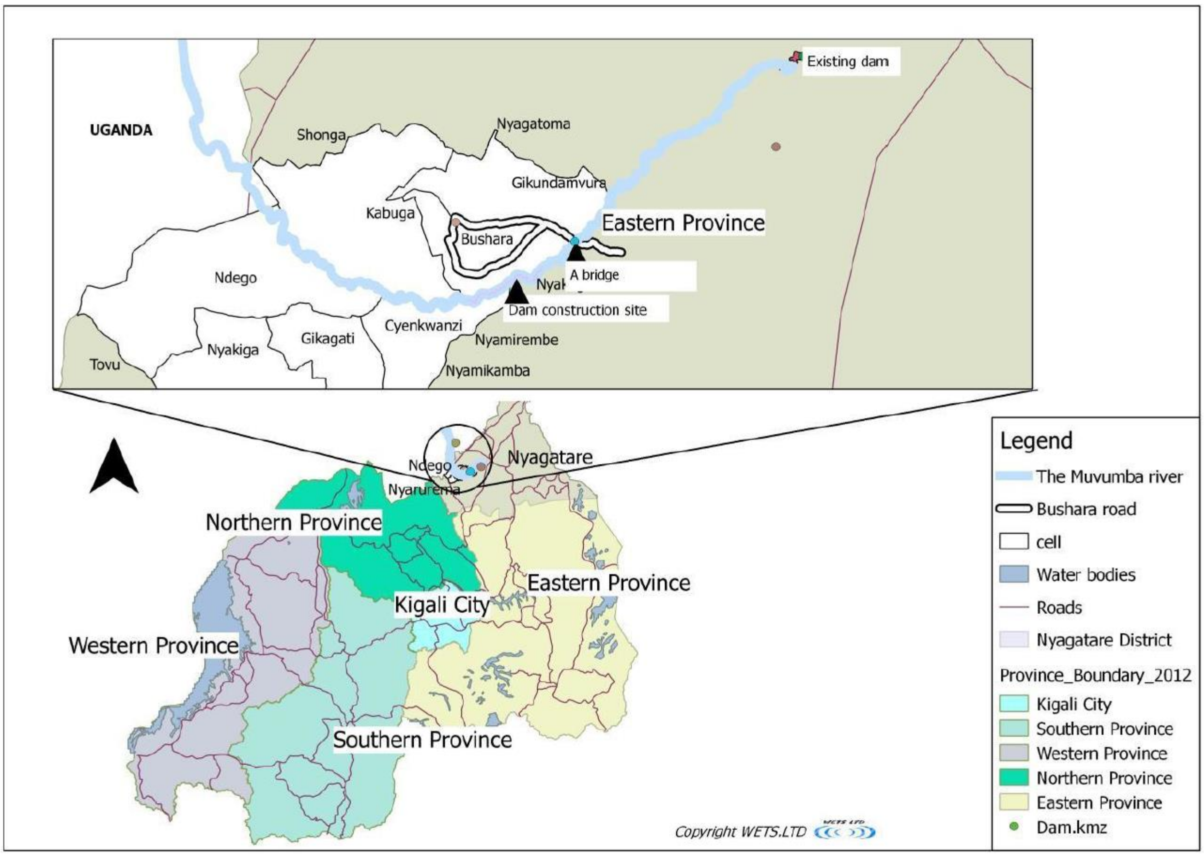


Figure 43. Location of the Muvumba Multipurpose Dam Project. The dam will be situated in Nyagatare (in Karama and Gatunda Sectors) of the country's Eastern Province[189].

Based on recommendations from the Muvumba Catchment Management Plan[190], catchment restoration will include the intensification and diversification of agroforestry techniques in target areas. Specifically, this will involve extending the range of species diversity and increasing the intensity of agroforestry tree planting that is already being used to stabilise terrace slopes and improve soil fertility. As mentioned under 'Ecosystem Profile' above, suitable local species, according to the Muvumba Catchment Management Plan, include conifers (*Podocarpus*), Parasol trees (*Polyscias fulva*), Kenya croton (*Croton megalocarpus*), Nile tulip (*Markhamia lutea*), Bitter leaf (*Vernonia*

[189] Ministry of Environment. 2017. Rwanda Water and Forestry Authority Muvumba Multipurpose Dam Development Project. Available at: https://esa.afdb.org/sites/default/files/RWANDA-MUVUMBA%20MULTIPURPOSE%20WATER%20RESOURCES%20DEVELOPMENT%20PROGRAM%20PHASE1-ESIA-P-RW-EA0-015.pdf

[190] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

amygdalina), and *Syzygium*, in addition to exotics like Alder (*Alnus acuminata*), Arabic gum (*Vachellia nilotica*) and Australian blackwood (*Acacia melanoxylon*). Information on the invasiveness, growth rate, water requirements and propagation of potential species is provided in below in Table 19.

Table 19. Factors considered for selection of agroforestry species.

Species	Status	Growth rate	Invasiveness	Water needs and drought tolerance	Propagation
Conifers (*Podocarpus*)	Indigenous	Fast	Low	Daily watering for first two weeks after planting; Water every two to three days 3–12 weeks after planting; after 12 weeks daily watering until roots are established[191]	Easily grown from seed or cuttings
Parasol trees (*Polyscias fulva*)	Indigenous	Fast	Low	More tolerant of drought than overwatering	Grows from seed or cuttings: Can be regenerated in the nursery from wildings
Kenya croton (*Croton megalocarpus*)	Indigenous	Fast	Potential to become invasive under favourable climatic conditions[192]	Seedlings should be watered twice a day	Can be propagated by sowing directly into the field or into pots. Cutting planting can also be practiced.
Nile tulip (*Markhamia lutea*)	Indigenous	Average	Low	Moderately drought-tolerant; Tolerates high soil moisture content and relative dryness between watering	Propagated from cuttings or seed; transplant seedlings 4–6 weeks after emergence
Bitter leaf (*Vernonia amygdalina*)	Indigenous	Fast	Low	Regular watering of seedlings required during dry periods	Propagated from cuttings or seed; transplant seedlings 4–6 weeks after emergence
Syzygium	Indigenous	Moderately fast	Low	Fairly drought resistant, but requires moist growing conditions with a high water table[193]	Propagated from seeds[194]

[191] UME. 2018. Watering newly planted trees and shrubs. Available at: https://extension.umn.edu/planting-and-growing-guides/watering-newly-planted-trees-and-shrubs
[192] Prota. No date. Croton megalocarpus Hutch. Available at: https://www.prota4u.org/database/protav8.asp?g=pe&p=Croton+megalocarpus+Hutch
[193] Ibid.
[194] Whatflower. 2020. Syzygium. Available at: https://whatflower.net/houseplant/syzygium/

Alder (*Alnus acuminata*)	Exotic	Moderately fast	Low	Moderately drought-tolerant; Tolerates high soil moisture content and relative dryness between watering	Propagated from seeds or cuttings
Australian blackwood (*Acacia melanoxylon*)	Exotic	Fast	Considered invasive in some countries	Drought-tolerant but frost-intolerant[195]	Propagated from seeds or cuttings[196]
Arabic gum (*Vachellia nilotica*)	Exotic	Fast	Considered invasive in some African countries	Very drought-tolerant	Easily propagated from seeds or cuttings

During consultations with district and local community members, they proposed that in addition to agroforestry and fruit trees, NAP interventions can also include other soil erosion control measures such as ditches planted with grass. The types of vegetation and complementary erosion control measures used will depend on land slope and the resultant erosion risk. These measures are summarised in Table 20.

Table 20. Matrix of soil erosion control measures according to soil depth and land slope[197].

Land slope	Soil erosion control measures	Erosion risk
0–6%	• Agroforestry, contour ploughing and alley cropping with grass strips • Forestation where soil depth is too limited and unsuitable for crops • Perennial crops, coffee, tea, banana and fruit trees	Very low and low risk
6–16%	• Progressive terraces (reinforced by agroforestry hedges and grass strips) • Perennial crops, coffee, tea, banana and fruit trees • Forestation where soil depth is too limited and unsuitable for crops	Medium risk
16–40%	• Bench terraces (only applicable in the case of suitable, stable parent material or geology to avoid introducing landslide risks) • Progressive terraces (reinforced by agroforestry hedges and grass strips) • Perennial crops, coffee, tea, banana and fruit trees • Forestation where soil depth is too limited and unsuitable for crops	High risk
40–60%	• Narrow cut terraces (only applicable in the case of suitable, stable parent material or geology to avoid introducing landslide risks) • Progressive terraces (reinforced by agroforestry hedges and grass strips) • Forestation (biological measures) • Perennial crops, coffee, tea, banana and fruit trees	Very high risk
>60%	• Forestation (biological measures) and trenches or ditches • Perennial crops, coffee, tea, banana and fruit trees	Extremely high risk

Intervention risks and mitigation measures

[195] Cadi. 2021. Acacia melanoxylon (Australian blackwood). Available at: https://www.cabi.org/isc/datasheet/2329#torainfall
[196] Ibid.
[197] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

Table 21. Potential risks and mitigation measures of each proposed intervention for the Muvumba River site.

Intervention	Risk category	Risk	Mitigation measure
Riparian buffer zone	Social	Loss of agricultural land along river to buffer zone	Agricultural lands beyond the 10-m buffer zone will not be lost, and will be targeted for agroforestry to improve agricultural productivity. Flood attenuation benefits of buffer zone will also improve agricultural outputs of surrounding croplands
	Social	Unequal cost-benefit profile favouring communities downstream of buffer zone	Reforesting the catchment upstream of the buffer zone will provide adaptation benefits to upstream communities
	Social	Buffer zone leading to a loss of access to Muvumba River for water collection and livestock watering	The riverbank will not be completely closed off. There will be specific areas where cattle will be able to access the river
	Sustainability	Encroachment of farming into the buffer zone	Agroforestry will be implemented in agricultural land just beyond the 10-m riparian buffer zone, providing fruit, timber and NTFPs to support livelihoods
Reforestation of catchment upstream of water intake and treatment plants	Social	Loss of agricultural land on hills in catchment	Planting multi-use, indigenous tree species will provide alternative forms of income (through NTFPs)
	Environmental	Vulnerability of tree seedlings to rainfall extremes and runoff	Fast-growing tree species will be selected
	Capacity	Limited capacity of local communities to manage reforestation	Training will be provided to environmental committees and local community members on reforestation

Summary budget

The total budget for EbA interventions at the Muvumba River pilot site is US$495,000. Below (Table 22) is an approximate breakdown of how the budget for the site could be spent, based on values of costs obtained from the 'LDCF2 project' ('*Building resilience of communities living in degraded forests, savannas and wetlands of Rwanda through an ecosystem-based adaptation approach*')[198]. Detailed budgets are provided in Annex 7.

[198] https://www.thegef.org/project/building-resilience-communities-living-degraded-forests-savannahs-and-wetlands-rwanda

Table 22. Summary budget for Muvumba River interventions.

Intervention	Input/activity	Estimated cost (US$)
Reforestation of catchment areas upstream from water intake and treatment plants	Training on forest restoration techniques — training will include members of both local catchment and Environment Committees	6,000
	Restoration of 150 ha of forests in catchment[199]	150,000 (1,000 per ha)
	Soil erosion control measures in the reforested catchment areas, including: i) forestation where soil depth is too limited and unsuitable for crops; ii) perennial crops, coffee, tea, banana and fruit trees; iii) and trenches or ditches	50,000
Demarcation and establishment of a buffer zone along river, using riparian vegetation restoration and planting fodder and fruit trees inside buffer zone	Training on the use of agroforestry techniques — local farmers	6,000
	Restoration of 10 m wide area on both sides of riverbank for 25 km of river (50 ha in total), using bamboo, and ANR of riparian vegetation	75,000 (1,500 per ha)
	Establishing agroforestry on 30 ha in restored riparian buffer zone areas[200]	30,000 (1,000 per ha)
All	One-day workshop with local communities to develop a nursery management system — training will include members of both local catchment and Environment Committees	3,000
	Nursery establishment for plants used in buffer zone and reforestation interventions[201]	100,000 (500 per ha)
	Support (including training) provided to local catchment committees and environment committees to equip them to maintain and implement interventions during the project period	20,000
Total		**440,000**

Implementation workplans and timetables

Implementation timetables for the selected interventions are presented in Annex 3.

Implementation arrangements

Given the challenges associated with tree planting in Rwanda's Eastern Province with its limited rainfall, stakeholders recommended to have a contractor who will be responsible for tree planting, irrigation requirements to allow for tree establishment and following up for at least two years thereafter to ensure that tree survival rate is maximised. In these conditions, the contractor will be requested to use local labour to ensure ownership but also to provide employment to the local communities. Stakeholders identified for the Muvumba interventions are:

[199] US$1,200 per hectare is allocated for forest restoration in the Muvumba catchment.

[200] US$1,000 is allocated to the development of agroforestry per ha in the riparian buffer zone. Some parts of the buffer zone will be left as restored indigenous vegetation (i.e. not contain agroforestry). Approximately 30 ha of the total 50 ha of restored riparian zone will be used for agroforestry.

[201] 1,500 trees will be planted per hectare of forest. A mortality rate of 40% is accounted for. Therefore, 2,200 seedlings will be planted in nurseries for each hectare of restored forest. An average of US$500 per hectare is allocated to purchase the seeds and build the nurseries for forest and riparian restoration and riparian agroforestry.

- District-level authorities that will be involved in project implementation on the ground, as well as coordinating with the local communities to raise awareness among local land users; and
- Rwanda Forest Authority, Rwanda Agriculture Board, ICRAF and other relevant stakeholders will provide ongoing technical input into the maintenance of interventions.

For sustainability purposes, it was requested by stakeholders to involve both local catchment protection committees and Environment Committees[202] in project implementation. These committees at cell level include representatives of the local community, farmers, women and the youth as well as NGOs operating in the area[203]. Such committees will be supported through the project to assist with the establishment of the riparian buffer zone, agroforestry interventions, erosion controls and catchment restoration activities. Members will be trained on land preparation, planting, mulching, fertiliser application and tree maintenance. Agricultural extension agents and technical experts from ICRAF, the Rwanda Forest Authority and the Rwanda Agriculture Board will provide technical advice on the maintenance of interventions.

[202] GoR. 2010. Official Gazette no. 45. Available at: https://rema.gov.rw/fileadmin/templates/Documents/rema_doc/Laws%20and%20Regulations_Updated/Ministerial%20Orders/Prime%20Minister's%20order%20%20for%20Committees%20in%20charge%20of%20the%20Environment%20conservation%20and%20protection.pdf
[203] REMA. 2020. Ministerial Orders. Available at: https://rema.gov.rw/index.php?id=30

2.3 *Site 3: Eastern savannas, Nyagatare District, Eastern Province*

<u>Site description</u>

Administrative location

The savannas targeted for EbA interventions under the NAP project fall within the Nyagatare District in the Eastern Province (Figure 44). They cover areas within the Matimba, Rwimiyaga and Karangazi Sectors, and border the Nyagatare Sector on their western extent (Figure 45). Within these three sectors, 15 Cells and 41 Villages fall within the intervention area (Table 23).

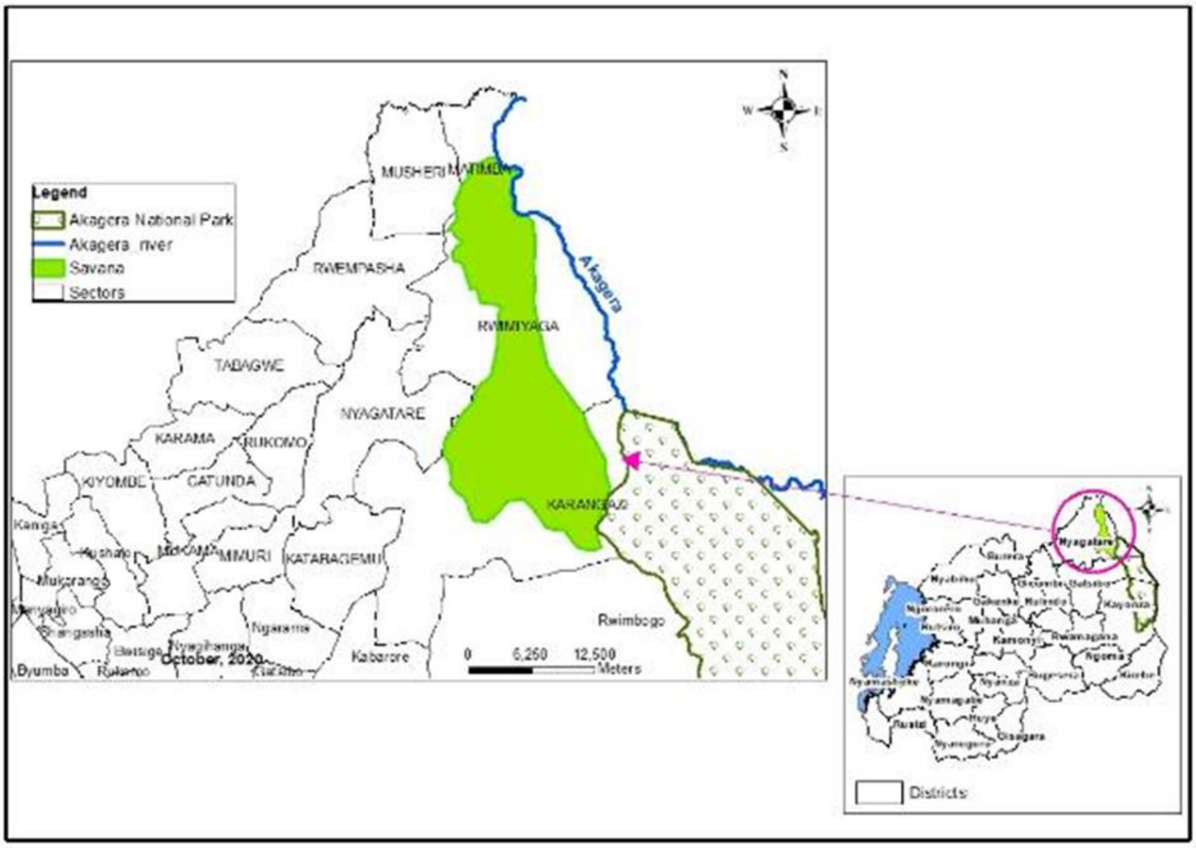


Figure 44. Administrative location of the eastern savannas. They fall within the Nyagatare District of the Eastern Province. Source: Theogene Habakubaho.

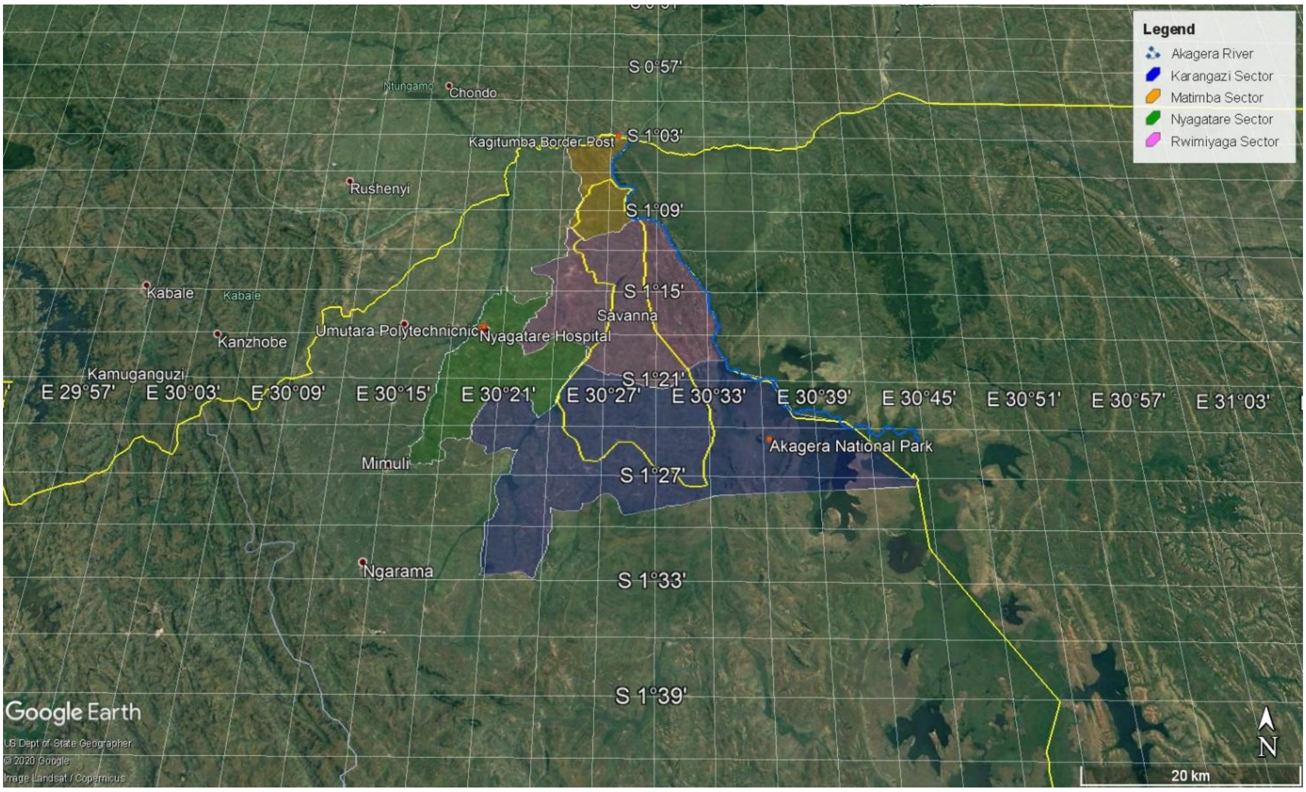


Figure 45. Sectors that the eastern savannas fall within, as well as important landmarks in the vicinity. Yellow polygon represents the border of the savannas targeted as a pilot site, while other yellow lines represent country borders. Image created in Google Earth Pro; location data provided by Theogene Habakubaho.

Table 23. Cells and Villages within the eastern savannas of Nyagatare District that will be targeted for EbA interventions.

No	Cell	Village
1	Kamate	Bugarama
2		Buhongoro
3		Kamate
4		Kigazi
5		Muzehe
6		Akayange
7	Ndama	Ndama
8		Rwabiharamba
9	Nyagashanga	Kabare
10		Kayange I
11	Nyamirama	Kayange II
12		Nyamirama II
13	Rwenyemera	Bwera
14	Bwera	Bwera
15		Ntoma
16		Rugaga
17	Matimba	Umudugudu Wa V
18		Umudugudu Wa VI
19	Ryabega	Marongero

20		Rugendo
21	Gacundezi	Rukundo II
22		Rukundo III
23	Kabeza	Rukiri I
24		Rukiri II
25	Kirebe	Gatebe I
26		Gatebe II
27		Kirebe
28		Rukindo
29	Ntoma	Gashwenu
30		Kibuye
31		Kimaramu
32		Rwembogo
33	Nyendo	Isangano
34		Nyamirama
35		Rebero
36	Rutungu	Bwera
37		Gakagati II
38		Rubira
39	Rwimiyaga	Byimana
40		Gakoma
41		Rwinyange

Climate and climate threats

The mean annual precipitation in the Rwimiyaga Sector — in which part of the Nyagatare savanna pilot site is situated — is 808 mm (Figure 46)[204]. The two rainy seasons from March–May and September–December receive a total rainfall of ~310 mm and ~354 mm respectively (Figure 47). Between 1981–2017, there has been a decreasing trend in rainfall amounts in the first wet season (March–May) and an increasing trend in rainfall for the second wet season (September–December) (Figure 48 and Figure 49). For annual rainfall between 1961 and 2018, the period between 1991 and 2000 has been the driest. These observations showed a marked rainfall deficit in 1992, 1993, 1996, 1999 and 2000 with rainfall excesses in 1998 and 2001.

[204] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

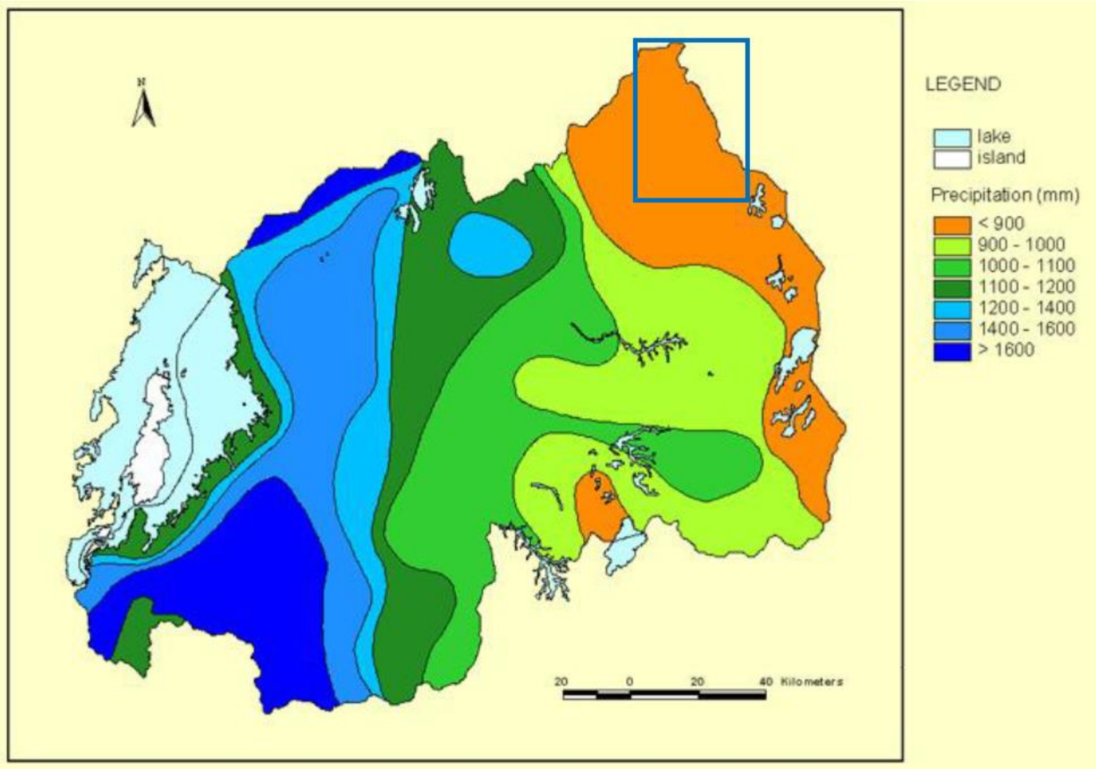


Figure 46. Annual average rainfall for Rwanda[205]. The Nyagatare savanna pilot site is indicated with a blue square.

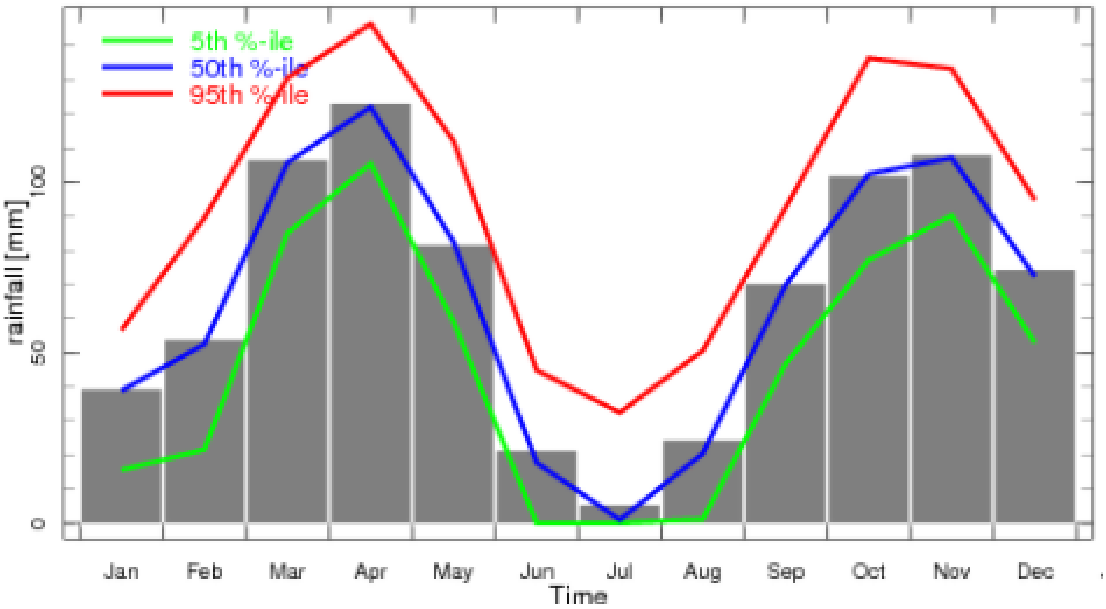


Figure 47. Average monthly rainfall (mm) for the Nyagatare savanna pilot site[206].

[205] Verdoodt A & van Ranst E. 2003. Land evaluation for agricultural production in the tropics. A large-scale land suitability classification for Rwanda.
[206] Meteo Rwanda. 2020. Climate Summary for Local Governments: Rwimiyaga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405213%3Ads#tabs-1

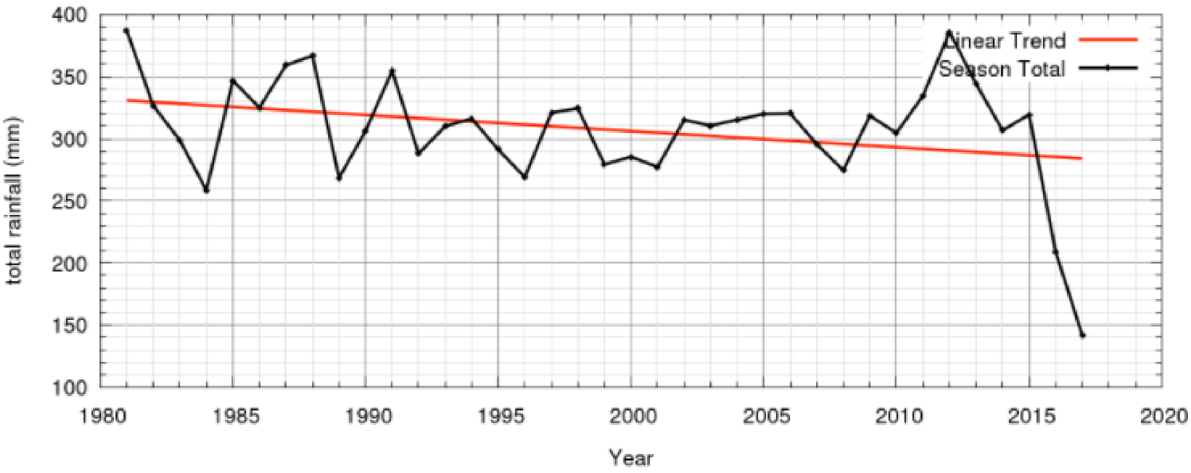


Figure 48. Trend in total seasonal rainfall from March–May for the Nyagatare savanna pilot site[207].

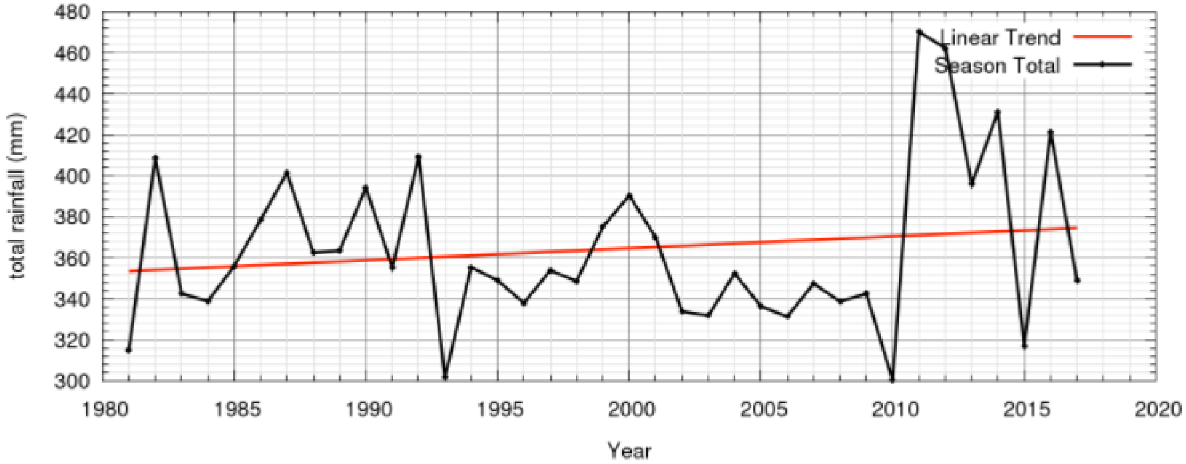


Figure 49. Trend in total seasonal rainfall from September–December for the Nyagatare savanna pilot site[208].

The first dry season occurs from late May to early September, with the dry season months prolonged in the lower altitude areas and towards the east. As the altitude of the area is lower than the rest of the country, the average temperature of 21°C is higher than averages in most other regions of the country (Figure 50)[209]. Temperature observation data indicates an average maximum temperature of 24°C and average minimum temperature of 14°C (Figure 51 and Figure 52).

[207] Meteo Rwanda. 2020. Climate Summary for Local Governments: Rwimiyaga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405213%3Ads#tabs-1

[208] Meteo Rwanda. 2020. Climate Summary for Local Governments: Rwimiyaga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405213%3Ads#tabs-1

[209] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

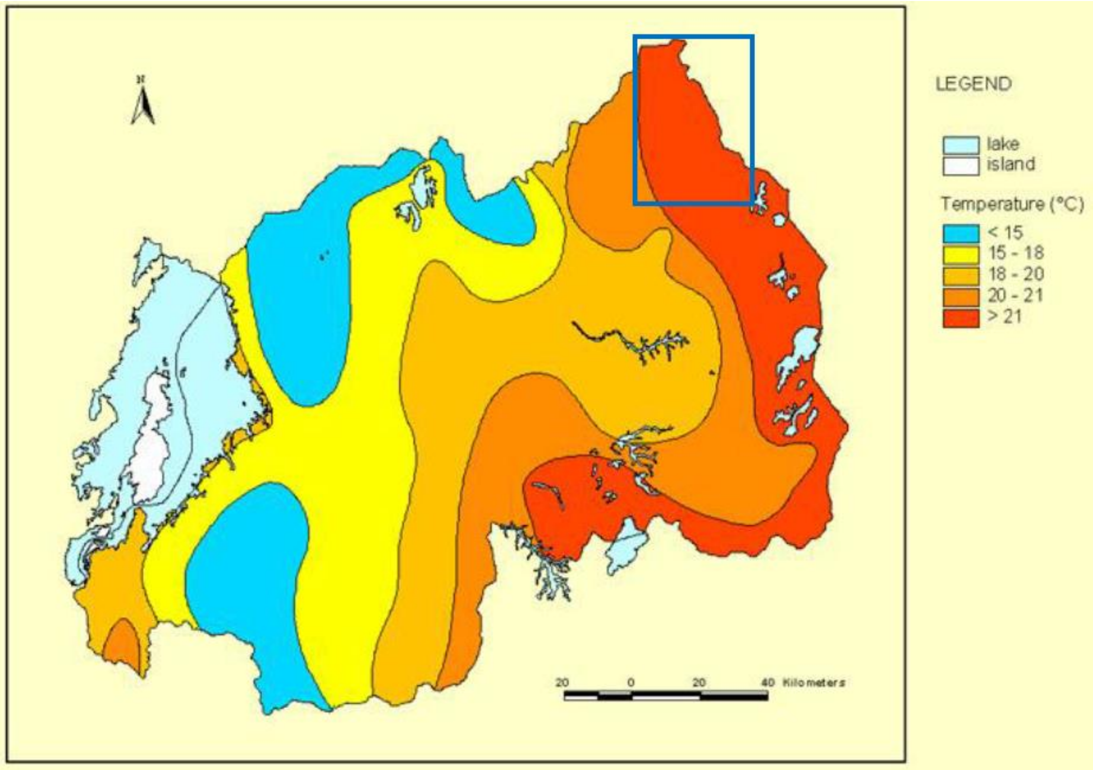


Figure 50. Average annual temperature for Rwanda[210]. The Nyagatare savanna pilot site is indicated with a blue square.

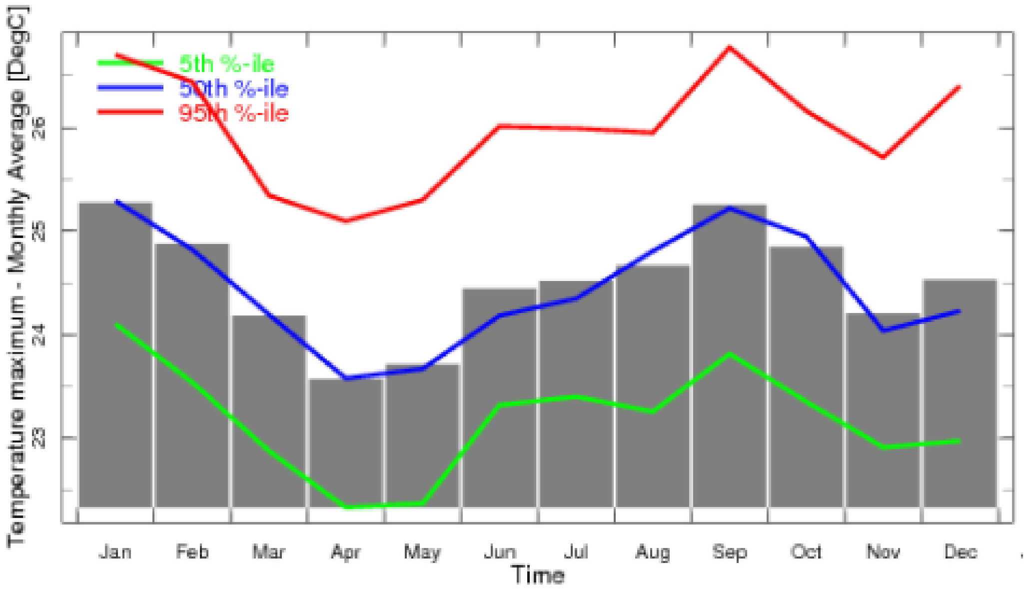


Figure 51. Average monthly maximum temperature (°C) for the Nyagatare savanna pilot site[211].

[210] Verdoodt A & van Ranst E. 2003. Land evaluation for agricultural production in the tropics. A large-scale land suitability classification for Rwanda.
[211] Meteo Rwanda. 2020. Climate Summary for Local Governments: Rwimiyaga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405213%3Ads#tabs-1

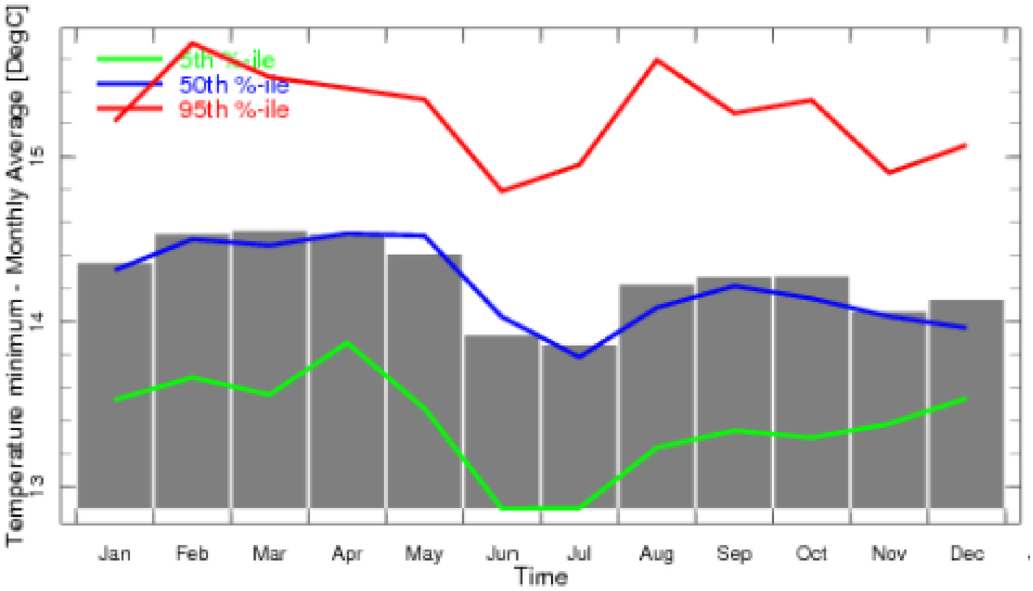


Figure 52. Average monthly minimum temperature (°C) for the Nyagatare savanna pilot site[212].

The eastern savannas, like most parts of Nyagatare District, are characterised by a high frequency of rainfall deficit, late rainfall onsets, early rainfall cessations and a substantial number of dry spells. This has resulted in the area being the most drought-prone region in the country. Prolonged droughts are frequent, tend to be cyclical and can be persistent. During the first wet season, the Nyagatare District savannas have a moderately low susceptibility to agricultural drought, which decreases to low susceptibility in the second wet season[213].

Droughts often result in food shortages, a reduction in plant and animal species and the displacement of people in search of food and pasture. Specific costs to livestock production include the limited availability of forage for livestock (which compounds overgrazing), loss of livestock and additional costs related to livestock maintenance, veterinary costs and supplemental feeding[214]. In addition to direct effects on food security and agricultural productivity, droughts — combined with the impacts of deforestation for agricultural land, overgrazing and wind erosion — has resulted in severe landscape-level degradation of lowlands and savannas.

The Nyagatare District area is also vulnerable to storm events with moderate gale force winds (52–72 km/hr) that have return periods of 5 or 10 years[215]. These storm events cause damage to crops — particularly banana, sorghum and maize — and buildings. In 2013 for example, storm events in Nyagatare resulted in six deaths, 16 injuries, 95 damaged or destroyed homes and 18 ha of affected crop lands. In addition, wind erosion results in large-scale soil loss which decreases the productive potential of the land[216]. During the wet seasons (short and long), soil loss is further exacerbated, while runoff rates are high as a result of decreased infiltrability of the soils.

Ecosystem profile

The Nyagatare District is characterised by low hills that are common in the eastern lowlands of Rwanda, as well as grassy plains. The low hills mostly contain savanna vegetation, while dense forest

[212] Meteo Rwanda. 2020. Climate Summary for Local Governments: Rwimiyaga Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%405213%3Ads#tabs-1
[213] MIDIMAR. 2015. The national risk atlas of Rwanda.
[214] Nzeyimana I & Philliper K. N.d. Drought conditions and management strategies in Rwanda.
[215] MIDIMAR. 2015. The national risk atlas of Rwanda.
[216] MIDIMAR. 2015. The national risk atlas of Rwanda.

patches are restricted to riverbanks[217]. The Muvumba River and Akagera National Park are the main natural ecosystems found in the Nyagatare. The district also accounts for more than 30 marshlands[218].

The plant diversity of Nyagatare District is characteristic of lowland savanna vegetation (i.e., it is a tree-grass mosaic) (Figure 53). Apart from crops dominated by large-scale rice cultivations in the wetlands and bean, maize and banana on the hills, natural vegetation consists predominantly of *Vachellia* (formerly the genus *Acacia*) tree species. The dominant grasses of the savannas are Red oat grass (*Themeda triandra*) and various thatching grass species (including *Hyparrhenia filipendula*[219]). In the southeastern part of the Nyagatare District, the Akagera National Park conserves a savanna-forest ecosystem. The park hosts a high diversity of plants, including many threatened species such as *Blighia unijugata* (Umuturamugina in the local language), African sandlewood (*Osyris lanceolata*, locally known as Kabaruka), Gummy canthium (*Afrocanthium lactescens*, locally known as Umukondokondo) and knob wood (*Zanthoxylum chalybeum*, also known as Intareyirungu). The invasive lantana *Lantana camara* is also prevalent throughout the savannas in the district and has been linked to changing land use[220]. Furthermore, the wetlands of the Nyagatare District are dominated by papyrus sedge (*Cyperus papyrus)* and flatsedge (*Cyperus latifolius)*[221].

Figure 53. Landscape and remaining plant species in the eastern savanna. Source: Theogene Habakubaho.

Under the 2016 'Rwanda Feeder Roads Development Project'[222] numerous alien ruderal/plant species that favour disturbed areas were identified in the Nyagatare District. These include timber trees such as silk oak (*Grevillea robusta*, locally known as Gereveriya) and *Eucalyptus* sp. (Inturusu), shrubs such as *Senna spectabilis* (Gasiya) and fruit trees such as *Mangifera indica* (Imyembe) and *Persea americana* (Avoka). The same document identified indigenous tree species that included

[217] MoE. 2017. Rwanda Water and Forestry Authority Muvumba Multipurpose Dam Development Project. Available at: https://esa.afdb.org/sites/default/files/RWANDA-MUVUMBA%20MULTIPURPOSE%20WATER%20RESOURCES%20DEVELOPMENT%20PROGRAM%20PHASE1-ESIA-P-RW-EA0-015.pdf

[218] Ministry of Agriculture and Animal Resources. 2016. Rwanda Feeder Roads Development Project: Final Report. Nyagatare District.

[219] MoE. 2017. Rwanda Water and Forestry Authority Muvumba Multipurpose Dam Development Project. Available at: https://esa.afdb.org/sites/default/files/RWANDA-MUVUMBA%20MULTIPURPOSE%20WATER%20RESOURCES%20DEVELOPMENT%20PROGRAM%20PHASE1-ESIA-P-RW-EA0-015.pdf

[220] Wronski T, Bariyanga JD, Sun P, Plath, M. & Apio A. 2017. Pastoralism versus agriculturalism—how do altered land-use forms affect the spread of invasive plants in the degraded Mutara rangelands of north-eastern Rwanda? *Plants*. 6: 19.

[221] MoE. 2017. Rwanda Water and Forestry Authority Muvumba Multipurpose Dam Development Project. Available at: https://esa.afdb.org/sites/default/files/RWANDA-MUVUMBA%20MULTIPURPOSE%20WATER%20RESOURCES%20DEVELOPMENT%20PROGRAM%20PHASE1-ESIA-P-RW-EA0-015.pdf

[222] Ministry of Agriculture and Animal Resources. 2016. Rwanda Feeder Roads Development Project: Final Report. Nyagatare District.

species of the genera *Vachellia, Euphorbia* and *Ficus.* The most common plant species found alongside roads in the Nyagatare District are listed below (Table 24).

Table 24. Most common plant species identified along roadsides in the Nyagatare District in the Rwanda Feeder Roads Development Project.

No.	Plant species	Common/local name	Morphology
1	*Acanthus pubescens*	Igitovu	Shrub
2	*Achyranthes aspera*	Umuhurura	Herb
3	*Albizia gummifera*	Umusebeya	Tree
4	*Blumea brevipes*	Igitabitabi	Herb
5	*Carica papaya*	Ipapayi	Tree
6	*Casuarina equisetifolia*	Filaho	Tree
7	*Erythrina abyssinica*	Umuko/Umurinzi	Tree
8	*Eucalyptus* sp.	Inturusu	Tree
9	*Euphorbia tirucalli*	Umuyenzi	Tree
10	*Gomphocarpus physocarpus*	Gasaho	Herb
11	*Grevillea robusta*	Gereveriya	Tree
12	*Hygrophylla auriculata*	Gangabukari	Herb
13	*Indigofera errecta*	Umusororo	Shrub
14	*Kyllinga errecta*	Uruvuya	Herb
15	*Lantana camara*	Umuhengeri	Shrub
16	*Leonotis nepetifolia*	Igicumucumu	Herb
17	*Mangifera indica*	Umwembe	Tree
18	*Mikania cordata*	Urugozi	Herb
19	*Mimosa pigra*	Umugeyo	Shrub
20	*Ocimum suave*	Umwenya	Herb
21	*Oryza sativa*	Umuceri	Herb
22	*Pennisetm purpureum*	Urubingo	Herb
23	*Persea americana*	Avoka	Tree
24	*Polygonum setulosum*	Igorogonzo	Herb
25	*Psidium guajava*	Ipera	Tree
26	*Senna spectabilis*	Gasiya	Shrub
27	*Tetradenia riparia*	Umuravumba	Shrub
28	*Vernonia amygdalina*	Umubirizi	Shrub
29	*Vachellia (Acacia) kirkii*	Umukinga	Tree
30	*Vachellia (Acacia) polyacantha*	Umugu	Tree
31	*Vachellia (Acacia) sieberiana*	Umunyinya	Tree

The Nyagatare District also accommodates a large variety of birds, reptiles and amphibians[223]. Most are located inside the Akagera National Park — which also hosts numerous endangered bird species such as shoebills (*Balaeniceps rex*, locally known as Munwarukweto), Southern ground-hornbills (*Bucorvus leadbeateri*, locally Ikigungumuka), Lappet-faced vultures (*Torgos tracheliotos*, locally Inkongoro) and Whiteheaded vultures (*Trigonoceps occipitalis*, locally Inkongoro) — but the savannas and grasslands outside the park also host considerable bird and large mammal diversity[224].

Baseline drivers and extent of ecosystem degradation

The savannas of the Nyagatare District (and other parts of the Eastern Province) are predominantly used for the grazing of livestock (such as cattle and goats) and agriculture/croplands. Deforestation to prepare land for such agricultural practices combined with subsequent overgrazing, prolonged drought and wind erosion have resulted in severe landscape-level degradation of lowlands and savannas (Figure 54). This has led to limited availability of forage for livestock (which further

[223] Ministry of Agriculture and Animal Resources. 2016. Rwanda Feeder Roads Development Project: Final Report. Nyagatare District.

[224] Gatali C. 2013. Herbivory and biodiversity conservation of the savannah habitats in Akagera National Park, Rwanda. Doctoral thesis, Department of Biological and Environmental Sciences, University of Gothenburg.

compounds overgrazing), and large-scale soil loss which decreases the productive potential of the land. During the rainy seasons (both short and long), soil loss is further exacerbated, while runoff rates are high as a result of decreased infiltration of the soils. The Nyagatare District loses 24 million tonnes of soil annually, which contributes to ~4% of Rwanda's national annual soil loss through erosion[225]. As a result of this erosion, 3.3% of the land covered by crops is deemed unsuitable for croplands.

Figure 54. Status of overgrazed rangelands in the Nyagatare savannas. Source: Theogene Habakubaho, September 2020.

As part of land reform and land redistribution, the Government of Rwanda (GoR) has imposed limits on farm sizes across the country. Consequently, in some areas in the eastern savannas, large herds of livestock have been confined within insufficient pasture areas, which has resulted in further overgrazing and land degradation[226].

The maximum daily water consumption for human and livestock population is projected to grow from the 2017 level of 24,000 m^3/day to 37,700 m^3/day by 2022 for the entire district[227]. This represents a ~36% increase in water usage, which — coupled with a climate change-induced increase in rainfall variability and a longer dry season — will reduce water availability in an area of the country that already displays water scarcity. As a result, agricultural and livestock productivity will be reduced, which will affect the health and livelihoods of local communities.

Topography

[225] Karamage F, Zhang C, Ndayisaba F, Shao H, Kayiranga A, Fang X, Nahayo L, Muhire Nyesheja E & Tian G. 2016. Extent of cropland and related soil erosion risk in Rwanda. *Sustainability*. 8: 609.
[226] REMA. 2010. Tool and Guideline #4: Practical Tools on Sustainable Agriculture. Available: https://www.rema.gov.rw/~remagov/fileadmin/templates/Documents/rema_doc/Environmental%20Managemnent%20Plractical%20Tools/4-%20Practical%20Tools%20on%20Sustainable%20Agriculture%20_Final%20Version_%2016-07-2010%20%23%20Paper%20A4.pdf
[227] MoE. 2017. Rwanda Water and Forestry Authority Muvumba Multipurpose Dam Development Project. Available at: https://esa.afdb.org/sites/default/files/RWANDA-MUVUMBA%20MULTIPURPOSE%20WATER%20RESOURCES%20DEVELOPMENT%20PROGRAM%20PHASE1-ESIA-P-RW-EA0-015.pdf

The eastern savannas are located in the eastern lowlands, with an altitude of 1,000–1,500 masl. The area is dominated by round-topped hills as well as flatlands separated by valleys[228]. While the topographical layout has potential for modern and mechanised agricultural farming, this is limited by the dominant granite basement aquifer, which results in low groundwater storage capacity and conductivity. The most extensive soil types within the low-lying area are humus-bearing soils and ferralsols. These ferralsols are derived from deeply weathered siliceous rocks and are therefore of low fertility, acidic and prone to toxicity because of its aluminium content. Despite this they are generally deep, easy to work and less erodible than other deeply weathered soils.

Land uses

Croplands comprise 68% of land cover in the Nyagatare District[229], though livestock grazing also constitutes a large proportion of the district's land use, particularly in the savanna regions[230]. Figure 55 below illustrates the mosaic of rangeland and cropland in the savanna area targeted under this project.

Figure 55. Satellite image of the Nyagatare savannas showing the mosaic land use patterns of rangelands and agriculture. Source: Theogene Habakubaho.

The mean size of land cultivated per household in the Nyagatare District is 0.77 ha. Consequently, Nyagatare is among the seven districts in Rwanda that have a high percentage (66%) of households that cultivate between 0.75 and 0.9 ha of land[231]. The main crops grown in Nyagatare include maize (35% of households), bush beans (13%), banana (13%) and cassava (11%). Other crops include banana, sorghum, rice, vegetables (mainly tomatoes and onion), sweet potatoes, soybean and groundnuts. Approximately 78% of the total production for key crops is marketed[232,233]. Maize (70%) and beans (80%) are the key crops sold, representing 71.2% of the total marketed produce in the district of Nyagatare. In addition to crops, livestock is another important source of income and food

[228] Ministry of Agriculture and Animal Resources. 2009. Land husbandry, water harvesting and hillside irrigation (LWH) project.
[229] Karamage F, Zhang C, Ndayisaba F, Shao H, Kayiranga A, Fang X, Nahayo L, Muhire Nyesheja E & Tian G. 2016. Extent of cropland and related soil erosion risk in Rwanda. *Sustainability*. 8: 609.
[230] Ministry of Agriculture and Animal Resources. 2016. Rwanda Feeder Roads Development Project: Final Report. Nyagatare District.
[231] MoE. 2018. Muvumba Catchment Management Plan (2018–2024).
[232] MoE. 2018. Muvumba Catchment Management Plan (2018–2024).
[233] MoE. 2017. Rwanda Water and Forestry Authority Muvumba Multipurpose Dam Development Project. Available at: https://esa.afdb.org/sites/default/files/RWANDA-MUVUMBA%20MULTIPURPOSE%20WATER%20RESOURCES%20DEVELOPMENT%20PROGRAM%20PHASE1-ESIA-P-RW-EA0-015.pdf

for agricultural households in Nyagatare. The livestock population of the district includes cattle (~199,000), goats (~182,000), chickens (~108,000), rabbits (~19,000), sheep (~18,000) and pigs (~6,000).

Hydrological profile

The eastern savannas are found within the Nile Basin[234]. Apart from the Akagera River — which marks the border with Tanzania — there are no other large perennial rivers (Figure 56). The only other notable river in the area is the Karangazi River, which is erratic and intermittent. This limited river network constitutes a considerable limitation with regards to water availability for people and animals.

Figure 56. Hydrographic network within the Nyagatare savanna pilot area.

Local communities

The Nyagatare District is divided into 14 sectors comprising 106 cells and 630 villages. Many of these villages were established under the "Imidugudu" programme, a government settlement policy that was implemented after the 1994 Genocide and which saw the regrouping of rural populations into villages.

Demographics

With a total population of ~466,000 people, the Nyagatare District is the second most populous district in Rwanda[235]. Approximately 49% of the population is male, and ~51% is female. See the "Demographics" subsection under the "Muvumba River" section above for further population statistics for the Nyagatare district.

Poverty levels

Approximately 44% of the district live in poverty, of which ~20% live in "extreme poverty". See the "Poverty levels" subsection under the "Muvumba River" section above for further poverty statistics for the Muvumba catchment section of the Nyagatare District.

[234] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[235] MoE. 2017. Rwanda Water and Forestry Authority Muvumba Multipurpose Dam Development Project. Available at: https://esa.afdb.org/sites/default/files/RWANDA-MUVUMBA%20MULTIPURPOSE%20WATER%20RESOURCES%20DEVELOPMENT%20PROGRAM%20PHASE1-ESIA-P-RW-EA0-015.pdf

Education levels of the Nyagatare District population are as follows:
- no education: ~73%;
- primary: ~18%;
- post-primary: ~1.7%;
- lower secondary: ~3.8%;
- upper secondary: ~2.7%; and
- university: ~1.0%[236].

Livelihoods

Similar to other parts of Rwanda, the primary livelihood strategies in the savannas of the Nyagatare District are predominantly focussed on agriculture. The majority of the land in the eastern savannas serve as rangelands for the grazing of livestock, particularly cattle and goats. Deforestation caused by the creation of new grazing areas — combined with subsequent overgrazing, drought and wind erosion — has resulted in severe landscape-level degradation of lowlands and savannas. This has led to a limited availability of forage for livestock (which further compounds overgrazing and exacerbates deforestation), and large-scale soil loss which decreases the productive potential of the land. Crop farming is therefore also a livelihood type used in the savannas to support livestock farming. The crop types grown in the Nyagatare District include, *inter alia,* wheat (35% of the total crops produced), beans (13%), bananas (13%), cassava (11%), sorghum (9%), soybeans (6%) and rice (2%)[237]. In addition to agriculture, people in Nyagatare District are also active in rice and maize processing, as well as in the production of local wine types[238].

Land tenure arrangements

Approximately 29% of households in Nyagatare District own agricultural lands that are smaller than 0.3 ha. In the eastern savannas, some households have rangelands larger than 25 ha. However, given the extent of degradation, as well as extended and more intense drought conditions resulting from climate change, even these larger rangelands are considered insufficient in size for sustainable livestock farming.

Access to resources

Only ~42% of the population in the Nyagatare District has access to clean drinking water[239], while 20% has no access to both clean drinking water and sanitation[240]. Located in a semi-arid zone, Nyagatare experiences issues with water availability. The majority of households in the district utilise surface water (rivers or valley dam water) and public standpipes.

Out of 105,686 resident households in the Nyagatare District, ~23% are electrified (compared with the national average of 11%), ~70% use improved cooking stoves, ~4% use cooking gas (4%), and <1% use biogas as their primary energy source. In terms of animal feed, cattle keepers in the eastern savannas use a variety of resources. While the majority of households (>80%) have access to natural pasture[241], a small portion of farmers use fodder banks of Napier and Kukuyu grasses combined with crop residues. However, the availability of this fodder is seasonally determined.

[236] GoR. 2017. Economic Activity Report. EICV5: The Fifth Integrated Household Living Conditions Survey 2016/2017. https://www.statistics.gov.rw/publication/eicv5thematic-reporteconomic-activity-thematic-reportpdf.
[237] MINAGRI. 2013. Crop Assessment Final Report.
[238] https://nyagatare.gov.rw/fileadmin/templates/Raports/Nyagatare_Potentialities.pdf
[239] Ministry of Agriculture and Animal Resources. 2016. Rwanda Feeder Roads Development Project: Final Report. Nyagatare District.
[240] Dusabe MC, Wronski T, Gomes-Silva G, Plath M, Albrecht C & Apio A. 2019. Biological water quality assessment in the degraded Mutara rangelands, northeastern Rwanda. *Environmental Monitoring and Assessment*. 191: 139.
[241] According to consultations with a Nyagatare district official conducted by the national consultant.

Indigenous breeds of cattle (for example, Ankole) are the most dominant breed type owned in the savannas, followed by crosses between indigenous and exotic breeds. Local farmers indicate that these two types are preferred because of their relatively higher resistance to the local climate conditions and fodder limitations.

Reliance on ecosystem services of local communities

Access to water has been perceived as a considerable constraint to the expansion of livestock production in the Nyagatare District. The local, traditional livestock breeds can typically walk long distances daily for water and grazing. However, the modern livestock varieties introduced into the Nyagatare area after 1994, which yield more milk and meat than the traditional varieties, are more sensitive to walking long distances for water. Therefore, rural development schemes in the district have included investments in improved storage dams for rainwater, as well as dams supplied with pumped groundwater. Restoration of natural vegetation can also be an important intervention to reduce sedimentation of rivers and dams, which will increase the availability of water for livestock.

Community organisations and structures

As mentioned under the 'Muvumba River' section, many of the Nyagatare District's 630 villages were established under the '*Imidugudu*' programme, which resulted in the regrouping of rural populations into villages. In addition, cattle keepers in the district are grouped into cooperatives with cooperative unions at the district level. With regards to environmental management, there are staff at the district, sector and cell levels that are responsible for environmental matters. Moreover, there is a ministerial order that establishes environmental committees, however this is not yet functional. These committees are to be established at the village, cell, sector and district levels.

Infrastructure and services available at the site

There are 12 milk collection centres in the Nyagatare District, with a total capacity of 71,000 litres. In terms of water infrastructure, only ~42% of Nyagatare District households use an improved drinking water source — the lowest percentage nationally. Improved drinking water sources include protected springs, public standpipes, water piped into a dwelling/yard, boreholes, protected wells and rainwater collection, as defined by the World Health Organization (WHO). The remainder of the district's population obtains water directly from surface water sources, such as rivers and lakes.

The World Bank's ongoing 'Muvumba Multipurpose Dam Development Project'[242] will involve the construction of an artificial dam along the Muvumba River in the Karama and Gatunda Sectors of the Nyagatare District, beginning early 2021. The dam will have a maximum height of 40 m and a storage capacity of 191 million m^3. The project's goals are to: i) improve water security for communities in the Nyagatare District that are prone to drought; ii) provide flood and water flow regulation; iii) provide alternative livelihood opportunities for local communities, including aquaculture and tourism; and iv) provide a supply of hydropower.

Additional information about services and infrastructure in the Nyagatare District is listed below:

- Nyagatare has 20 health centres, two health posts, one prison dispensary and one district hospital.
- The current market infrastructure in Nyagatare offers two main types of structures: modern markets and selling points.
- About 50% of indicative feeder roads are in bad or very bad condition.

[242] MoE. 2017. Rwanda Water and Forestry Authority Muvumba Multipurpose Dam Development Project. Available at: https://esa.afdb.org/sites/default/files/RWANDA-MUVUMBA%20MULTIPURPOSE%20WATER%20RESOURCES%20DEVELOPMENT%20PROGRAM%20PHASE1-ESIA-P-RW-EA0-015.pdf

- Regarding distances to basic services (such as schools and health centres), Nyagatare District ranks lower than the national average.

Climate change problems that the EbA interventions will address

Climate change projections indicate that the length of the dry season and temperatures in Rwanda will increase. Under a RCP8.5 scenario, the difference in rainfall between the wettest and driest months will increase by 59 mm between 2040–2059 and 118 mm between 2080–2099 compared with baseline values from 1986–2005 (Figure 57), indicating elevated rainfall variability between seasons[243]. Monthly temperatures for the region are predicted to rise by 1.7–2°C between 2040–2059 and 3.5–4.5°C between 2080–2099 compared with baseline historic values (Figure 58 and Figure 59)[244]. This increased monthly rainfall variability and hotter temperatures — which will result in higher evaporation rates — will be particularly detrimental for the Eastern Province which is already dry compared with the rest of Rwanda, exacerbating the degradation of savannas. Consequently, the agriculture-based livelihoods of many local farmers are at risk, as soil fertility and the availability of forage for livestock will continue to decrease. Without effective climate change adaptation in this region, livestock farmers are likely to lose their livelihoods, resulting in heightened poverty levels and further landscape degradation as they look for alternative forms of income generation.

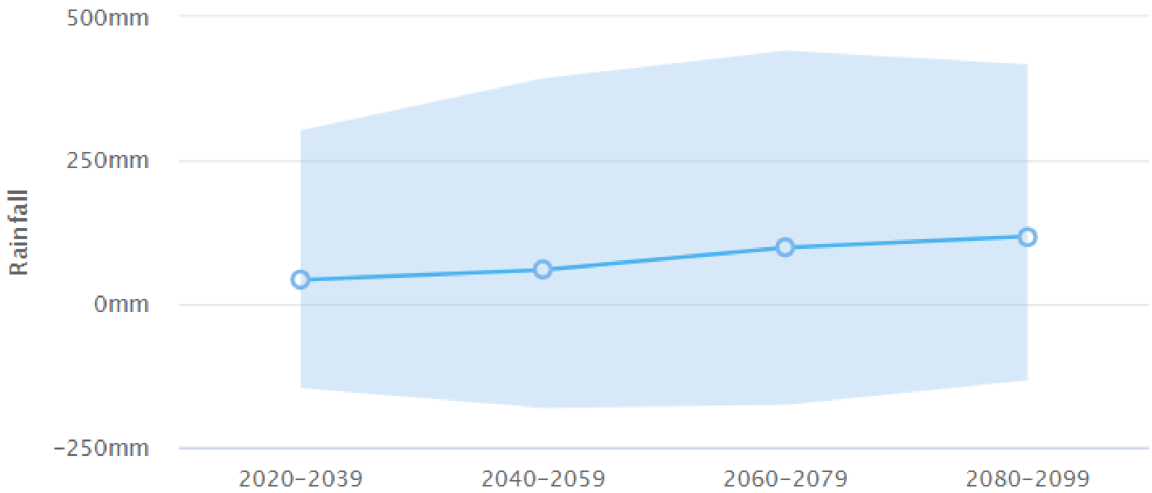


Figure 57. Projected change in the annual range in monthly rainfall (mm) for the Nyagatare savanna pilot site from 2020–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[245] (GCMs)[246].

[243] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#
[244] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#
[245] IPCC. 2014. Fifth Assessment Report.
[246] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

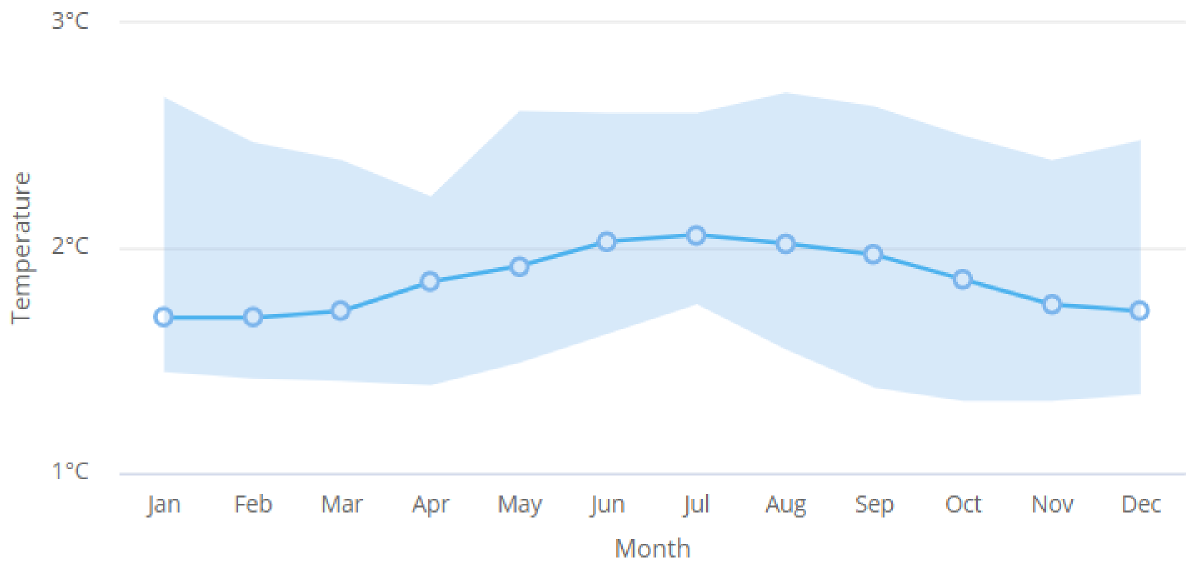


Figure 58. Projected change in monthly temperature (°C) for the Nyagatare savanna pilot site from 2040–2059 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[247] (GCMs)[248].

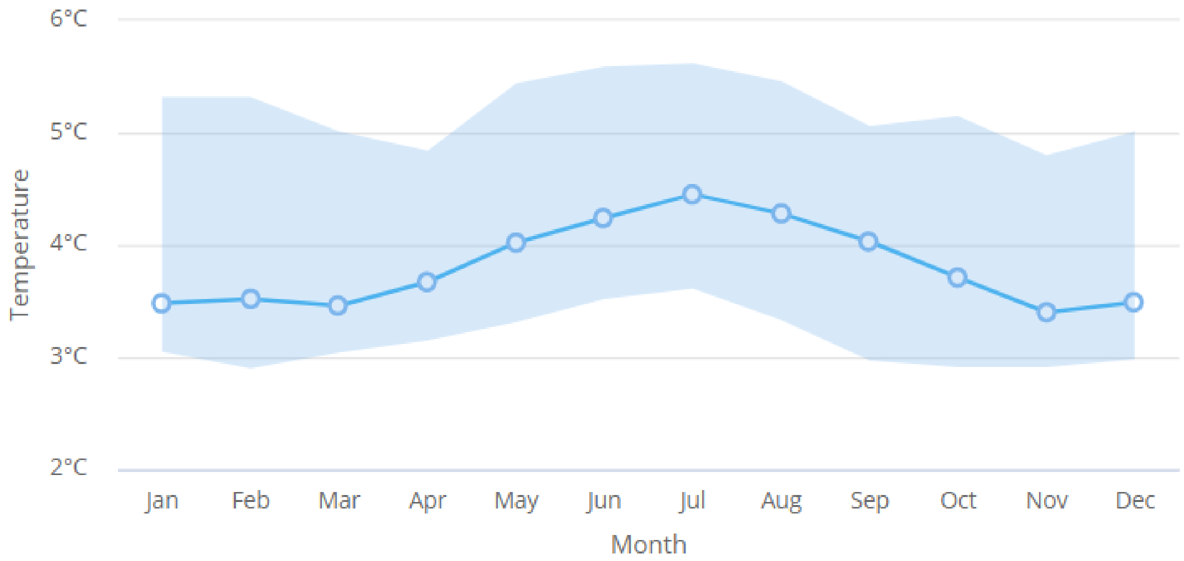


Figure 59. Projected change in monthly temperature (°C) for the Nyagatare savanna pilot site from 2080–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[249] (GCMs)[250].

<u>Detailed description of interventions</u>

Recommended EbA interventions to be piloted by champion farmers at a site in the eastern savanna areas of the Nyagatare District would promote silvopastoralism to strengthen livestock production (for meat and milk) and increase tree cover in the savannas by:

[247] IPCC. 2014. Fifth Assessment Report.
[248] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#
[249] IPCC. 2014. Fifth Assessment Report.
[250] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

- fencing paddocks with drought-tolerant trees to protect exposed soils from wind erosion and prevent livestock from grazing during pasture regeneration periods (thereby promoting sustainable grazing practices);
- planting drought-resistant tree species in rangelands to provide additional fodder and shade for livestock, wood for communities, protect soils against the effects of erosion (wind and water) and promote water infiltration; and
- planting fodder and medicinal plants for use by livestock and local communities, respectively.

These interventions were discussed with stakeholders, including local communities, and were positively received. Stakeholders did not provide alternatives to the proposed interventions. Some community members, however, proposed the project address water supply for cattle given the critical need of water in the area. Some cattle keepers are attempting to pump water from Akagera River and other small streams, but the costs are high and most of them cannot afford it. The district officials indicated that is aware of this issue and is exploring the possibility of using the Muvumba Multipurpose Dam and Gabiro Irrigation Hub projects that will pump water from Akagera to support provision of water to cattle keepers in these savannas. The provision of water in this way — which is not an EbA intervention — was therefore not assessed in the site's MCA as it is outside the scope of the project.

The proposed target site is situated in close proximity to the Akagera National Park, with a small portion of the site's south-eastern portion bordering the north of the park (Figure 56). The interventions will promote ecosystem restoration and reduce pressure in areas adjacent to the park, thereby contributing to biodiversity conservation in the larger area. Only indigenous species will be used for planting activities, meaning that there is no risk of invasive species encroaching into the park. The project will additionally consult Akagera National Park sponsors and managers, local communities and other relevant stakeholders on the proposed activities.

Results of multi-criteria analysis (MCA)

Table 25 below indicates the results of the multi-criteria analysis for the eastern savannas. The list of interventions includes only those proposed in the ProDoc, as no other EbA interventions were suggested during stakeholder consultations or identified in the rapid options analysis. For more detail, please refer to the scorecard in Annex 2.

Table 25. Results of the MCA of EbA interventions for the eastern savannas (score: 0 = unfeasible, 1 = perfect intervention).

Intervention assessed	Score
Planting drought-resistant trees in rangelands	0.79
Planting fodder and medicinal plants for use by livestock and humans, respectively	0.78
Fencing off paddocks with drought-tolerant trees	0.73

All three proposed EbA interventions scored highly and will be included within this pilot site. These three interventions are complementary to each other and all contribute and strengthen the main ecosystem services including erosion control and the provision of resources, such as fodder, medicinal species and timber. Additionally, each intervention will assist in rangeland regeneration through direct restoration and reduction of exposure to climate-related hazards such as erosion and reduced degradation from overgrazing. They are further detailed in the sections below.

Fencing off paddocks with drought-tolerant trees

Some cattle keepers in the savannas have fenced their rangelands (Figure 60), mainly with *Euphorbia tirucalli* (Umuyenzi) and few of them have included agroforestry species such as exotic *Grevillea* spp. During consultations, local communities and district officials welcomed the idea of fencing off paddocks as well. According to these stakeholders this will not only keep livestock out of the neighbouring pastures, but also improve the management of rangelands as it will allow control over both the movement of livestock and the productivity, quality, and utilisation of rangelands. This will allow them to alternate different paddocks, allowing for the regeneration of grasses.

Figure 60. Satellite image of rangelands in the eastern savannas of Nyagatare District. Currently, only rangeland borders are fenced, but paddocks are not. Source: Theogene Habakubaho, September 2020.

To date, agroforestry as an intervention to support livestock in East African rangelands has mostly focussed on mixed farming systems, in which animals are generally enclosed and fed by cut-and-carried plant foods including crop residues, as well as other feeds such as concentrates[251]. Over the last three decades, new approaches have emerged involving the planting of mostly exotic fodder trees that are often grown along field boundaries where they do not compete with crops, and along contours where they help to limit soil erosion[252]. However, several of the tree species that have been used have a relatively high risk associated with their use. For example, while *Calliandra calothyrsus* has been widely used for erosion control in the region, it is considered invasive. Other species, such as *Leucaena diversifolia* and its hybrid *Leucaena trichandra* have not been extensively examined in the literature, but are likely to be considered invasive in the future. Other risks with the use of exotic tree species such as *Sesbania sesban*, includes modification of nutrient regimes and alteration of ecosystems and is considered invasive.

Agroforestry practices have recently been adopted by more than 200,000 small-scale dairy farmers in highland regions of Kenya, Uganda, Tanzania and Rwanda[253]. Fodder from these trees can then be used as a substitute for dairy meal or as a supplement for basal diet including crop residues and grasses. These trees are useful because: i) by supplementing basal food supply, and increasing shade for livestock, the quantity and quality of dairy and meat production improves; ii) as increased water shortages worsen crop and forage yield and make livestock-raising more vulnerable, drought-tolerant trees can provide a steady forage supply during the dry seasons and offset any losses in other fodder loss; and iii) new seed introductions of fodder-producing, drought-tolerant tree species

[251] Dawson IK, Carsan S, Franzel S, Kindt R, van Breugel P, Graudal L, Lillesø JPB, Orwa C. & Jamnadass R. 2014. Agroforestry, livestock, fodder production and climate change adaptation and mitigation in East Africa: issues and options. *World Agroforestry Center*, Nairobi. Kenya.

[252] Franzel S, Carsan S, Lukuyu B, Sinja J & Wambugu C. 2014 Fodder trees for improving livestock productivity and smallholder livelihoods in Africa. *Current Opinion in Environmental Sustainability* 6: 98–103.

[253] Dawson IK, Carsan S, Franzel S, Kindt R, van Breugel P, Graudal L, Lillesø JPB, Orwa C. & Jamnadass R. 2014. Agroforestry, livestock, fodder production and climate change adaptation and mitigation in East Africa: issues and options. *World Agroforestry Center*, Nairobi. Kenya.

can improve livelihoods through the creation of seed sales between farmers[254]. Lists of potential fodder-producing tree species are provided in Table 26 and Table 27 below.

Planting drought-resistant trees in rangelands (silvopasture)

This intervention was also appreciated by stakeholders, cattle keepers in particular. However, during consultations cattle keepers raised concerns about the implementation of this intervention, specifically how planted trees will survive with the presence of cattle. Moreover, the limited rainfall and lack of water in the area may affect the survival rate of planted trees. They recommended the planting of trees in phases and during the period when there is enough fodder to support cattle in one section of rangelands or provide a strong protection of young trees until they become mature. Another concern was who will be involved in planting these trees and what the follow-up mechanism will be. The local communities indicated that in the past they were heavily fined when their cows ate any planted trees. They requested to be involved in the planning, planting and follow ups, with each member being given inputs and technical support to plant in his/her rangelands.

The best practices of silvopastoral interventions in the World-Bank-funded ‘Landscape Approach to Forest Restoration and Conservation’ (LAFREC) project (in the Gishwati-Mukuru landscape, Western Province) can be emulated in the silvopastoral intervention of the LDCF-funded NAP project. These include establishing trees (through planting and managed natural regrowth) on ridge-tops, extreme slopes, riparian buffers, and as live fences, shelter belts and shade trees. Although this approach would involve a marginal loss in the pasture area, it is likely to improve the overall productivity of rangelands — in addition to enhancing forest cover and biological connectivity — by protecting against land degradation, providing shelter for animals from climatic extremes, and through provision of additional fodder and forest products. These EbA interventions can be implemented in such a way as to link natural forest blocks through micro-corridors in the silvopastoral landscape. Additionally, silvopastoral interventions will be accompanied by training on improved livestock and pasture management.

Planting fodder and medicinal plants for use by livestock and humans, respectively

Another proposed EbA intervention is planting fodder and medicinal plants for use by livestock and humans, respectively. This would assist in relieving pressure on rangeland species that currently provide these goods and therefore promote rangeland diversity and resilience to climate change. Similar to the other two interventions, all stakeholders appreciated the interventions and highlighted concerns for consideration during the implementation including timing, follow up and maintenance of planted fodder and medicinal plants, as well as the involvement of beneficiaries in implementation.

Species selection for the EbA interventions

For the agroforestry interventions in the eastern savannas to be successful, they will need to be resilient to projected short- and long-term climate change impacts for the Nyagatare region, as well as address the baseline drivers of ecosystem restoration. In the savannas, a prolonged dry season and decreasing rainfall are the main climate change threats facing local communities, as well as the associated decline in forage availability and soil fertility. For the long-term success of EbA interventions in the savannas, these climate change impacts and baseline degradation drivers should be central to intervention design. Therefore, tree species to be planted in the eastern savannas should: i) be chosen according to its ecological requirements, and ecologically adapted indigenous tree species should be planted where possible; ii) be identified based on their potential contribution

[254] Dawson IK, Carsan S, Franzel S, Kindt R, van Breugel P, Graudal L, Lillesø JPB, Orwa C. & Jamnadass R. 2014. Agroforestry, livestock, fodder production and climate change adaptation and mitigation in East Africa: issues and options. *World Agroforestry Center*, Nairobi. Kenya.

to climate change adaptation; and iii) benefit local communities[255]. Table 26 below provides a list of indigenous tree species that can be used for the agroforestry interventions in the eastern savannas, based on the aforementioned criteria. Of the species listed in Table 26, *A. adiantifolia* and *M. lutea* are both easily propagated from seeds or cuttings and are fast growers, tolerant of many soil types and drought conditions, respectively. Most of the remaining species — with the exception of *A. amara* and *E. abyssinica* — should be planted in nurseries beforehand and transplanted. *A. petersiana, E. abyssinica* and *L. schimperi* are least desirable as they are: i) slow growing and require clay-like soils; ii) potentially poisonous; or iii) require female and male forms to propagate respectively.

Table 26. Suitable indigenous tree species for use within the agroforestry interventions in the Nyagatare eastern savannas and their potential benefits[256]. Soil fertility refers to ecosystem services such as litter production and nitrogen fixation.

Scientific name	Local name	Climate resilience role	Livelihood impact role	Planting requirements and characteristics[257]
Albizia adiantifolia	Umusebeya	Drought resistant, soil fertility, shading	Bee forage, fuel wood, timber	Propagation is mostly through scarified seeds collected directly from adult plants, or from root cuttings. A fast-growing evergreen that can tolerate a wide range of soil types.
Albizia amara	Umunanira	Drought resistant, soil fertility, soil stabilisation	Fodder/mulch, fuel wood, traditional medicine	Scarified seeds can be sown *in situ*. This species requires light conditions and show a marked resistance to drought.
Albizia petersiana	Umumeyu	Soil fertility, shading, soil stabilisation	Construction material, fuel wood, handicraft, timber, traditional medicine	Slow growing tree that requires clay-like soils. It can easily be grown from seeds.
Erythrina abyssinica	Umuko	Drought resistant, soil fertility, shading, soil stabilisation, insect and disease resistant	Bee forage, fuel wood, handicraft, timber, traditional medicine, ornamental	Can be propagated through scarified seeds (obtained from fruit) in a nursery or through cuttings planted in the wet season. Deciduous tree with a moderate growth rate that is tolerant of low rainfall conditions. A potential risk is that this species produces poisonous seeds, bark and leaves.
Lannea schimperi	Umumuna	Drought resistant, shading, soil stabilisation, insect	Bee forage, construction material, fuel wood,	Grown from seeds, however caution must be taken to use both

[255] Rwanda Environment Management Authority. 2019. Ecosystem-based adaptation guidelines for climate resilient restoration of savannah, wetland and forest ecosystems of Rwanda.
[256] Rwanda Environment Management Authority. 2019. Ecosystem-based adaptation guidelines for climate resilient restoration of savannah, wetland and forest ecosystems of Rwanda.
[257] Useful Tropical Plants. N.d. Available at: http://tropical.theferns.info/c.

		and disease resistant	handicraft, fodder/mulch, edible fruits, timber, traditional medicine	male and female forms if fruit and seeds are required.
Markhamia lutea	Umusave	Soil fertility, soil stabilisation, insect and disease resistant	Bee forage, construction material, fuel wood, ornamental, timber	Can germinate from direct sowing in sunny areas. Fast-growing evergreen tree that can tolerate distinct dry seasons and tolerates drought conditions once established.
Markhamia obtusifolia	Umukundambazo	Soil stabilisation, insect and disease resistant	Bee forage, fuel wood, ornamental, timber, traditional medicine	Can be cultivated from seeds.
Pappea capensis	Umurerampango	Drought resistant, soil fertility, shading, soil stabilisation, insect and disease resistant	Bee forage, construction material, fuel wood, handicraft, timber	Seeds can be collected directly from fruit and grown in nurseries before planting in the field. Slow-growing evergreen tree suitable to a wide variety of climatic conditions including extended drought.
Parinari curatellifolia	Umunazi	Insect and disease resistant	Bee forage, construction material, fuel wood, edible fruits, ornamental, timber, traditional medicine	Propagation through seeds germinated in nurseries. Evergreen tree tolerant to long dry season and low rainfall.
Ximenia caffra	Umusasa	Insect and disease resistant	Fuel wood, handicraft, traditional medicine, edible fruits	Propagation is through seeds germinated in nurseries. Deciduous tree that is drought tolerant once established.

The Tropical Forages Tool[258] was also used to assess suitable tree species for the three proposed interventions in the eastern savannas. This tool is useful for two reasons: i) it provides general[259] as well as species-specific[260] guidelines on the establishment of forage tree species in the tropics; and ii) it allows for the selection of key criteria to filter out species that are not applicable to the desired specific conditions. Table 27 below provides a further four tree species that could be used in the eastern savanna EbA interventions that were not identified in the REMA guidelines in Table 26 above (because some are not indigenous to the area). All species in Table 27 below: i) have minimal or low environmental risks; ii) can survive at the latitude and altitudes of the eastern savanna region; iii) can survive in current and projected future rainfall and temperature conditions; iv) can tolerate the open savanna ecosystem conditions (i.e. can survive with full or partial sunlight); v) are not invasive and do not proliferate as weeds; and vi) are suitable for all three proposed interventions — i.e. establishing live fences for paddocks, planting drought-resistant trees in rangelands to provide additional livestock fodder and shade and additional uses, and planting fodder and medicinal plants for use by livestock

[258] Tropical Forages: an interactive selection tool – Digital ISBN 978958694234-8. Available: https://www.tropicalforages.info/identify/key.html
[259] https://www.tropicalforages.info/text/intro/guidelines.html
[260] https://www.tropicalforages.info/text/entities/index.htm#index_C

and humans, respectively. For these reasons, along with the fact that the Tropical Forages Tool provides helpful guidelines for successful establishment of each species, it is acceptable that not all of its suggested species are indigenous to Rwanda. Of the list provided in Table 27, *C. cajan* and *S. sesban* are the most likely to be tolerant of a larger range of conditions and soils. *G. sepium* and *S. scabra* have potentially greater soil constraints, but their seeds can be sown relatively easily in the field.

Table 27. Tree species identified for EbA interventions in the eastern savannas, and their potential benefits, using the Tropical Forages Tool[261].

Scientific name (common name)	**Fodder details**	**Native/exotic**	**Climate resilience role**	**Livelihood impact role**	**Planting requirements and characteristics[262]**
Cajanus cajan[263] (pigeonpea)	Browsed directly or cut and carry	Native to India, but naturalised in sub-Saharan Africa	Soil erosion control, shade for crops and/or livestock, very drought tolerant, tolerant of hot conditions (>35°C), soil fertility (N fixation)	Fuel wood, medicinal uses, edible fruits	Propagated through seeds sown in situ. Slow-growing evergreen shrub that can be grown in a variety of soil types.
Gliricidia sepium[264] (quickstick)	Cut and carry	Native to Central America, but naturalised in sub-Saharan Africa	Soil erosion control, very drought tolerant, soil fertility (N fixation), shade	Fuel wood, timber, construction material, furniture, bee forage, ornamental, medicinal uses, pest control	Can be propagated from cuttings in good soils, otherwise seeds can be planted directly after land preparation or grown in a nursery.
Sesbania sesban[265] (common sesban)	Cut and carry. Leaves a good source of protein for cattle and sheep	Native to Rwanda	Branches as mulch, soil erosion control, useful windbreak, drought tolerant	Fuel wood, fibres from bark used for making ropes and nets, medicinal uses, leaves, flowers and cooked seeds are eaten, pest control	Scarified seeds can be cultivated in nurseries. Fast-growing deciduous species that can tolerate low rainfall and poor soils.
Stylosanthes scabra[266] (vogel)	Perennial pasture or cut and carry	Native to Caribbean, but naturalised in Kenyan savannas	Highly drought tolerant, soil fertility	Medicinal uses	Seeds can be collected from adult plants and sown in situ. Well adapted to nutrient poor soils.

Intervention risks and mitigation measures

[261] Tropical Forages: an interactive selection tool – Digital ISBN 978958694234-8. Available: https://www.tropicalforages.info/identify/key.html
[262] Useful Tropical Plants. N.d. Available at: http://tropical.theferns.info/c.
[263] https://www.tropicalforages.info/text/entities/cajanus_cajan.htm
[264] https://www.tropicalforages.info/text/entities/gliricidia_sepium.htm
[265] https://www.tropicalforages.info/text/entities/sesbania_sesban.htm
[266] https://www.tropicalforages.info/text/entities/stylosanthes_scabra.htm

Table 28. Potential risks and mitigation measures of each proposed intervention for the Eastern savannas site.

Intervention	Risk category	Risk	Mitigation measure
Fencing off paddocks with drought-tolerant trees	Capacity	Limited knowledge among pastoralists about management of introduced tree species	Training on live fence management best practices will be provided to local pastoralists
Planting drought-resistant trees in rangelands	Social	Unequal distribution of benefits favouring farmers with larger rangelands and access to water for irrigation	Project management will identify most vulnerable farmers to pilot interventions
Planting fodder and medicinal plants for use by livestock and humans, respectively	Social	Unequal distribution of benefits — may preference farmers with larger rangelands to accommodate crop planting, and access to water for irrigation	Project management will identify most vulnerable farmers to pilot interventions
All	Environmental	Vulnerability of tree seedlings to hot and dry conditions	Only drought-tolerant tree species will be planted

Summary budget

The total budget for interventions at the eastern savannas is US$557,000. Below (Table 29) is an approximate breakdown of how the budget for the eastern savannas site could be spent, based on values of costs obtained from the 'LDCF2 project' ('*Building resilience of communities living in degraded forests, savannas and wetlands of Rwanda through an ecosystem-based adaptation approach*')[267]. Detailed budgets are provided in Annex 7.

Table 29. Summary budget for interventions to be implemented in the eastern savannas.

Intervention	Input/activity	Estimated cost (US$)
Planting drought-resistant trees in rangelands (silvopastoralism)	Training on savanna restoration and silvopastoral techniques, including protection and watering of trees	6,000
	Planting drought-resistant trees in 160 ha of rangelands to provide fodder and shade, including initial watering	120,000 (750 per ha)
	Watering costs for seedlings (until establishment) including transport of water to sites as necessary	40,000
Planting fodder and medicinal plants for use by livestock and humans, respectively	Training on the use of agroforestry techniques	6,000
	Planting fodder and medicinal plants (establishing agroforestry) on 150 ha of agricultural land[268]	112, 500 (750 per ha)
Fencing paddocks with drought-tolerant trees	Training on the management of live fences around paddocks, including protection and watering	6,000
	Planting drought-tolerant trees as live fences around paddocks	94,000

[267] https://www.thegef.org/project/building-resilience-communities-living-degraded-forests-savannahs-and-wetlands-rwanda
[268] An average of US$1,000 per hectare is allocated to the development of agroforestry in the Eastern savannas.

All	Training on the production and use of organic compost	6,000
	Training on water-harvesting and evaporation-reducing techniques[269]	6,000
	One-day workshop with local communities to develop a nursery management system for the savannas	3,000
	Nursery establishment for the tree-planting interventions[270]	120,000 (300 per ha)
	Support (including training) provided to establish and equip environment committees to maintain and implement interventions during the project period	20,000
Total		**413,000**

Implementation workplans and timetables

Implementation timetables for the selected interventions are presented in Annex 3.

Implementation arrangements

Given the challenges associated with tree planting in Rwanda's Eastern Province with its limited rainfall, watering requirements and drought tolerance of species should be a strong consideration throughout the implementation period. Stakeholders recommended to have a contractor who will be responsible for tree planting and following up for at least two years thereafter to ensure that tree survival rate is maximised. In these conditions, the contractor will be requested to use local labour to ensure ownership but also to provide employment to the local communities. Stakeholders identified for the Nyagatare interventions are:

- District-level authorities that will be involved in project implementation on the ground, as well as coordinating with the local communities to raise awareness among local land users;
- Rwanda Forest Authority, which will provide technical expertise in selecting appropriate species; and
- Rwanda Agriculture Board, which will assist the project managers in selecting highly productive drought-resistant tree species to be used in the EbA interventions (based on guidelines provided in Section 0).

For sustainability purposes, it was requested by stakeholders to involve both local catchment protection committees and Environment Committees[271] in project implementation. These committees at cell level include representatives of the local community, women and the youth as well as NGOs operating in the area[272].

Upon the new Ministerial Order[273] to establish Environment Committees, it was recommended by district officials that the project supports the establishment of these committees in the intervention area and provide them with training on implementing EbA interventions. The involvement of these committees in project implementation will ensure sustainability beyond the project period. According

[269] Six days of training will be organised with small groups of farmers in the Eastern savannas on water harvesting techniques, as well as techniques to reduce evaporation on farmland.
[270] An average of US$300 per hectare is allocated to purchase the seeds and build the nurseries for the tree-planting interventions in the eastern savannas.
[271] GoR. 2010. Official Gazette no. 45. Available at: https://rema.gov.rw/fileadmin/templates/Documents/rema_doc/Laws%20and%20Regulations_Updated/Ministerial%20Orders/Prime%20Minister's%20order%20%20for%20Committees%20in%20charge%20of%20the%20Environment%20conservation%20and%20protection.pdf
[272] REMA. 2020. Ministerial Orders. Available at: https://rema.gov.rw/index.php?id=30
[273]https://rema.gov.rw/fileadmin/templates/Documents/rema_doc/Laws%20and%20Regulations_Updated/Ministerial%20Orders/Prime%20Minister's%20order%20%20for%20Committees%20in%20charge%20of%20the%20Environment%20conservation%20and%20protection.pdf

to the ministerial order, Environment Committees will be responsible for: i) ensuring the implementation of the laws, policies, programmes and plans relating to the protection, conservation and promotion of the environment in Rwanda; ii) monitoring challenges related to awareness-raising of the population on environmental protection and appropriate land use; and iii) ensuring that persons who destroy the environment are pursued by the relevant institutions.

Committees will be established at Provincial, District, Sector and Cell level. At Cell level — which is closest to the community — the committee will comprise the following:

- a representative of National Women Council at Cell level;
- a representative of National Youth Council at Cell level;
- a representative of the private sector at Cell level;
- two experts in environmental matters approved by the Council of the Cell;
- a representative of non-government organisations dealing with environmental matters who is elected by his/her peers;
- persons in charge of environment in the Executive Committees of the Villages; and
- persons in charge of social affairs in the Executive Committees of the Villages.

2.4 Site 4: Shagasha Tea Estate, Rusizi District, Western Province

<u>Site description</u>

Administrative location

The Shagasha Tea Estate is located predominantly in the Rusizi District of the Western Province. The tea factory itself lies within the Giheke Sector, while the entire estate extends into the Nkungu Sector. A small area of the estate is located in the Ruharambuga Sector of the Nyamasheke District, which also falls within the Western Province. In the Giheke Sector, the estate covers parts of the Giheke and Kigenge Cells. In the Nukungu Sector, the estate falls within the Ryamuhirwa and Kiziguro Cells, and in the Ruharambuga Sector the plantation covers a small section of the Save Cell. Figure 61 below illustrates the administrative location of the Shagasha tea plantation and factory.

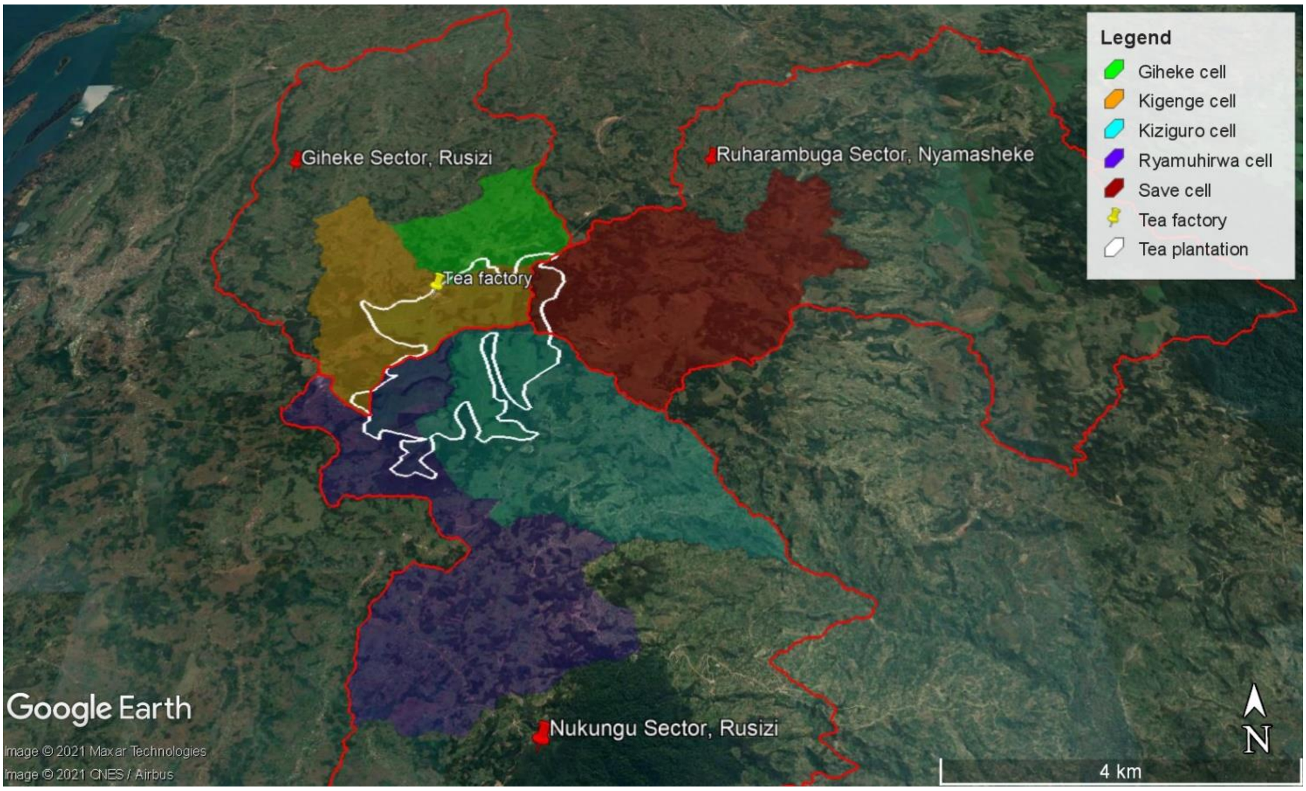


Figure 61. Administrative location of the Shagasha Tea Estate, including the locations of the factory and the plantation, as well as the administrative cells and sectors the estate falls within. Map generated on Google Earth Pro. Administrative borders downloaded from World Bank dataset[274]. Tea factory location and tea plantation border provided by Theogene Habakubaho.

Climate and climate threats

Mean annual precipitation within the Giheke Sector — in which the Shagasha Tea Factory is situated — is ~1,329 mm (Figure 62)[275], mostly split across short and long wet seasons (435 mm and 565 mm respectively, Figure 63). This precipitation has shown a decline during both wet seasons between 1981–2017, and particularly the short, wet season (March–May) (Figure 64 and Figure 65). Peak tea production in the area is reduced during the wet seasons. Sensitive to periods of intense rainfall, efficient tea production requires a certain amount of rainfall to be distributed evenly throughout the

[274] https://datacatalog.worldbank.org/dataset/rwanda-admin-boundaries-and-villages
[275] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

year. Rainfall variability can therefore negatively affect tea production. If it is too dry during the planting season (September to December), planting is delayed, adversely affecting seedling growth. In addition, little or too much rain prevents the application of fertilisers, negatively affecting the quality and quantity of tea produced by mature plants. Extended dry seasons have a severe impact on soil moisture content, adversely affecting production in the following season. In addition, in terms of pests, the red spider mite (*Tetranychus urticae*), although not currently a major problem for the tea industry, increases in abundance during the dry season, causing damage to mature plants.

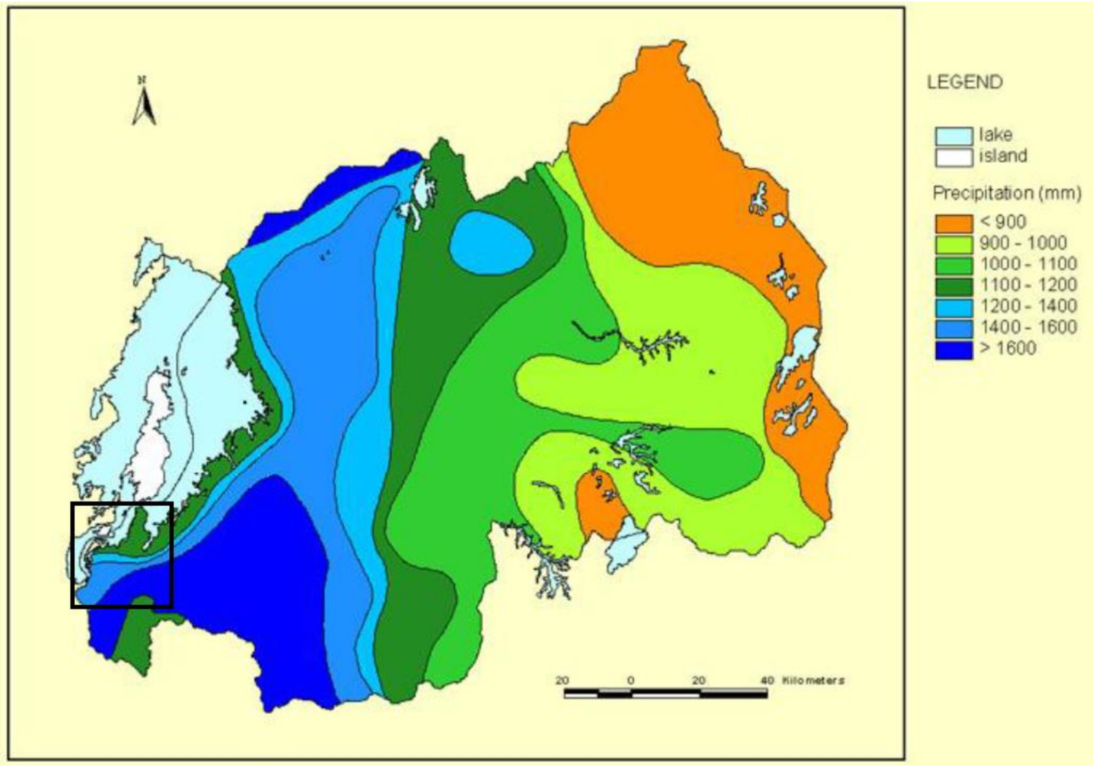
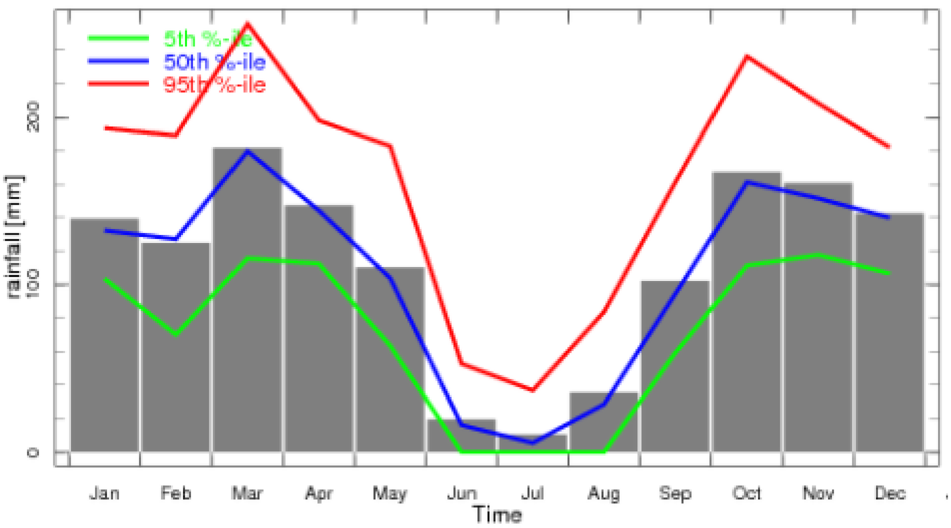


Figure 62. Annual average rainfall for Rwanda[276]. The Shagasha Tea Factory pilot site is indicated with a black square.



[276] Verdoodt A & van Ranst E. 2003. Land evaluation for agricultural production in the tropics. A large-scale land suitability classification for Rwanda.

Figure 63. Average monthly rainfall (mm) for the Giheke Sector [277].

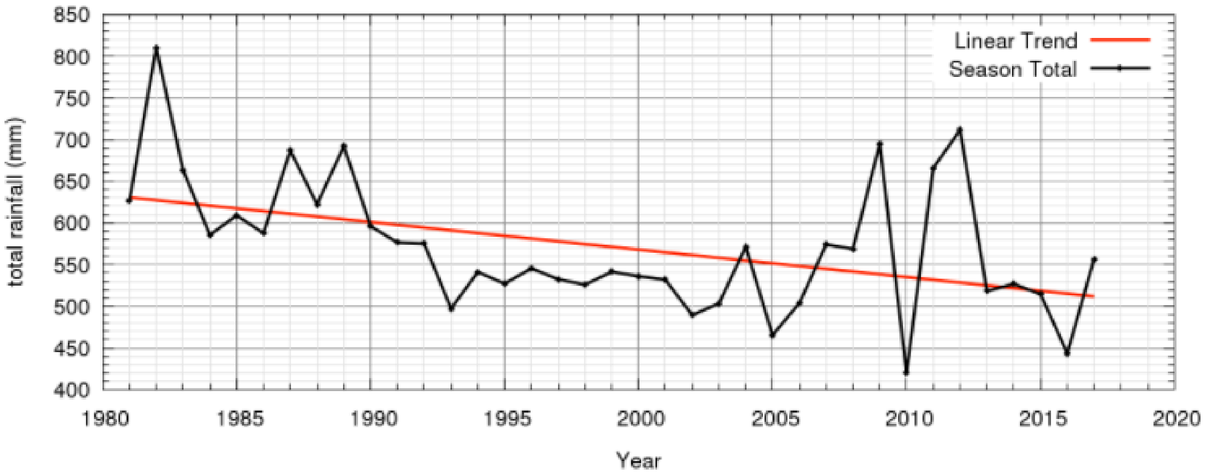


Figure 64. Trend in total seasonal rainfall from March–May for the Giheke Sector[278].

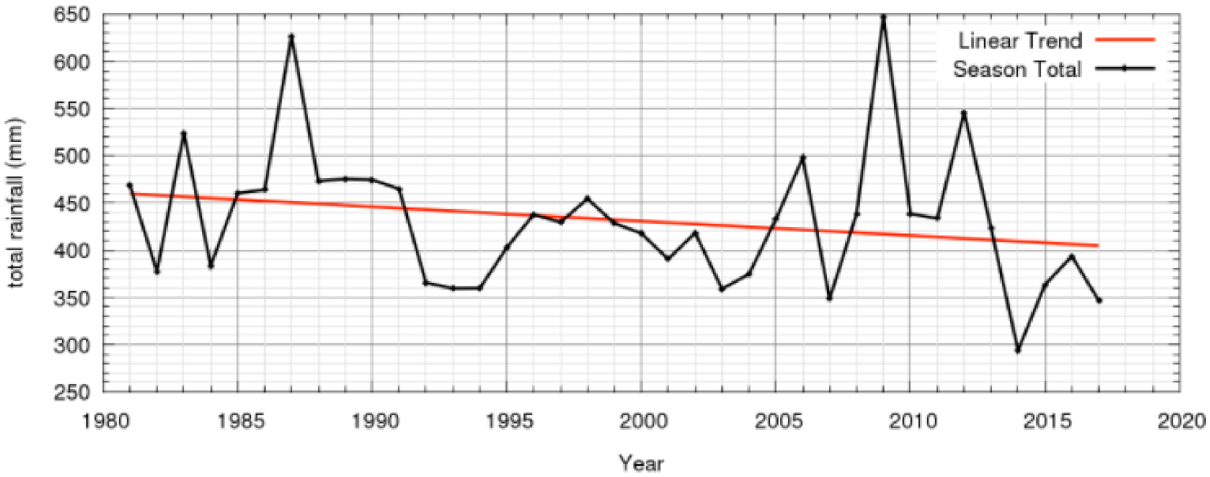


Figure 65. Trend in total seasonal rainfall from September–December for the Giheke Sector[279].

Average annual temperatures within the Shagasha Tea Estate are between 15–18°C (Figure 66). The average maximum temperature for the Giheke Sector is ~25°C, while the average minimum temperature is ~15°C[280] (Figure 67 and Figure 68). At present, the ideal temperatures for tea production in Rwanda are between 18–20°C, which are characteristic of altitudes between 1,600 and 2,200 masl. Such temperatures are consistent throughout the year in the southwest, allowing tea to be harvested throughout the year. Most tea production in Rwanda occurs in valleys (rather than on slopes), exposing them to frost damage — particularly alongside streams — on the coldest days of the year[281] (such damage has been recorded at Shagasha).

[277] Meteo Rwanda. 2020. Climate Summary for Local Governments: Giheke Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%403605%3Ads#tabs-1.
[278] Meteo Rwanda. 2020. Climate Summary for Local Governments: Giheke Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%403605%3Ads#tabs-1.
[279] Meteo Rwanda. 2020. Climate Summary for Local Governments: Giheke Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%403605%3Ads#tabs-1.
[280] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[281] July

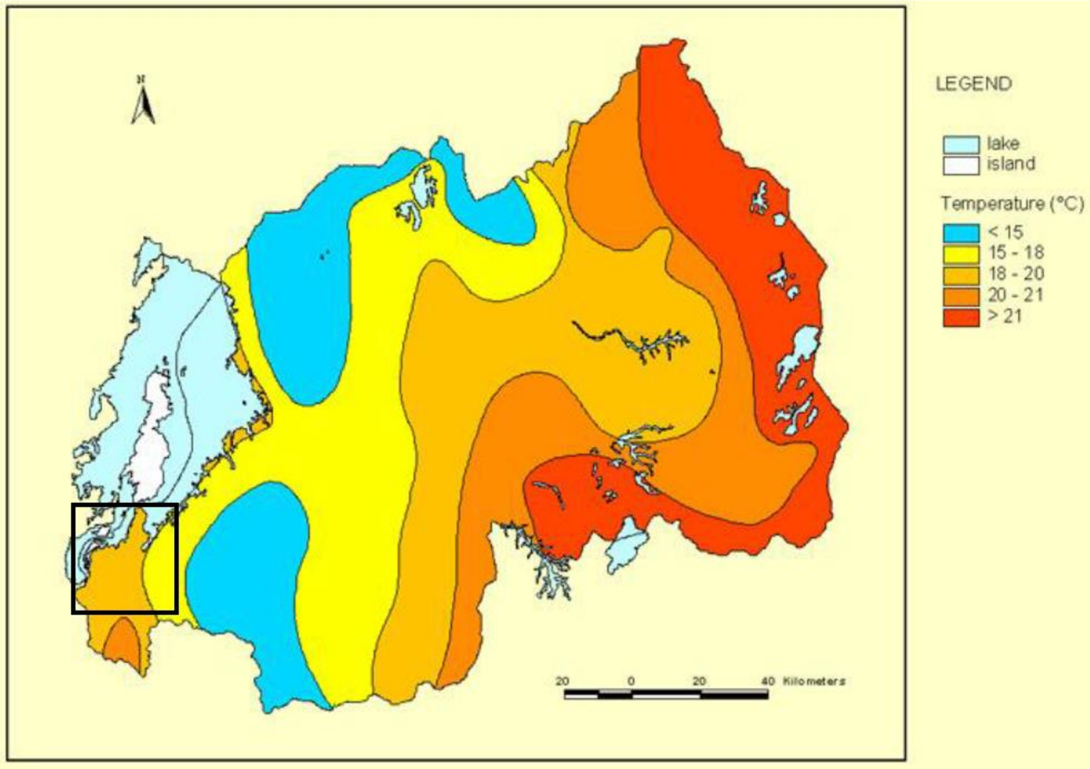


Figure 66. Annual average temperature for Rwanda[282]. The Shagasha Tea Factory pilot site is indicated with a black square.

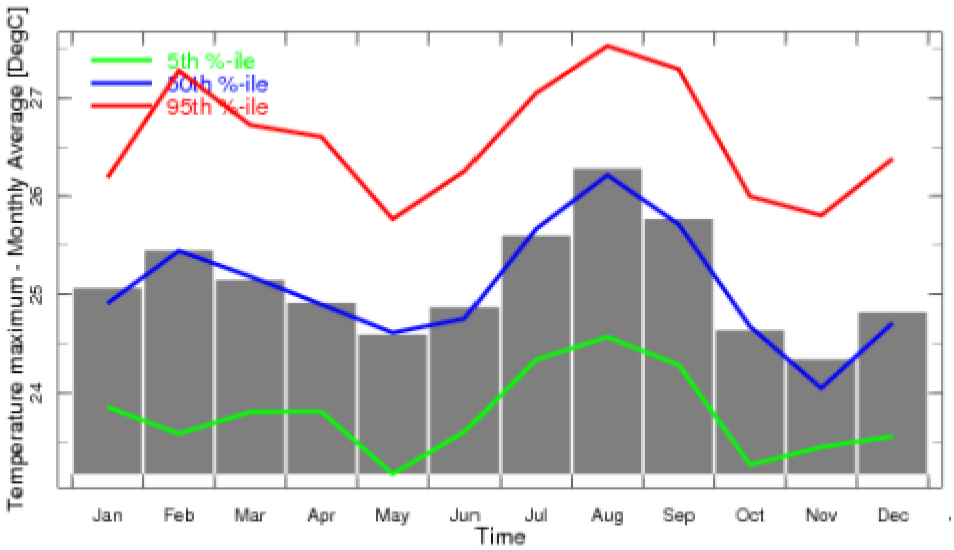


Figure 67. Average monthly maximum temperature (°C) for the Giheke Sector [283].

[282] Verdoodt A & van Ranst E. 2003. Land evaluation for agricultural production in the tropics. A large-scale land suitability classification for Rwanda.
[283] Meteo Rwanda. 2020. Climate Summary for Local Governments: Giheke Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%403605%3Ads#tabs-1.

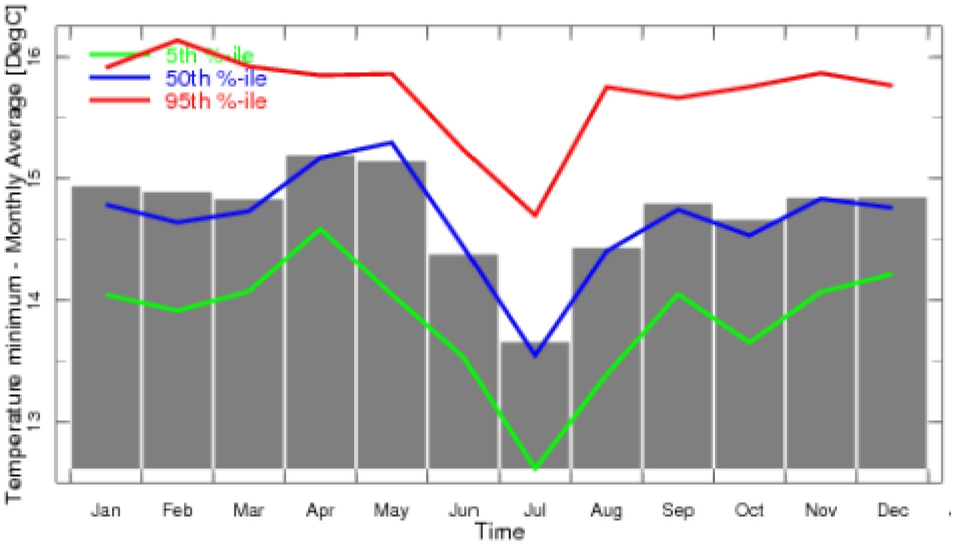


Figure 68. Average monthly minimum temperature (°C) for the Giheke Sector [284].

Periods of heavy rainfall lead to reduced soil fertility because of the associated erosion, flooding and landslides. In 2012, flooding in Rusizi resulted in three deaths, 341 homes damaged or destroyed and affected 125 ha of cropland[285]. This pilot area also has a moderate to high susceptibility to landslides based on the steepness of slopes in the area and high rainfall amounts compared with most of the country. Approximately 200–300 individuals in Rusizi are vulnerable to landslides related to moderate to very high slope susceptibility. Another climatic hazard is windstorms with gale force winds (72–79 km/hr) every 5 years and storms with strong gale force winds (79–100 km/hr) every 10 years[286]. In 2013, windstorms in Rusizi resulted in one death, 199 damaged or destroyed homes and 235 ha of damaged cropland.

Ecosystem profile

While there is little information available online regarding vegetation around the tea estate itself, the nearby Nyungwe National Park is likely to be a useful baseline/information source for the agroforestry intervention proposed for the Shagasha site, particularly since the forest in Nyungwe contains many plant species that have traditional uses[287]. The major natural ecological system in the Shagasha Tea Estate is the Shagasha Natural Forest, a six-hectare, isolated montane forest at an altitude of 1,950 masl. The forest is located in a depression near the Shagasha Tea Factory, and is a secondary forest dominated by tree species such as river macaranga (*Macaranga kilimandscharica)* and false assegai (*Maesa lanceolata)*. Some primary tree species, such as forest newtonia (*Newtonia buchannani*) and dwarf umbrella tree (*Strombosia schefflera),* are still present particularly along a stream that crosses the forest. There is also a swamp located in the centre of the forest. The forest belongs to one of the Shagasha tea farmers' cooperatives (COOPTHE Shagasha) and it has been largely protected from deforestation because it harbours water sources (the stream and swamp) that supply almost all the water used in the factory. Despite this, some people have started cultivating in the northern part of the central swamp. The remainder of the Shagasha Tea Estate is occupied by tea plantations, agricultural land and woodlots/planted forest

[284] Meteo Rwanda. 2020. Climate Summary for Local Governments: Giheke Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%403605%3Ads#tabs-1.
[285] MIDIMAR. 2015. The national risk atlas of Rwanda.
[286] MIDIMAR. 2015. The national risk atlas of Rwanda.
[287] https://www.nyungweforestnationalpark.org/flora-fauna-wildlife-nyungwe-forest-national-park/.

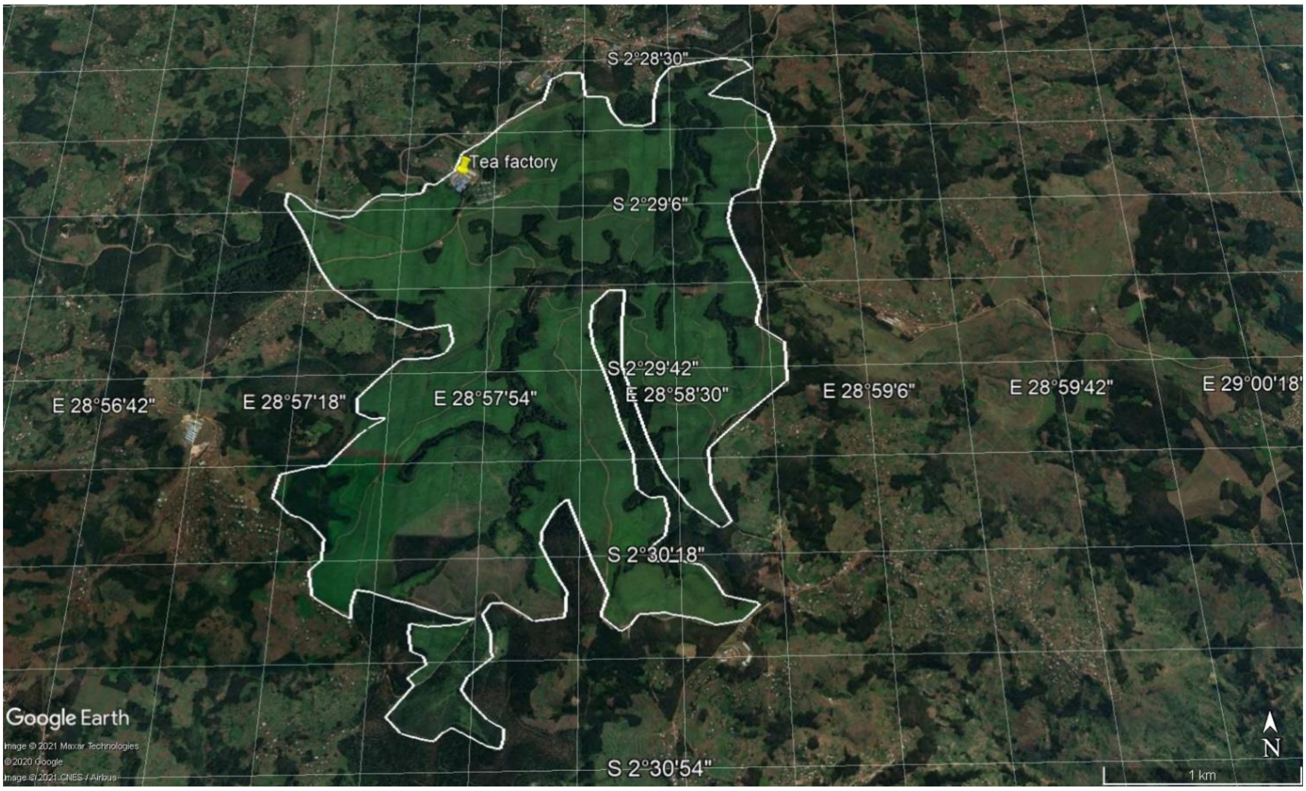


Figure 69).

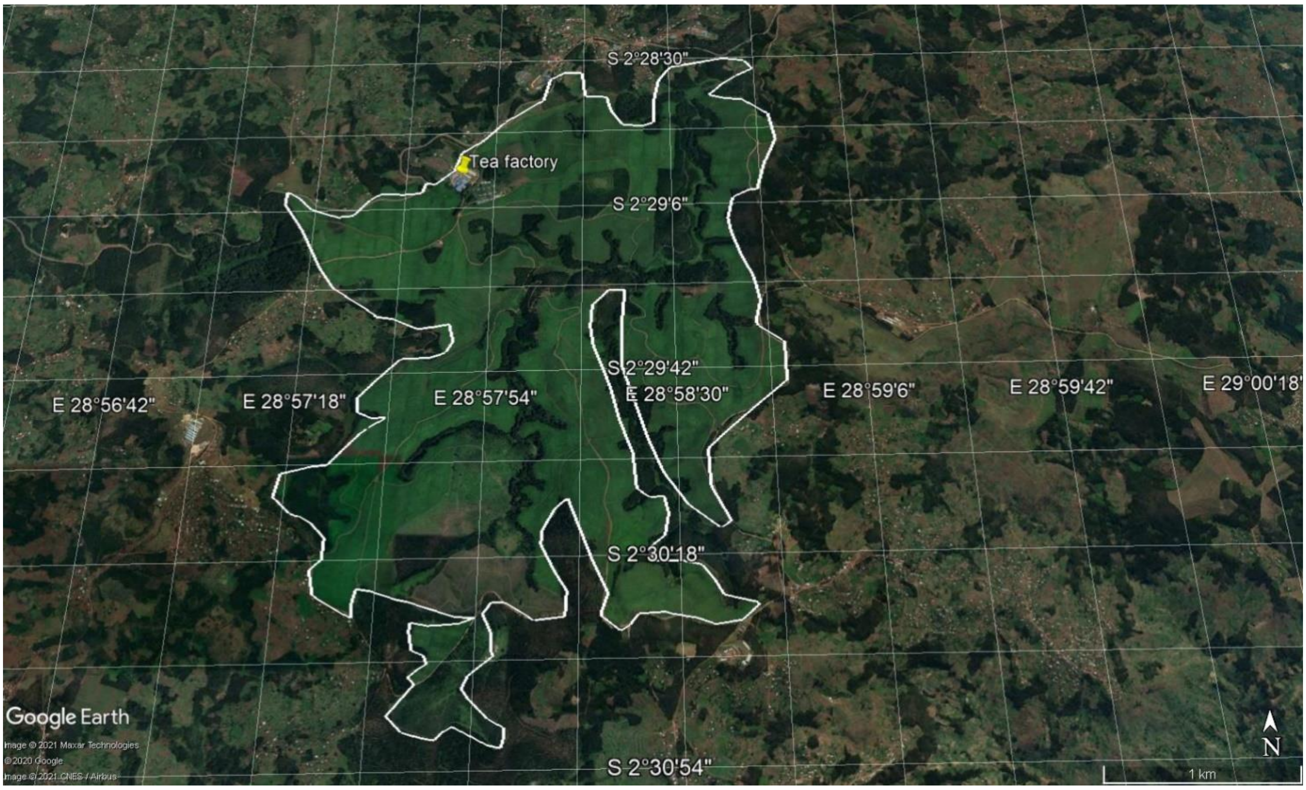

S 2°28'30"
Tea factory
S 2°29'6"
S 2°29'42"
E 28°56'42"
E 28°57'18"
E 28°57'54"
E 28°58'30"
E 28°59'6"
E 28°59'42"
E 29°00'18"
S 2°30'18"
S 2°30'54"
Google Earth
1 km
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Figure 69. Map of the Shagasha Tea Estate (area enclosed in white line). Darker green areas are the remaining patches of the Shagasha Forest, which is located in a depression and which contains streams supplying water to the estate. Source of Tea Estate boundary and factory location: Theogene Habakubaho.

Shagasha Forest is also characterised by native tree species such as woodland waterberry (*Syzygium guineense),* peacock flower (*Albizia gummifera), Dichaetanthera corymbose* and forest fever tree (*Anthocleista grandiflora)*. These species in turn provide habitat for numerous epiphytes such as orchids, mosses, ferns and lichens. Despite its small size, Shagasha Forest is similar to Nyungwe Forest, and supports a rich floral diversity and harbours some endangered species, including L'Hoest's monkey (*Allochrocebus lhoesti*), which is also found in the eastern side of Nyungwe forest. According to local communities, there is also a small population of silver monkeys (*Cercopithecus dogetii)* in the Shagasha Forest. These primates are very isolated from other groups found in Nyungwe Forest and require special attention for their protection to avoid genetic drift.

Baseline drivers and extent of ecosystem degradation

The Rusizi District loses 14 million tonnes of soil through erosion annually, which contributes 2.3% of Rwanda's national annual soil erosion[288]. Intensive agriculture and resultant deforestation are the main causes of this erosion. Monocrops likely contribute substantially to this degradation and consequent loss of ecosystem services such as soil erosion control. Limited land availability, as in most areas of the country, is also a major driver of degradation. In addition, ecosystem degradation in the Shagasha area — particularly on hillslopes and mountainsides — results from the fact that the ideal temperature range for tea crops is 18–20°C, which means higher elevation areas with lower temperatures are favoured for tea plantations. Therefore, many plantations occur in ecologically and topographically diverse mountainous areas, which are also more prone to soil erosion, ad which leads to flooding in the valleys below. The harvesting of firewood used in tea treatment is also a major driver of degradation in the forests in the Shagasha area.

Topography

The Shagasha Tea Factory is located in the lowlands of the Bugarama plain which has an altitude of ~900 m and forms part of the African Rift Valley tectonic depression[289]. The Shagasha area appears to have a low slope percentage that mostly do not exceed 20% (Figure 70), while the highest points of the area are in the western portion closer to Lake Kivu with areas above 40% slope category.

Figure 70. Images of the Shagasha Tea Plantation topography, showing hills and plains. Source: Theogene Habakubaho.

In terms of soil, the predominant soil type is basalt which is generally permeable and rich in iron. The soil is less acidic, with an average availability of clay. At some points on the shores of Lake Kivu,

[288] Karamage F, Zhang C, Ndayisaba F, Shao H, Kayiranga A, Fang X, Nahayo L, Muhire Nyesheja E & Tian G. 2016. Extent of cropland and related soil erosion risk in Rwanda. *Sustainability*. 8: 609.
[289] Ministry of Agriculture and Animal Resources. 2009. Land husbandry, water harvesting and hillside irrigation (LWH) project.

some phyllodes-derived soils, clay and sand with quartz crystals as well as other easily erodible type of soils exists. The soil of the area is generally fertile and several types of crops can be grown productively with appropriate agricultural practices in place.

Land uses

The agricultural sector in Rwanda contributes a third of the country's GDP and provides ~80% of its employment. In the Rusizi District — where the Shagasha Tea Factory is located — 75% of land is dedicated to agricultural production through crops[290]. The plantations around the Shagasha Tea Factory primarily grow tea (see Figure 71 below) which is a particularly valuable crop because of its considerable export value and contribution to ~20% of Rwanda's total exports. The sustained development of the tea industry in Rwanda is therefore a major priority for the GoR. Strategic sub-programme 3.3 of the Agriculture Sector Investment Plan (ASIP2) focusses on the development of value chains for export crops, including those related to tea. An essential part of the plan is improving the quality of tea, allowing it to be sold on specialised markets for higher prices than that sold on bulk commodity markets. However, tea quality is extremely sensitive to changes in climatic conditions.

Figure 71. Shagasha Natural forest and planted forest around tea plantation. Source: Theogene Habakubaho.

Rwanda's tea sector has significant potential to benefit large numbers of poor people. The crop is already Rwanda's second most significant export earner and is a vital source of income for more than 30,000 smallholders and 60,000 households across 11 of the 30 districts in the country. These smallholders produce more than 65% of Rwanda's tea. Moreover, Rwanda produces among the highest quality tea in global markets, giving it a strong base to further develop international competitiveness.

In addition to crop production, livestock is another important source of income and food for agricultural households in the Rusizi District. Approximately 63% of all households in the district raise some type of livestock, ranking it second last among all Western Province districts (after Rubavu District) on this indicator, likely because of the relative importance of crop agriculture in this area.

Hydrological profile

The Shagasha Tea Factory is located in the Lake Kivu catchment, which is a transboundary catchment with the DRC[291]. This catchment consists of a number of smaller catchments that drain into Lake Kivu, which is the major water body in the area. One of the rivers identified is the Cyongoroka River which flows along the eastern boundary of the urban area. The pilot area has a relatively large

[290] GoR. EICV3 District Profile: Rusizi.
[291] Rwanda Environment Management Authority. 2015. Rwanda: State of environment and outlook report 2015.

number of wetlands found within valleys between hills which are mostly cultivated, with tea comprising the majority of the cultivated land.

Local communities

There are currently two cooperatives of smallholder farmers that utilise the Shagasha Tea Factory: COOPTHE Shagasha and The Villageois/Umacyagi. Please consult the 'Community organisations and structures' section below for further detail on these cooperatives and how they operate.

Demographics

The estimated total population of Rusizi District is 417,000. This represents 16% of the total population of the Western Province and 4% of the total population of Rwanda. Rusizi District has a young population, with ~82% of the population younger than 40 years old. It has the largest average household size of all districts in Rwanda, at ~5 persons per household. Women comprise 53% of the district's population[292].

Poverty levels

In the Rusizi District, 55% of the population is classified as non-poor, with ~45% of the population classified as living in either poverty or extreme poverty. In Rwanda, the poverty line refers to a minimum food consumption basket offering the required nutrients for a Rwandan likely to be involved in physical labour, along with an allowance for non-food consumption (RWF 118,000). Extreme poverty refers to the cost of buying an equivalent food consumption basket if no non-food consumption occurred. Currently, the extreme poverty line in Rwanda is at RWF 83,000. Approximately 20.5% of the population of Rusizi District are classified as 'poor', with ~24.5% living in extreme poverty.

Education levels of the Rusizi District population are as follows:
- no education: ~66%;
- primary: ~23%;
- post-primary: ~3.5%;
- lower secondary: ~3.5%;
- upper secondary: ~2.2%; and
- university: ~1.3%[293].

Livelihoods

The Shagasha Tea Factory and surrounding plantations form part of the Imbarutso[294] partnership model (initiated in 2012) between the Wood Foundation (jointly funded by the Gatsby Foundation) and ~12,000 smallholder farmers. Imbarutso is designed to strengthen the competitiveness of Rwanda's tea industry and ensure that smallholders benefit from the resulting growth. The partnership works with the GoR, the private sector (including investments from Unilever[295]), cooperatives and smallholder farmers to increase their margins[296]. Smallholder farmers affiliated with the partnership are all shareholders in the tea factory. These shareholders will eventually take complete ownership

[292] GoR. EICV3 District Profile: Rusizi.
[293] GoR. 2017. Economic Activity Report. EICV5: The Fifth Integrated Household Living Conditions Survey 2016/2017. https://www.statistics.gov.rw/publication/eicv5thematic-reporteconomic-activity-thematic-reportpdf.
[294] A Kinyarwandan word meaning "to catalyse".
[295] Unilever. 2020. Sustainable tea — leading the industry. Available at: https://www.unilever.com/sustainable-living/reducing-environmental-impact/sustainable-sourcing/sustainable-tea-leading-the-industry/.
[296] Available at: https://www.thewoodfoundation.org.uk/making-markets-work-for-the-poor/rwanda/imbarutso/. Accessed on 19 February 2018.

of the tea factory. The tea factories and plantations under the partnership account for ~25% of Rwanda's tea production, most of which is shipped to Pakistan[297].

In Rusizi District, the overall employment rate of the resident population aged 16 and above is ~78% (the national average is ~84%). The unemployment rate is 0.6% (national average: ~0.9%) and the economic inactivity rate ~22% (national average: ~15%). In terms of income source, district data show that household income is driven by agriculture (~44%), followed by wage income (~23%), business income (~16%), rents (~10%) and private transfers (6.7%). The smallest contributor to household income in Rusizi District is public transfer income (1%).

Along with crop production, livestock is another important source of income and food for agricultural households. Approximately 63% (~68% at the national level) of all households in Rusizi District raise some type of livestock, ranking it second lowest among all Western Province districts on this indicator. The Girinka program[298] (also known as 'One Cow per Poor Family') has increased the number of cows that produce milk countrywide, including in Rusizi.

Land tenure arrangements

Approximately 75% of households in Rusizi own land to grow crops, and for the majority of households (~89%) this land is smaller than 2 ha[299]. Shortage of land constitutes a major challenge for agriculture and agro-production development, not only in Rusizi District but also in other areas of Rwanda. According to consultations with cooperative representatives, the small size of land is a constraint to the expansion of tea plantations in the Shagasha area.

Smallholder farmers affiliated with the Imbarutso partnership are all shareholders in the tea factory and will eventually gain its complete ownership. The cooperatives will need to play a significant role in the implementation of the EbA interventions, given that most of the proposed interventions will be implemented on their lands, and they are the direct beneficiaries. Representatives of these cooperatives expressed their preference for a community-based implementation approach, similar to how the tea plantation itself is managed.

Access to resources

See 'Ecosystem profile' section above regarding access to water sources.

Reliance on ecosystem services of local communities

Local communities rely on ecosystem services such as soil erosion prevention/slope stabilisation to protect their crops and households during the rainy seasons. The Rusizi District as a whole loses 14 million tonnes of soil to erosion annually[300]. Furthermore, the quality of water in the Shagasha forest also depends on healthy ecosystem functioning, as it is the major water source for the factory and for communities around the forest.

Community organisations and structures

As mentioned under the 'Livelihoods' section above, the Shagasha Tea Factory and surrounding plantations form part of the Imbarutso partnership model between the Wood Foundation and ~12,000

[297] The New Times. 2019. Rwanda targets over Rwf90billion from tea exports. Available at: https://www.newtimes.co.rw/news/rwanda-targets-over-rwf90bn-tea-exports
[298] UNICEF. 2012. Equity case study: Rwanda — One Cow per Poor Family. Available at: https://sites.unicef.org/equity/archive/index_65274.html
[299] GoR. EICV3 District Profile: Rusizi.
[300] Karamage F, Zhang C, Ndayisaba F, Shao H, Kayiranga A, Fang X, Nahayo L, Muhire Nyesheja E & Tian G. 2016. Extent of cropland and related soil erosion risk in Rwanda. *Sustainability*. 8: 609.

smallholder farmers. The Kenya Tea Development Agency (KTDA) — the world's largest producer of smallholder tea — was contracted to serve as the initial management agent for the tea factories. KTDA manages 66 Kenyan tea processing outlets on behalf of smallholder farmers, representing about 600,000 farmers and producing about 12% of the world's black tea. The Wood Foundation/ Gatsby Foundation have since recruited leading tea experts with global experience to fill the key management positions of the factory. They are responsible for providing professional field and factor management services and running a formal capacity-development programme to ensure the gradual transition to 100% Rwandan-staffed factories over time[301].

At present, the Shagasha Tea Factory is managed by the Wood Foundation, who own 60% of the factory's shares. The remaining shares are split between the cooperatives of smallholder farmers (20%) and the GoR (20%). The major role of factory management is to support the government's vision to develop the Rwandan tea industry, while assisting the Rwandan tea farmers to expand their tea crops and to increase the quality and quantity of green leaf production through strengthening the capacity of Rwandan tea growers and management. Factory management also oversees the purchase of green tea, treatment of green leaves and marketing of the finished product. In addition, it provides technical support to farmers, including the production of seedlings and extension services provided by agronomists.

The Wood and Gatsby Foundations will fully exit and transfer their shares over to the farmers when the investment has been repaid and the smallholders have met key performance indicators on management, governance and transparency, leaving in place professionally run factories that are fully owned by smallholders. This approach should considerably raise the incomes of the farmers involved. Moreover, if successful, the approach potentially provides a model for the privatisation of other factories and the development of new sites in Rwanda.

Cooperatives in Shagasha Tea Estate

There are two cooperatives of smallholder farmers within the Shagasha Tea Estate: COOPTHE Shagasha and The Villageois/ Umacyagi. COOPTHE Shagasha owns 37% of the tea plantation's land, while The Villageois/ Umacyagi own 62%. The remaining 1% is owned by the Shagasha Tea Factory itself.

<u>COOPTHE Shagasha</u>

COOPTHE Shagasha is a cooperative with 832 members, including 541 men (~65%) and 291 women (~35%). Its tea plantations cover 515 ha lying on the tea estates blocks of Rwamiko, Nyarushishi and Gatantandara. The cooperative has a General Assembly that is its main governing and decision-making body, which meets three times a year. The General Assembly has 43 delegates, including 13 women and 30 men, elected for a term of three years by all members in different areas of the tea perimeter. The General Assembly also sets up and oversees the Board of Directors and the Surveillance Commission.

<u>The Villageois/Umacyagi</u>

The Villageois/Umacyagi is a cooperative with 4,032 members, of which ~58% are men and ~42% are women. Its collective tea plantation area is ~734 ha, covering tea estate blocks in the Rusizi and Nyamasheke Districts in the sectors of Giheke, Nkungu, Nyakarenzo, Mururu, Kamembe, Gihundwe, Shangi, Bushenge, Ruharambuga and Karengera. Each farmer has its own plantation and supplies the production to the factory through the cooperative. The cooperative is managed by a board of five, which serve for three years. Similar to COOPTHE Shagasha, meetings are held three times annually. The Villageois/Umacyagi also has a General Assembly that oversees the Board of Directives.

[301] https://www.gatsby.org.uk/africa/programmes/rwandan-tea-sector.

Infrastructure and services available at the site

The Shagasha Tea Factory is used for the production of tea from the produce of the surrounding communities' tea plantations, and accounts for 25% of Rwanda's national tea production. The management of the factory comprises tea production experts hired by the Wood and Gatsby Foundations, whose services are being used to build the capacity of the local tea farmers that will ultimately take ownership of the factory and its operations.

Climate change problems that the EbA interventions will address

Future climate change is expected to result in increases in average temperatures and exacerbate rainfall variability in Rwanda, including the Rusizi District. Long-lived climate-sensitive crops such as tea are particularly threatened by such changes as they take several years to mature and the pay-back period per plantation is approximately 15 years. The most notable effect of climate change on tea is a rise in temperatures, which will affect the suitability of where tea is grown. Under a RCP8.5 scenario, temperatures are expected to increase in the Rusizi District by 1.7–2.1 between 2040–2059 and 3.4–4.6 between 2080–2099 compared with historic values (1986–2005) (Figure 72 and Figure 73)[302]. Lower lying areas in particular are predicted to become hotter, decreasing the productivity and quality of tea production. Conversely, tea production in higher lying areas that are currently too cold may become possible. However, planting tea at higher altitudes may increase their exposure to frost, resulting in production declines.

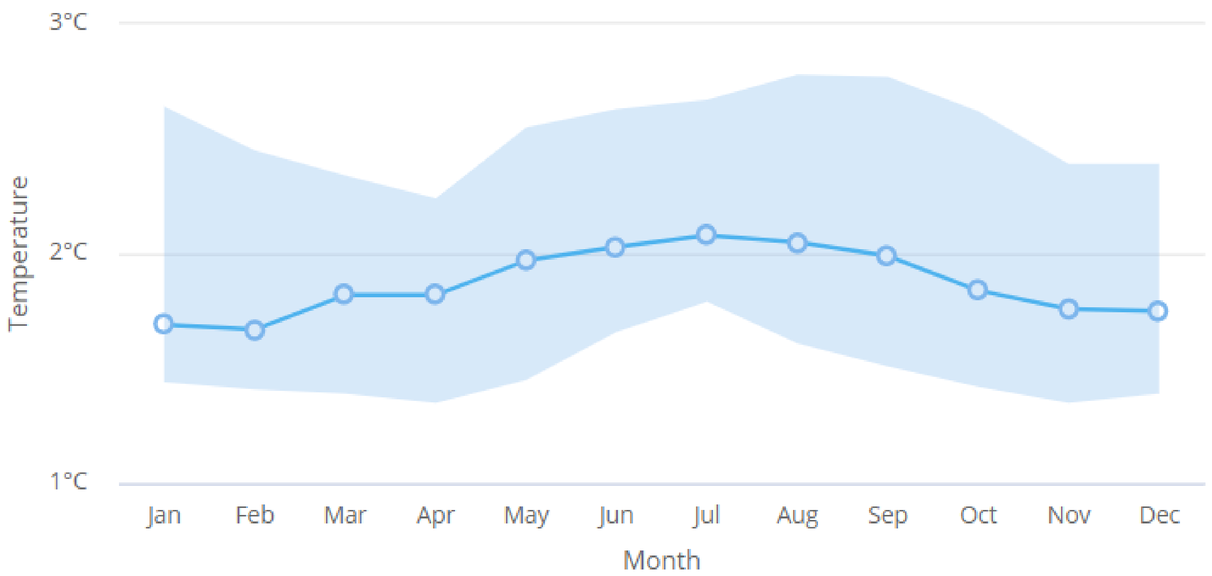

Figure 72. Projected change in monthly temperature (°C) for the Shagasha Tea Factory area from 2040–2069 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[303] (GCMs)[304].

[302] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

[303] IPCC. 2014. Fifth Assessment Report.

[304] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

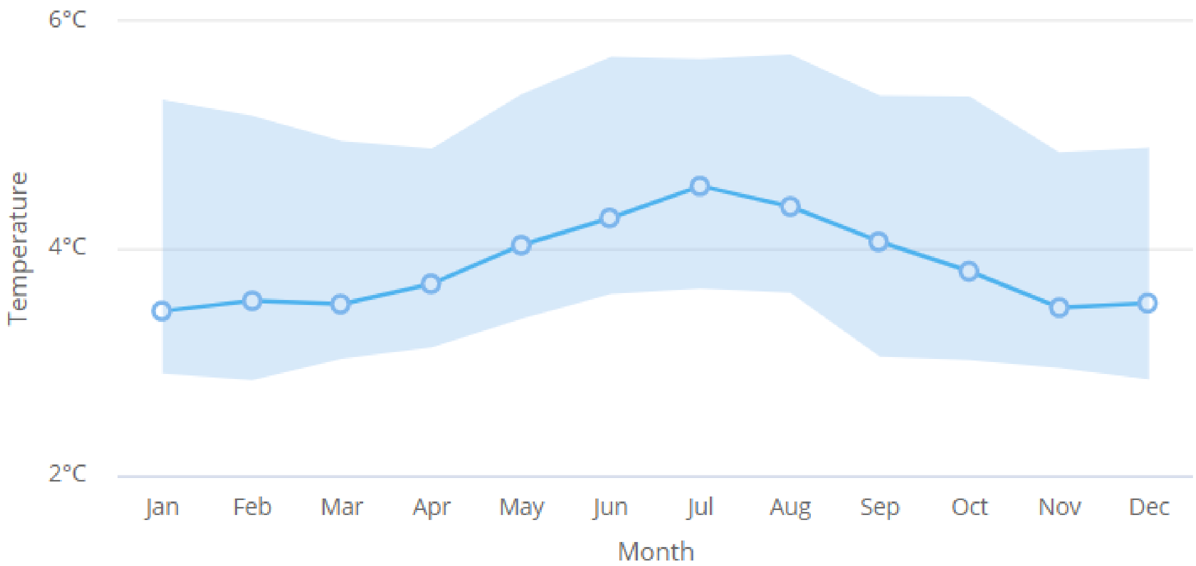

Figure 73. Projected change in monthly temperature (°C) for the Shagasha Tea Factory area from 2080–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[305] (GCMs)[306].

Regarding an increase in rainfall variability, projections indicate an increase in the frequency and intensity of heavy rainfall events, compounding problems such as soil erosion and fertiliser application mentioned above. During the shorter wet season (March–May), rainfall is expected to increase by 12 mm between 2040–2059 compared with historic values, while rainfall in the longer wet season (September–December) in the same time period is predicted to increase by 19 mm (Figure 74)[307]. Between 2080–2099, rainfall is expected to increase by 30 mm in the shorter wet season and 112 mm during the longer wet season (Figure 75). The percentage rainfall during very wet days is also expected to increase by 22% between 2040–2059 and 60% between 2080–2099, indicating more intense heavy rainfall events and increased flooding (Figure 76). The variability between dry and wet months will also increase, with the range predicted to be 35 mm between 2040–2059 and 69 mm between 2080–2099 (Figure 77). In addition, the dry season is expected to lengthen, negatively affecting tea production and exacerbating the impact of the red spider mite.

[305] IPCC. 2014. Fifth Assessment Report.

[306] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

[307] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

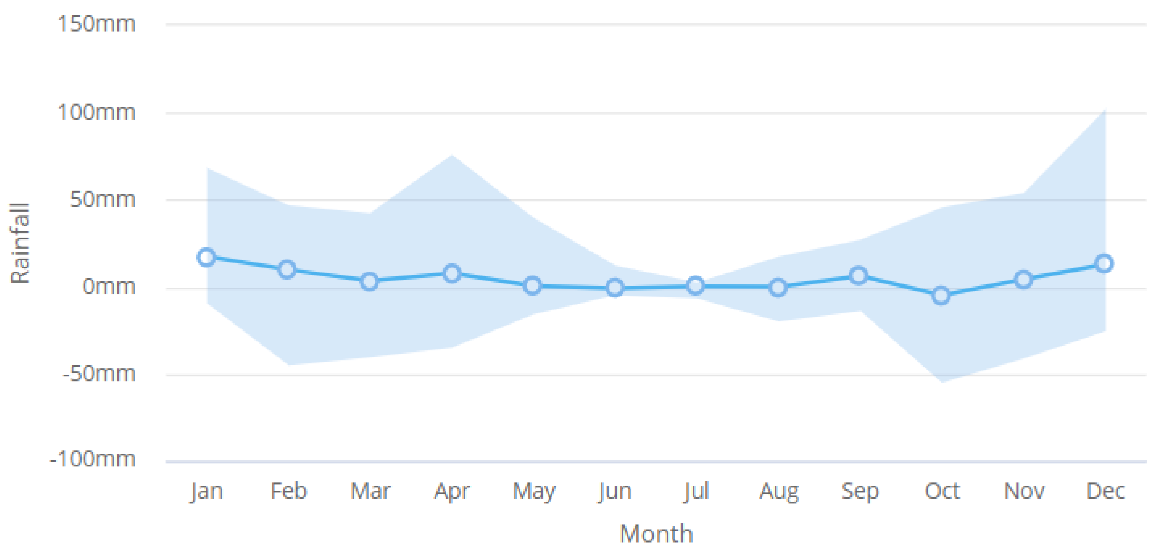

Figure 74. Projected change in monthly rainfall (mm) for the Shagasha Tea Factory area from 2040–2059 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[308] (GCMs)[309].

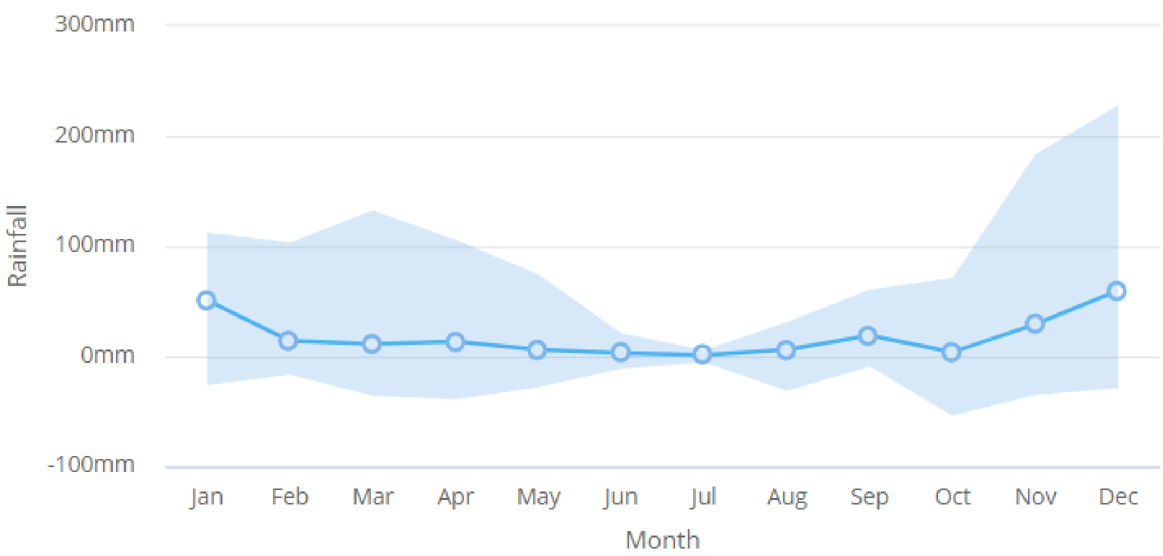

Figure 75. Projected change in monthly rainfall (mm) for the Shagasha Tea Factory area from 2080–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[310] (GCMs)[311].

[308] IPCC. 2014. Fifth Assessment Report.
[309] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#
[310] IPCC. 2014. Fifth Assessment Report.
[311] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

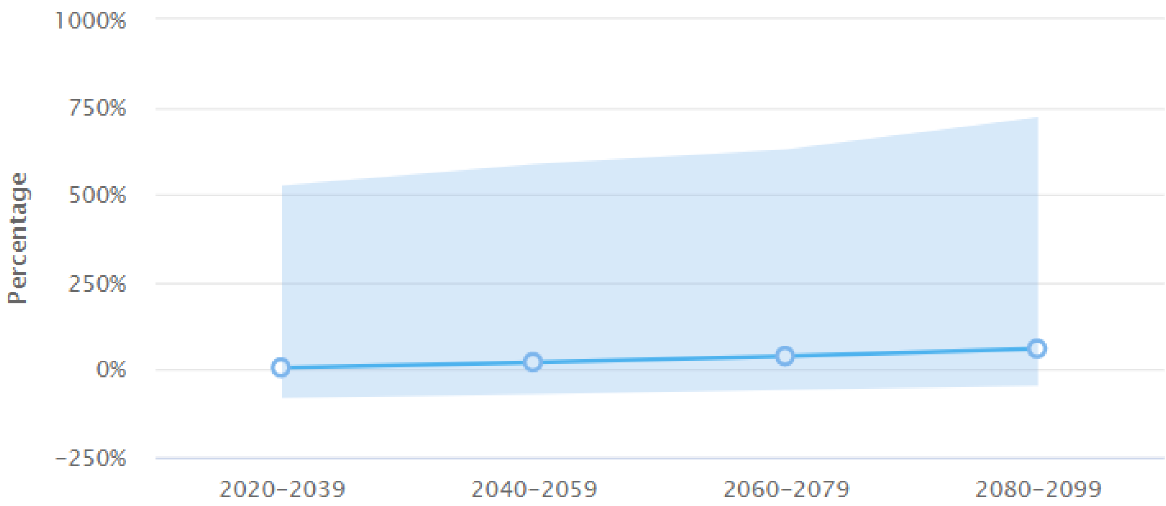

Figure 76. Projected change in rainfall of very wet days (%) for the Shagasha Tea Factory area from 2020–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[312] (GCMs)[313].

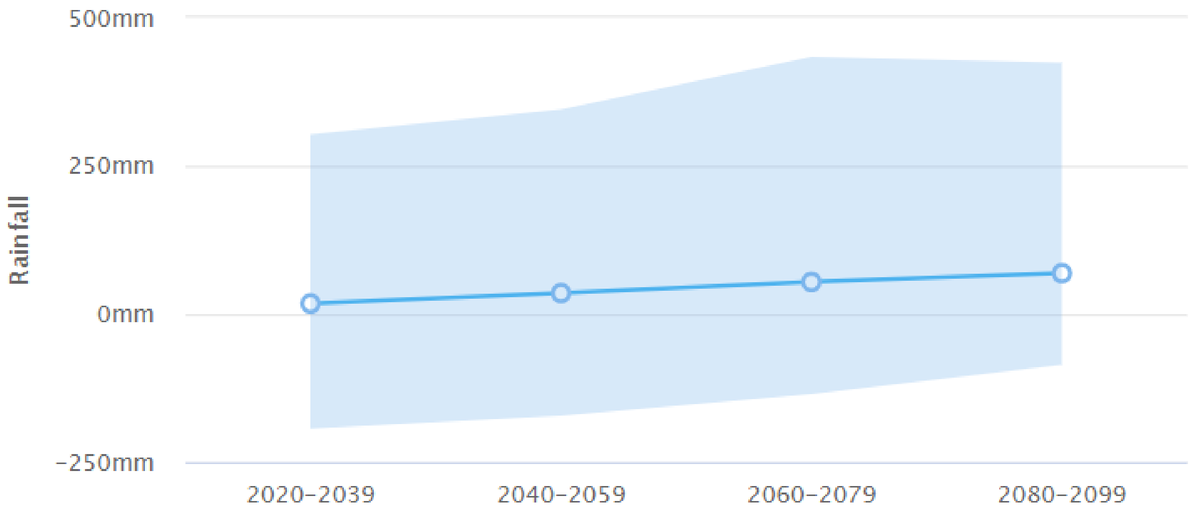

Figure 77. Projected change in the annual range of monthly rainfall (mm) for the Shagasha Tea Factory area from 2020–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[314] (GCMs)[315].

Detailed description of interventions

All the stakeholders consulted including experts, district officers, factory management and cooperative representatives provided input on the feasibility and viability of proposed interventions (reducing water stress and soil moisture loss by planting drought-tolerant tree species, intercropping, and plantation of grasses on verges of tea plots). They provided suggestions on the design of these interventions, as well as proposed additional interventions. Their input is summarised below.

Initially proposed NAP interventions

[312] IPCC. 2014. Fifth Assessment Report.
[313] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#
[314] IPCC. 2014. Fifth Assessment Report.
[315] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

Reducing water stress and soil moisture loss through the planting of drought-tolerant tree species

This intervention was highly supported by all stakeholders consulted. Members from The Villageois cooperative expressed appreciation for the use of fruit tree species, while representatives from COOPTHE plantations as well as industrial blocks supported the planting of agroforestry trees that provide benefits in addition to fruit, such as wood and NTFPs. This intervention is therefore designed to accommodate both fruit and non-fruit multi-use tree species.

Intercropping

While the benefits of intercropping would include limiting soil moisture loss and erosion, as well as providing alternative food sources and income-generation opportunities, this intervention was received with some hesitation. Cooperative management indicated that current policy is to discourage intercropping because potential competition between tea and other crops may affect the tea plants. This intervention would therefore require strong technical support, training and follow up. The agroforestry intervention described above would also provide many of the same benefits as the intercropping intervention. It was therefore decided that intercropping not be implemented at the Shagasha Tea Estate, and that the budget could be better spent on addressing baseline drivers of ecosystem degradation around the plantation (further discussed in the 'Additional interventions suggested by stakeholders' sub-section below).

Plantation of grasses on the verges of tea plots

The purpose of this intervention is to bind soil, prevent erosion and reduce rainfall runoff, in addition to providing fodder for livestock. It was supported by all consulted stakeholders, and it was requested and recommended to extend this intervention to the edges of riverbanks and streams that run through the plantations. This request has been incorporated into the intervention's design.

Additional interventions suggested by stakeholders

- The tea factory management requested to be supported in the plantation of forest trees to meet the demand for fuelwood in factory operations. There is land of around 200 ha available for this activity. This intervention would reduce the pressure on remaining natural forests, including the Shagasha forest, and reduce the area of bare land around the tea estate, thereby reducing runoff and erosion. This intervention will be implemented instead of the initially proposed intercropping intervention, because by reducing the degradation of remaining natural forests it will strengthen the overall climate resilience of the Shagasha area.
- Given the large amount of firewood used in the factory, the factory management requested a study to be conducted on energy efficiency and alternative energy sources that can be used in factory operations. While this could be budgeted for as an activity under the project, stakeholders have raised that wood fires produce a specific tea flavour during the leaf-drying process. Rising temperatures in Rwanda are already a threat to tea quality, so it would be economically unviable to use an alternative energy source that further impacts tea quality or flavour. Instead, the inclusion of an intervention to establish woodlots to provide fuel has been evaluated as the preferred solution to reducing deforestation in the Shagasha area.

The planting of trees in the 200 ha of available land is a complementary intervention to the proposed EbA interventions as it will address the baseline degradation of the Shagasha forest, but is not an EbA intervention itself that would contribute to the climate change resilience of the tea estate (and was therefore not assessed in the MCA). The extension of grass planting to streams located in the tea plantations will be incorporated into the design of the grass-planting intervention. The final suggested additional activity — conducting an energy-efficiency study — is not an EbA intervention and therefore was also not assessed in the MCA, although it would assist in reducing forest degradation caused by unsustainable fuelwood collection.

Results of multi-criteria analysis (MCA)

Table 30 below indicates the results of the multi-criteria analysis for Shagasha Tea Estate. The list of interventions includes those proposed in the ProDoc and during stakeholder consultations, as well as additional interventions identified in the rapid options analysis. For more detail on the scoring of each intervention, please refer to the scorecard in Annex 2.

Table 30. Results of the MCA of EbA interventions for the Shagasha Tea Estate (score: 0 = unfeasible, 1 = perfect intervention).

Intervention assessed	Score
Reducing water stress and soil moisture loss through the planting of drought-tolerant tree species as a form of agroforestry	0.78
Plantation of grasses on the verges of tea plots for erosion control	0.77
Conservation and restoration of riparian vegetation along streams and wetlands to prevent channelisation of headwater streams	0.71
Conservation of remaining natural forests and restoring degraded forests around the plantation to increase shade and water infiltration	0.63
Intercropping	0.58

The interventions to establish agroforestry and plant grasses on tea plot verges scored the highest in the MCA. Conservation and restoration of riparian vegetation scored relatively high and will be integrated into the design of the grass-planting intervention. Conservation and restoration of remaining natural forests, as well as intercropping, scored relatively low in the MCA and will not be included in the final selected interventions. As discussed earlier, the establishment of woodlots around the Shagasha tea plantation will be implemented as an alternative intervention. Further details about the proposed interventions, including complementary interventions not assessed in the MCA (e.g. establishing woodlots) are provided in the sections below.

Reducing water stress and soil moisture loss through the planting of drought-tolerant tree species

Overview

The first EbA intervention proposed at Shagasha Tea Estate involves reducing water stress and soil moisture loss by planting multi-use, drought-tolerant tree species as a form of agroforestry (see the section on agroforestry in Ibanda-Makera for a detailed description of agroforestry, its benefits and best practices). This intervention will provide shade, which will reduce both soil moisture loss and ambient temperatures, as well as further limit runoff and erosion (tea plants are already strong binders of soil). In addition, in the lower lying plantations, the cover provided by trees will protect tea plants from frost. Agroforestry trees will also provide fuelwood (for cooking and for use in the tea-making process in the factory), which will address the baseline driver of ecosystem degradation — i.e. the cutting of natural trees around the estate for fuelwood. Additional benefits of the multi-use tree species include: i) fruit trees will provide additional food for smallholder farmers and supplement their income; ii) legumous trees will improve soil fertility through nitrogen fixation and thereby reduce the usage of fertiliser; and iii) all tree species will improve soil fertility and conserve soil moisture through the mulching of their leaves.

This intervention, and particularly the introduction of trees that provide fruits and other benefits, was highly appreciated by individual households that own tea plantations. In industrial blocks and COOPTHE plantations, people were also supportive of the intervention, but expressed their preference for agroforestry trees that produce fuel wood over fruit trees. The design of the intervention will therefore need to consider the needs and preferences of the different types of plantation owners in the estate, with fruit trees being more important on individual farms and fuel wood trees preferred in cooperative plantations.

The total area covered by the entire tea estate is ~730 ha. Agroforestry will be implemented on 300 ha of this area, specifically on tea plots (as opposed to along streams and roads).

Species selection for agroforestry

Eleven tree species suitable for agroforestry in the Shagasha tea estate are presented in Table 31 below. These species are all grown among crops in the Bugesera District in the Eastern Province, which is a drier region of Rwanda than Shagasha (~850 mm mean annual precipitation[316] compared to Shagasha's ~1,330 mm annual average[317]), meaning all the species are relatively drought tolerant and will therefore withstand drought periods at the tea estate. In addition, all the tree species can provide soil moisture conservation through the mulching of their leaves and their provided shade. Fast-growing species can be planted along with slow-growing species to deliver benefits over a longer period of time. Indigenous species, including *C. molle, E. abyssinica, M. lutea* and *V. amygdalina* should be prioritised, all of which can be easily propagated through the direct sowing of seeds or through cuttings. *M. lutea* is a fast-growing species that will provide benefits relatively quickly, while caution should be taken for *E. abyssinica* which produces poisonous stems, leaves and seeds. The remaining exotic species should be considered secondarily for agroforestry. Of these, *C. calothyrsus*, *J. mimosifolia* and *L. trichandra* are all fast-growing species that can be propagated easily through the sowing of seeds *in situ* or through cuttings.

Table 31. Suitable indigenous and exotic species for agroforestry use in tea plantations in the Shagasha tea estate and their potential benefits[318].

Scientific name	Local name	Exotic or indigenous	Climate resilience role	Livelihood impact role	Planting requirements and characteristics[319]
Calliandra calothyrsus	Kariyandara	Exotic	Soil erosion control, soil fertility (mulch and N-fixing), shade, windbreak	Bee forage, fuel wood, timber, fodder, ornamental	Scarified seeds can be sown directly or grown in nurseries. Fast-growing evergreen tree that can survive long dry spells and nutrient-poor soils.
Combretum molle	Umushubi	Indigenous	Soil fertility (mulch), shade	Bee forage, fuel wood, charcoal, farm tools	Planted using seeds that can be acquired from fruit. Slow-growing deciduous tree that grows well in areas with a distinct dry season.
Dombeya goetzenii	Umukore	Exotic	Soil fertility (mulch), shade	Bee forage, fuel wood, charcoal, farm tools, timber,	Cultivation is through fresh or stored seeds that can be grown in nurseries. Semi-

[316] Manzi M, Mutabazi J, Hirwa CD & Kugonza DR., 2013. Socio-economic assessment of indigenous goat production system in rural areas of Bugesera District in Rwanda. *Livestock Research for Rural Development*, 25: 2013.

[317] Meteo Rwanda. 2020. Climate Summary for Local Governments: Giheke Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%403605%3Ads#tabs-1.

[318] Kuria A, Uwase Y, Mukuralinda A, Iiyama M, Twagirayezu D, Njenga M, Muriuki J, Mutaganda A, Muthuri C, Kind R, Betemariam E, Cronin M, Kinuthia R, Migambi F, Lamond G, Pagella T & Sinclair F. 2017. Suitable tree species selection and management tool for Rwanda. [Database]. World Agroforestry Centre (ICRAF). Available: http://apps.worldagroforestry.org/suitable-tree/

[319] Useful Tropical Plants. N.d. Available at: http://tropical.theferns.info/c.

				medicinal uses, fibre	deciduous tree that grows at a moderate speed.
Erythrina abyssinica	Umuko	Indigenous	Soil fertility (mulch and N-fixing), soil erosion control, riverbank stabilisation, live fence	Bean stakes, fodder, fuel wood, timber, medicinal uses, bee forage, ornamental	Can be propagated through scarified seeds (obtained from fruit) in a nursery or through cuttings planted in the wet season. Deciduous tree with a moderate growth rate that is tolerant of low rainfall conditions. A potential risk is that this species produces poisonous seeds, bark and leaves.
Grevillea robusta	Gereveriya	Exotic	Soil fertility (mulch), shade, live fence, wind break	Bee forage, bean stakes, fuel wood, charcoal, timber, farm tools, fodder, ornamental	Propagation is through seeds soaked as a pre-treatment and grown in a nursery or through the use of cutting from half-ripe wood. Evergreen tree that has a moderate growth rate and tolerates drought conditions.
Jacaranda mimosifolia	Jacaranda	Exotic	Soil fertility (mulch), shade, live fence	Fuel wood, timber, bee forage, farm tools, ornamental	For planting from seeds, no pre-treatment is needed but should be soaked for 24 hours. Branch cuttings can also be used. Fast-growing deciduous tree that can tolerate long dry seasons.
Leucaena trichandra	Resena	Exotic	Live fence, soil fertility (mulch and N-fixing)	Edible food parts, fuel wood, timber, fodder	Fast-growing evergreen tree that can be grown from scarified seeds or cuttings of semi-ripe wood.
Manihot glaziovii	N/A	Exotic	Shade, soil fertility (mulch)	Edible food parts, medicinal uses, fodder, bee forage, ornamental	Propagation through seeds sown *in situ* and through cuttings. Deciduous tree that is drought tolerant and can grow in poor soils.
Markhamia lutea	Umusave	Indigenous	Soil fertility (mulch and N-fixing); shade	Fuel wood, timber, charcoal, medicinal uses, bee forage, bean stakes, ornamental	Can germinate from direct sowing in sunny areas. Fast-growing evergreen tree that can tolerate distinct dry seasons and tolerates drought conditions once established.
Sesbania sesban	Umunyegenyege	Exotic	Live fence, shade, soil fertility (mulch), wind break	Fuel wood, charcoal, timber (construction), medicinal uses, fodder, bee forage, gums and resins	Scarified seeds can be cultivated in nurseries. Fast-growing deciduous species that can tolerate low rainfall and poor soils.

Vernonia amygdalina	Umubilizi	Indigenous	Soil fertility (mulch), live fence	Fuel wood, medicinal uses, bee forage, fodder, ornamental	Propagation through seeds grown in a nursery or through cuttings. Slow-growing deciduous species that prefers moist environments but can tolerate drought conditions once established.

Planting of woodlots

Planting forestry trees in woodlots on the 200 ha of hills surrounding the tea factory will increase the forest cover while also providing fuelwood for the drying of tea leaves, which would ease pressure on the surrounding natural forest. This intervention will therefore help address the baseline driver of the degradation of the landscape surrounding the tea factory. Shagasha Factory uses a large amount of wood for tea treatment — specifically for the purpose of drying tea leaves. This wood is collected from factory-owned forest surrounding the factory, or purchased from surrounding communities. This puts a lot of pressure on existing forests and exposes soil to erosion especially in areas surrounding the plantation. While these impacts can be reduced by implementing renewable energy technology at the factory for the purpose of tea processing, and thereby reduce the demand for fuelwood from the factory, stakeholders have indicated that drying of tea with fuelwood is preferable. This is because wood-drying has a strong influence on the flavour of tea, and the use of, for example, solar dryers do not produce tea with the same amount of flavour. Therefore, the impact of fuelwood harvesting in the area can be reduced through the planting of woodlots.

Species selection for woodlots

Table 32 below provides a list of species suitable for growing woodlots at Shagasha Tea Factory. The choice of species to be used for woodlots at Shagasha was informed by considering several factors. First, the growth rate of the species was a strong consideration, and most of the species listed either have fast or moderately fast growth rates[320]. Second, all the species in the table are relatively drought tolerant, as most (or related species) have been successfully used in woodlots in the Bugesera District in Rwanda's Eastern Province, which receives less rainfall than Rusizi District. Third, while it would be preferable for the chosen species to be indigenous, the number of native species suitable for woodlots is limited. Therefore, the table mostly lists exotic species, but the selection only considered non-invasive species.

Table 32. Suitable species for woodlots at Shagasha Tea Factory[321].

Scientific name	Local name	Exotic or indigenous	Growth rate	Invasiveness	Planting requirements and characteristics
Artocarpus heterophyllus	Igifenesi	Exotic	Moderately fast	No	Propagation from seed or cuttings. Young plants prefer shade and increasing light levels as they mature. Prefers

[320] World Agroforestry Centre. 2021. Interactive Suitable Tree Species Selection and Management Tool for East Africa: Rwanda. Available at: http://apps.worldagroforestry.org/suitable-tree/rwanda?term_node_tid_depth=All&field_location_splocation_rwanda_nid=17856&field_origin_location_rwanda_value=All&field_products_r_value=All&field_ecological_services_r_value=All&field_niche_r_value=Woodlot&title=
[321] World Agroforestry Centre. 2021. Interactive Suitable Tree Species Selection and Management Tool for East Africa: Rwanda. Available at: http://apps.worldagroforestry.org/suitable-tree/rwanda?term_node_tid_depth=All&field_location_splocation_rwanda_nid=17856&field_origin_location_rwanda_value=All&field_products_r_value=All&field_ecological_services_r_value=All&field_niche_r_value=Woodlot&title=

					well-drained alluvial soil[322].
Dovyalis macrocalyx	N/A	Exotic	Moderately fast	No	Propagation from seed. Prefers deep loamy soils. If fruit and seed are required, both male and female forms need to be grown[323].
Eucalyptus globulus	Inturusu/ ruvuvu/salinya	Exotic	Fast	No	Coppicing should be at a height of 10–20 cm above the ground. This species is commonly grown on rather short rotations of 8–12 years or 10–15 years to produce pulpwood, fuelwood or posts. Undesirable shoots are cut back during the first two years after sprouting[324].
Eucalyptus maculata	Inturusu	Exotic	Fast	No	Requires coppicing to maximise growth[325]
Eucalyptus maidenii	Ruvuvu	Exotic	Fast	No	Requires coppicing, thinning and pruning to maximise growth[326].
Eucalyptus saligna	Salinya	Exotic	Fast	No	Highly sensitive to competition from weeds during the first two years, and therefore measures to control emerging weed growth must be carried out several times. Rotations of 6–10 years are used for producing fuelwood and pulpwood. *E. saligna* is a choice species for short coppice rotation[327].
Euclea racemosa	Umushikiri	Indigenous	Fast	No	No pre-treatment of seed is necessary. Plants can be coppiced[328].
Grevillea robusta	Gereveriya	Exotic	Medium	No	Can be propagated through seed and

[322] Fern, K. 2019. Artocarpus heterophyllus. Available at: http://tropical.theferns.info/viewtropical.php?id=Artocarpus+heterophyllus
[323] Fern, K. 2019. Dovyalis macrocalyx. Available at: http://tropical.theferns.info/viewtropical.php?id=Dovyalis+macrocalyx
[324] The Functional Attributes and Ecological Database: Tree Species. 2021. Eucalyptus globulus. Available at: http://db.worldagroforestry.org//species/properties/Eucalyptus_globulus
[325] World Agroforestry Centre. 2021. Eucalyptus maculate. Available at: http://apps.worldagroforestry.org/suitable-tree/species/rwanda/eucalyptus-maculata
[326] World Agroforestry Centre. 2021. Eucalyptus maidenii. Available at: http://apps.worldagroforestry.org/suitable-tree/species/rwanda/eucalyptus-maidenii
[327] World Agroforestry Centre. 2021. Eucalyptus saligna. Available at: http://apps.worldagroforestry.org/treedb2/speciesprofile.php?Spid=812
[328] Tropical Plants Database, Fern, K. 2021. Euclea racemose. Available at: http://tropical.theferns.info/viewtropical.php?id=Euclea+racemosa

					cuttings. No pre-treatment of seed is required, and it germinates readily in a moist environment. The optimum temperature for germination is about 25°C at a rate of 60–80% in 20–28 days. Cuttings can be easily established using shoots from seedlings or saplings, which can also be air-layered. Seedlings are normally planted at a spacing of 2.5–3 x 3–4 m. *G. robusta* regrows well after complete defoliation following pruning and pollarding, which can be carried out repeatedly to yield wood and to regulate shading and competition with adjacent crops[329].

Planting of grasses on the verges of tea plots and stream banks

Native grasses which are strong binders of soil, such as elephant/Napier grass (*Pennisetum purpureum;* Figure 78), will be planted on the verges of tea plots to prevent erosion, reduce runoff and be harvested as fodder for livestock. Elephant grass also has the potential to be used as mulch for the tea plantations, which provides nutrients and assists in retaining moisture[330]. If mulch is used, it should be placed in a way that does not touch the stems of the tea plants as this encourages the infestation of weevils and other pests. This EbA intervention remains viable and feasible based on stakeholder consultations. Cooperative leaders requested to extend this intervention to riverbanks of streams which cross plantations, as this will reduce erosion and stream sedimentation by stabilising streambanks. In addition, where tea is planted on slopes greater than 25%, a single row of elephant grass should be planted after every ten rows of tea to further provide erosion control[331].

Elephant grass is the ideal species for planting along tea crop verges because it: i) is native to tropical Africa; ii) is highly productive, making it an important forage species for cattle; iii) is used for mulch; iv) controls soil erosion; v) controls weeds and deters stemborers from crops; vi) is suitable for the current and projected future temperatures at Shagasha; and vii) can withstand the site's high rainfall while at the same time is tolerant of drought[332]. Another advantage of elephant grass is that it is already widely used as forage and fodder in Rwanda[333], making it easily accessible for project implementers.

[329] The Functional Attributes and Ecological Database: Tree Species. 2021. Grevillea robusta. Available at: http://db.worldagroforestry.org//species/properties/Grevillea_robusta

[330] Infonet Biovision. 2020. Tea. Available at: https://infonet-biovision.org/PlantHealth/Crops/Tea.

[331] Unilever Sustainable Agriculture Initiative. 2003. Sustainable tea: Good agricultural practice guidelines. Available at: https://www.unilever.com/Images/es-2003-sustainable-tea-good-agricultural-practice-guidelines-for-large-tea-estates_tcm244-409723_en.pdf.

[332] Feedipedia. 2021. *Elephant grass (Pennisetum purpureum)*. Available: https://www.feedipedia.org/node/395.

[333] Mutimura M, Lussa AB, Mutabazi J, Myambi CB, Cyamweshi RA & Ebong C. 2013. Status of animal feed resources in Rwanda. *Tropical Grasslands-Forrajes Tropicales* 1: 109–110.

Figure 78. Elephant grass (*Pennisetum purpureum*) to be planted on verges of tea plots in the Shagasha Tea Estate. Source: Feedipedia: Elephant grass.

Although elephant grass grows well in heavy rainfall conditions, it does not tolerate poor drainage and is not suited to flood conditions[334]. For this reason, it is not recommended for planting along streambanks to stabilise these slopes. Instead, Koronovia grass (*Brachiaria humidicola;* Figure 79) is suggested for this component of the intervention. Native to East Africa, this grass species can tolerate high temperatures and heavy rainfall conditions, as well as poor drainage, and can withstand short-term flooding[335]. This makes it preferable to elephant grass and other flood-intolerant grasses for streambank stabilisation. Another advantage of Koronovia grass is that it is indigenous to tropical East Africa. Given that streams provide transport routes that facilitate the spread of invasive species[336], this is an important consideration for species selection. The grass can also be grazed by cattle[337], and is well established in agriculture in Rwanda[338].

Figure 79. Koronovia grass (*Brachiaria humidicola*) to be planted along streambanks in the Shagasha tea plantation. Source: Feedipedia[339].

<u>Intervention risks and mitigation measures</u>

[334] Feedipedia. 2021. *Elephant grass (Pennisetum purpureum)*. Available: https://www.feedipedia.org/node/395.
[335] Feedipedia. 2021. *Koronivia grass* (*Brachiaria humidicola*). Available: https://www.feedipedia.org/node/585.
[336] Great Rivers Greenway. 2021. *Recommendations for streambank planting*. Available: https://greatriversgreenway.org/design-guidelines/environmental/streambank-planting/.
[337] Feedipedia. 2021. *Koronivia grass* (*Brachiaria humidicola*). Available: https://www.feedipedia.org/node/585.
[338] Mutimura M, Ebong C, Rao IM & Nsahlai IV. 2017. Effect of cutting time on agronomic and nutritional characteristics of nine commercial cultivars of Brachiaria grass compared with Napier grass during establishment under semi-arid conditions in Rwanda. *African Journal of Agricultural Research* 12: 2692–2703.
[339] Feedipedia. 2021. *Koronivia grass* (*Brachiaria humidicola*). Available: https://www.feedipedia.org/node/585.

Table 33. Potential risks and mitigation measures of each proposed intervention for the Shagasha Tea Estate site.

Intervention	Risk category	Risk	Mitigation measure
Reducing water stress and soil moisture loss through the planting of drought-tolerant tree species	Social	Displacement of land that could be used for crop farming	Selection of trees that provide shade and that have roots which bind soil and reduce erosion will increase the overall productivity of farm plots
	Social	Limited knowledge on forestry practices among crop farmers	Training on agroforestry best practices will be provided to all champion farmers who pilot agroforestry interventions
	Environmental	Vulnerability of tree seedlings to drought	Only drought-tolerant tree species will be planted
	Environmental	Agroforestry trees shading out crops, which would affect tea crop productivity	Trees will be thinned and pruned and planted with their long-term canopy size in consideration. Leaves will be used for mulch and branches for fuelwood
Plantation of grasses on the verges of tea plots and stream banks	Sustainability	Grasses on streambanks may be vulnerable to high intensity rainfall events when water flow is high	A flood-tolerant grass species has been selected for planting on streambanks
	Environmental	Streams may carry weedy or invasive species seeds downstream to other areas	Only native grasses will be planted along stream banks and these grasses should be monitored for alien species establishment

Summary budget

The total budget for interventions at the Shagasha Tea Estate is US$606,000. Below (Table 34) is an approximate breakdown of how the budget for the Shagasha Tea Estate site could be spent, based on values of costs obtained from the 'LDCF2 project' ('*Building resilience of communities living in degraded forests, savannas and wetlands of Rwanda through an ecosystem-based adaptation approach*')[340]. Detailed budgets are provided in Annex 7.

Table 34. Summary budget for interventions to be implemented at the Shagasha Tea Estate.

Intervention	Input/activity	Estimated cost (US$)
Reducing water stress and soil moisture loss through the planting of drought-tolerant tree species as a form of agroforestry	Training on the use of agroforestry techniques	6,000
	Establishing agroforestry on 300 ha of tea estate	225,000 (750 per ha)
Planting of grasses on verges of tea plots and stream banks	Planting grasses on verges of tea plots and stream banks	100,000

[340] https://www.thegef.org/project/building-resilience-communities-living-degraded-forests-savannahs-and-wetlands-rwanda

Planting of woodlots around the tea plantation to increase shade and water infiltration, and provide a sustainable source of fuelwood for the factory	Establishment of woodlots on 200 ha of land around the plantation	$150,000 (750 per ha)
Total		**506,000**

Implementation workplans and timetables

Implementation timetables for the selected interventions are presented in Annex 3.

Implementation arrangements

There stakeholders' views on the terms of implementation arrangements for the proposed interventions at Shagasha differed. The district authorities would like to lead the implementation of these interventions using existing structures and expertise at the district level. With this arrangement, the district will contract cooperatives to prepare nurseries and tree planting. Conversely, the factory management indicated that the factory is in a better position to implement these interventions using their existing framework for tea seedlings. In this framework, nurseries are prepared by members of cooperatives in coordination with factory management, while seedlings are distributed to farmers through their cooperatives and technical support is provided by agronomists based at the factory.

Cooperatives should play an important role in project implementation given that most of the proposed interventions will be implemented on their land and they are the direct beneficiaries. In terms of actual implementation of interventions, cooperatives expressed a preference for a community-based implementation approach such as the one used for tea plantation.

During consultation with a National Agriculture Expert Board (NAEB) expert it was suggested that all three actors at the site — district authorities, factory management and cooperatives — be involved in project management and implementation of interventions to ensure their sustainability. This can be achieved either through a joint steering committee, or through the sharing of responsibilities such as preparation of nurseries, tree planting and maintenance, as well as financial management. The NAEB expert recognised that at Shagasha the cooperatives have strong, well-established management structures that can coordinate with the factory management to oversee and run these interventions, but that the district government should play a supervisory role and be responsible for financial management.

A community-based implementation approach is the best implementation approach for the Shagasha Tea Estate, unlike at other sites where a contractor is preferred. During the site visit, it was observed by the national consultant that some nurseries are well maintained (Figure 80 below), which shows the experience of farmers in preparation of nurseries — an advantage to the proposed interventions. This approach will also provide short-term employment to local communities and members of cooperatives.

Figure 80. Nurseries at the Shagasha Tea Factory. Source: Theogene Habakubaho.

2.5 Site 5: Nyandungu Wetland, Kicukiro and Gasabo Districts, City of Kigali

According to the NAP ProDoc, wetland restoration through the development of a Sustainable Urban Drainage System (SUDS) was originally proposed for the Kimicanga wetland, which is located in the Gasabo District of Kigali. However, during initial stakeholder consultations, it emerged that the targeted section of the Kimicanga wetlands is included in the World Bank-funded Rwanda Urban Development Project (RUDP II). It was therefore deemed more beneficial for the RUDP II project to encompass the entire section from Kimicanga to the Nyabugogo wetlands and for the NAP project to support interventions in an area not covered by this larger project. The most appropriate alternative was identified as co-funding the Nyandungu Ecotourism Project[341], which focusses on another urban wetland in Kigali — the Nyandungu wetland — that is vulnerable to similar flooding risks as Kimicanga. The benefits of this alternative option include: i) design studies and contractors of the Ecotourism Project as already in place, allowing for a quick disbursement and achievement of objectives; ii) Nyandungu has similar characteristics and risks as Kimicanga, which means that lessons learned can be easily replicated in other urban wetlands; and iii) the existing project already complies with GEF/UNDP requirements.

<u>Site description</u>

Administrative location

The Nyandungu wetland is located partially in the Kicukiro District and partially in the Gasabo District, which are both within the City of Kigali.

Climate and climate threats

Kigali has a tropical wet and dry climate, which is modified by its high elevation. The average temperature is 20°C (Figure 81), with an average minimum of 16°C and an average maximum of 28°C (Figure 82 and Figure 83). Average annual rainfall is ~900 mm (Figure 84), which mostly occurs during the short rainy season (March to May) and the longer rainy season (September to December). Average rainfall during the short rainfall season is 360 mm and during the long rainy season is 338 mm (Figure 85).

[341] FONERWA. 2019. Nyandungu Urban Wetland Eco-Tourism Park. Available at: http://www.fonerwa.org/portfolio/nyandungu-urban-wetland-eco-tourism-park.

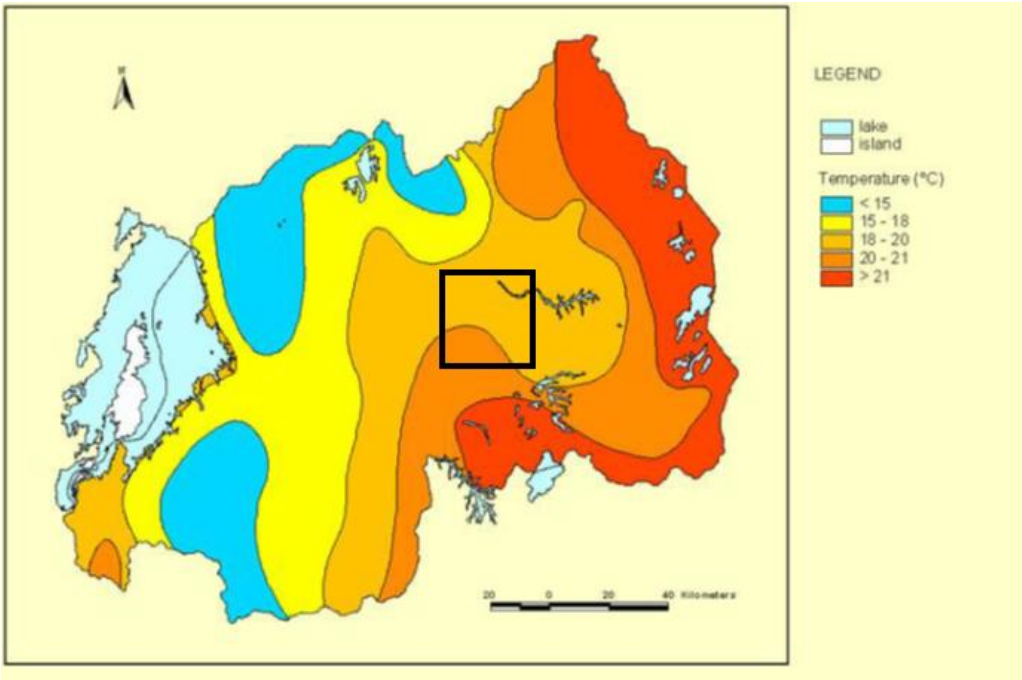

Figure 81. Annual average temperature for Rwanda[342]. The Nyandungu pilot site is indicated with a black square.

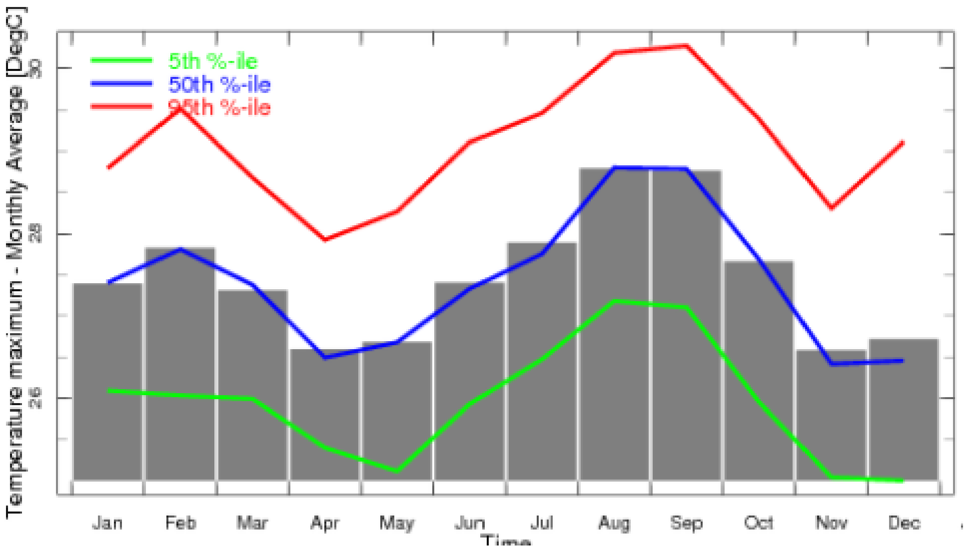

Figure 82. Average monthly maximum temperature (°C) for the Kicukiro Sector[343].

[342] Verdoodt A & van Ranst E. 2003. Land evaluation for agricultural production in the tropics. A large-scale land suitability classification for Rwanda.
[343] Meteo Rwanda. 2020. Climate Summary for Local Governments: Giheke Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%403605%3Ads#tabs-1.

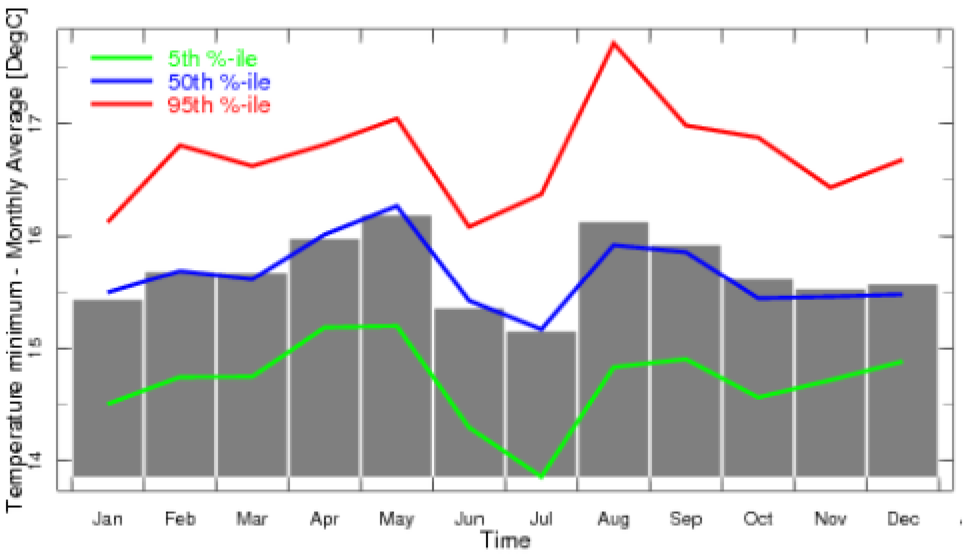

Figure 83. Average monthly minimum temperature (°C) for the Kicukiro Sector [344].

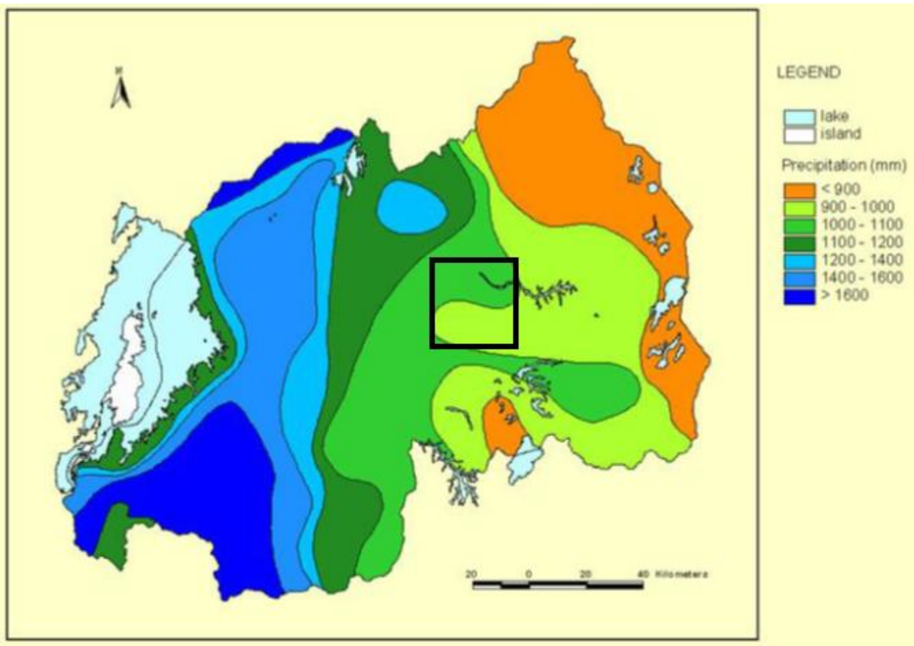

Figure 84. Annual average rainfall for Rwanda[345]. The Nyandungu pilot site is indicated with a black square.

[344] Meteo Rwanda. 2020. Climate Summary for Local Governments: Giheke Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%403605%3Ads#tabs-1.

[345] Verdoodt A & van Ranst E. 2003. Land evaluation for agricultural production in the tropics. A large-scale land suitability classification for Rwanda.

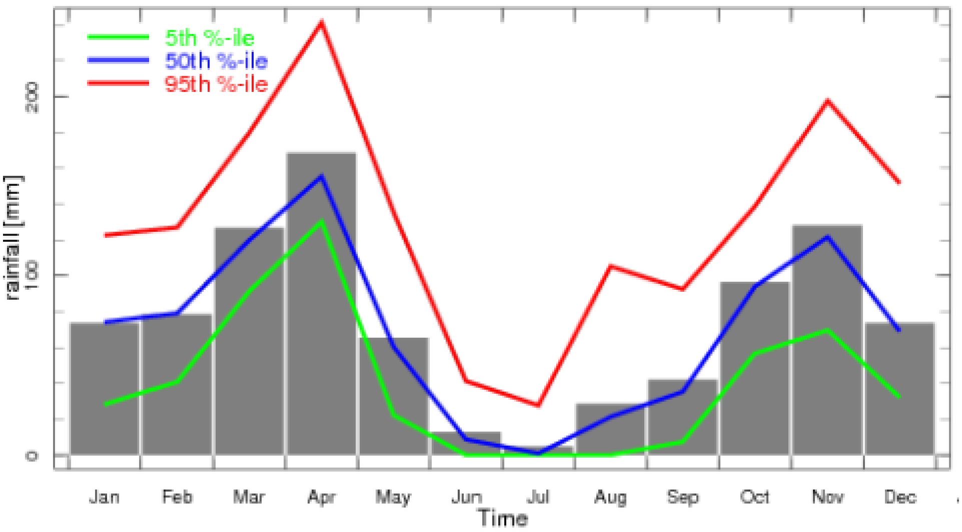

Figure 85. Average monthly rainfall (mm) for the Kicukiro Sector [346].

The Nyandungu wetland is a flood-prone area (see Figure 86[347] below) due to four main factors: i) it is on low-lying land which receives high volumes of surface flow from the densely populated surrounding hills; ii) its soils are clayey and therefore have a low water-holding capacity; iii) the wetland receives wastewater from various institutions (such as the Prison of Kimironko) and nearby households; and iv) the Mwanana River, which flows through the wetland, is narrow and is often flooded when there is heavy rainfall[348].

Figure 86. Floods in Nyandungu wetland.

Ecosystem profile

Vegetation in the Nyandungu wetland is characterised by two distinct types: natural and anthropogenic (exotic). The natural vegetation is mostly growing in the wetlands while the anthropogenic occurs predominantly in the drier areas of the complex. Dominant natural wetland vegetation is dominated by *Papyrus* spp. (local name: urufunzo), *Cyperus latifolius* (urukangaga), *Phragmites mauritianus* (imiseke) and *Typha latifolia*. Native trees that remain in the area include *Acacia hockii* (umugenge), *Acacia abyssinica* (umunyinya) and *Euphorbia grantii* (umudwedwe). In

[346] Meteo Rwanda. 2020. Climate Summary for Local Governments: Giheke Sector. Available at: http://maproom.meteorwanda.gov.rw/maproom/Summary/index.html?region=irids%3ASOURCES%3AFeatures%3APolitical%3ARwanda%3ASectors%3ASect_ID%403605%3Ads#tabs-1.
[347] REMA. 2012. Study for Establishing Urban Wetland Recreation and Eco-Tourism Park in Nyandungu Valley, Kigali City (Rwanda): Final Report.
[348] REMA. 2012. Study for Establishing Urban Wetland Recreation and Eco-Tourism Park in Nyandungu Valley, Kigali City (Rwanda): Final Report.

addition to these, exotic trees that have been introduced to the wetland by REMA include: *Filao* spp., *Cassia spectabilis*, *Grevilea robusta*, *Euphorbia irucali* (umuyenzi) and *Morus alba* (iboberi). Other indigenous species in the wetland include grasses that are used as livestock pasture, as well as numerous herbaceous species including: *Bidens pilosa* (inyabarasanya), *Galisonga parviflora* (kimari), *Rhynchelytrum repens* (urwarikafundi), *Clerodendrum rotundi* (ikiziranyenzi), *Vernonia amygdalina* (umubirizi), *Solanum abyssinum* (umutobotobo), *Commelina bengalensis* (uruteja), *Digitaria* spp. (urwiri), *Brachiaria brisantha* (ivubwe), *Guizotia scabra* (igishikashike), *Leotonia nepetaefolia* (igicumucumu), *Sida cordifolia* (umucundura), *Tageta minuta* (nyiramunukanabi), and *Ocimum suave* (umwenya)[349].

Baseline drivers and extent of ecosystem degradation

The City of Kigali is one of the fastest growing cities in Rwanda, in terms of population size. A city of 1.3 million people, Kigali is almost ten times larger than the country's next largest city, Rubavu[350]. Based on a medium-case population growth scenario, the population of Kigali is predicted to reach 2.5 million in 2025, and 4.3 million in 2040[351]. In addition, Kigali is the most densely populated city in Rwanda with 1,552 people per km^2 in 2012[352]. The rapid growth of Kigali and the associated human activities are putting significant pressure on the city's existing green spaces. For example, a 9.6-ha site in the area around the lake in Nyarutarama is being developed for luxury housing and hotels. This area was one of the best sites in Kigali to observe birds, including several migrant species, because of its high levels of native tree species[353]. The development of the site has resulted in informal agriculture, deforestation and a marked decrease in the diversity of bird species.

The City of Kigali Development Plan report[354] states that "deforestation, cultivation and urbanisation in and around Kigali have led to the serious destruction of wildlife biodiversity and the city no longer enjoys the same magnitude of biodiversity". The introduction of alien invasive plant species is also damaging the natural environment of the city[355]. Despite the increasing revenues generated from tourism based on biodiversity in Kigali, the conversion of biodiversity-rich areas into alternative land uses has continued[356]. Areas are being cleared for agriculture in wetlands, decreasing the pollution and flood abatement capacity of wetlands[357]. For example, the Kabuye Sugar Works project[358] plans to develop 2,000 ha of wetland for sugar cane production. Such wetland clearances have significant impacts on habitat loss.

The current pace of development and poor management of wetlands in combination with the effects of climate change are leading to increased flood risks that have an economic impact on the city and reduce the resilience of the population. The intensification of human activities and the increasing destruction of wetlands also lead to biodiversity loss. Part of the reason wetlands are being badly managed is that there is a lack of knowledge in Rwanda on how wetlands can be used to manage pollution and flood risks and their value to biodiversity. Furthermore, there is a lack of knowledge on the importance of native tree species and how to propagate them. There is therefore a need to demonstrate a model that shows the potential of wetlands to abate pollution and flood risk and that this can be achieved by creating a wetland site rich in native flora that will act to increase biodiversity

349 REMA. 2012. Study for Establishing Urban Wetland Recreation and Eco-tourism Park in Nyandungu Valley, Kigali City (Rwanda): Final Report.
350 REMA. 2017. State of Environment and Outlook Report: Achieving Sustainable Urbanization.
351 City of Kigali. 2013. The Kigali City Master Plan Report - Detailed physical plan for Gasabo and Kicukiro Districts.
352 REMA. 2017. State of Environment and Outlook Report: Achieving Sustainable Urbanization.
353 REMA and FONERWA. 2016. Nyandungu Urban Wetland Eco-Tourism Park Full Project Document Cover Sheet.
354 City of Kigali. 2012. The City of Kigali Development plan. Available: https://kigalicity.gov.rw/fileadmin/templates/Documents/policies/Kigali_City_Development_Plan__2013-2018__City_development_Plan_.pdf
355 REMA. 2009. Rwanda State of Environment and Outlook – Summary for Decision Makers.
356 REMA. 2009. Rwanda State of Environment and Outlook – Summary for Decision Makers.
357 REMA and FONERWA. 2016. Nyandungu Urban Wetland Eco-Tourism Park Full Project Document Cover Sheet.
358 http://www.minagri.gov.rw/index.php?id=469&tx_ttnews[tt_news]=32&cHash=6f7107f9aeb16a3bcfb30e0d356e1768

and generate revenue, which is the purpose of the Nyandungu Urban Wetland Eco-tourism Park project[359].

The Nyandungu wetland complex was once a military zone and was subsequently used as agricultural land. More recently, from about 2010, REMA began a tree-planting project to return the complex to a matrix of savanna scrub and marshland[360]. However, there are still pastoralists illegally grazing cattle and goats on the wetland site, and the underutilisation and minimal management of the site has led to flooding of the downstream area of the complex. The site also receives polluted water — including sewage outflow — from Kimironko Prison[361]. The Nyandungu Wetland Eco-tourism Park project will include the introduction of reed bed water treatment intervention to filter sewage outflow from the prison and runoff, however the city of Kigali needs to improve its sewerage management and redirect sewerage away from the wetland.

Topography

Kigali's land surface is very hilly, with an altitude ranging from 1,300 to 1,600 masl[362]. Nyandungu Wetland is located in one of the lower-lying areas of the city at 1,360 masl, and it is surrounded by hills that reach at altitudes of 1,480 masl.

Land uses

Prior to the 1980s, the wetland was under the jurisdiction of the Ministry of Agriculture and Animal Resources, and some land within the complex was converted to sugar cane fields and to crop nurseries. In the 1980s and early 1990s the wetland was transferred to the Ministry of Defence and was used to train paratroops. After the 1994 genocide, some private farmers used the land for agriculture and sand quarrying. A coffee-washing station was also built within the Nyandungu wetland complex. Subsequently, REMA has started rehabilitating and restoring the wetland. However, some people still use the grassy areas of the wetland for livestock grazing. Local communities also obtain drinking water from the wetland, harvest medicinal plants and collect raw materials for handicrafting activities[363].

Hydrological profile

Nyandungu wetland is drained by two streams: Mwanana and Kabagenda. Both flow into the Mulindi stream, a tributary of the Nyabarongo River[364]. The Mwanana-Kabagenda system contributes to the Mugesera-Rweru freshwater lakes and wetland system, which in turn is a major contributor to the Nyabarongo wetland-river system — which has national and international importance.

Demographics

The main contributors to increasing population are natural growth due to births and deaths, rural-to-urban migration and the pull for economic emancipation. By the 2012 census, Kigali had a district population of 1,132,686, accounting for 10.7% of the country's population. Population density is high given the urban nature of the three districts. Nyarugenge is the most densely populated district with

[359] Rema and FONERWA. 2016. Nyandungu Urban Wetland Eco-Tourism Park Full Project Document Cover Sheet.
[360] REMA. 2010. Nyandungu Tree Planting and Guarding Project. [Mentioned in: FONERWA. 2016. Nyandungu Urban Wetland Eco-Tourism Park Full Project Document Cover Sheet.]
[361] REMA and FONERWA. 2016. Nyandungu Urban Wetland Eco-Tourism Park Full Project Document Cover Sheet.
[362] REMA. 2017. State of Environment and Outlook Report: Achieving Sustainable Urbanization.
[363] REMA. 2012. Study for Establishing Urban Wetland Recreation and Eco-Tourism Park in Nyandungu Valley, Kigali City (Rwanda): Final Report.
[364] REMA. 2012. Study for Establishing Urban Wetland Recreation and Eco-Tourism Park in Nyandungu Valley, Kigali City (Rwanda): Final Report.

2,124 people/km^2. Gasabo has 1,234 people/km^2 while Kicukiro has a density of 1,911 people/km^2 [365]. Gasabo and Kicukiro Districts are where the Nyandungu wetland is located.

Kigali is a magnet for people looking to escape poverty and seeking economic opportunities and better services, such as education, health and security. Net migration into Kigali City in 2012 was 434,695 people, with more men arrivals (244,346) than women (190,349). Of Kigali's Districts, Gasabo is the preferred destination for migrants coming to the city from other parts of Rwanda, and 13% of its population are migrants[366]. In Kicukiro and Nyarugenge, migrants account for 9% and 7% of the population, respectively. The trend is expected to continue because of the city's opportunities for jobs and trade[367]. Refugees returning to the country after the genocide against the Tutsis also contributed to the numbers of in-migrants in Kigali. For example, data from the United Nations High Commissioner for Refugees (UNHCR) indicated that by 2012, there were 1,973 urban refugees living in Kigali as a result of the different phases of migration to the city since 1997[368].

Poverty levels

Poverty in Kigali City declined from 27.5% in 2010 to 20.9% in 2014[369]. The poverty rate in Nyarugenge in 2013/2014 was 19.9%, in Gasabo it was 23.4% and in Kicukiro it was 16.3%[370]. The unemployment rate in Kigali is 11% — far higher than the national unemployment rate of 2%. Unemployment is worse among women (16%) than men (6.5%)[371].

Livelihoods

Although Kigali is an urban centre occupied by urban infrastructure, agriculture is still the most common land use in Kigali, covering ~60% of the land use. Wetlands cover ~13% of the land and are frequently used for agriculture; most of the arable land in Kigali is found in or adjacent to wetlands and in lowland areas. There are three levels of agriculture. The first occurs at the level of household plot, where vegetables, fruits, medicinal plants and small livestock are tended to provide food for the family. At the next level, wetlands, mainly in the urban areas of Nyabugogo, Kicukiro, Muhima and Kimihurura, are cultivated at a larger scale, such as market gardening of high-value crops including sugarcane, rice sericulture and fish farming. The third level involves farming along the slopes, which is dominated by agroforestry, fruit and vegetable growing, mainly banana, beans, potatoes, cassava and maize, among other crops[372].

Livestock, mainly goat, poultry and cattle, graze on some 23.75 ha within the city. Urban agriculture is important for food security and when practiced locally, reduces the transport impacts of importing food, including greenhouse gas emissions from vehicles transporting produce into the city. Some of the environmental impacts of urban agriculture are the potential for excess fertilizers to run off into wetlands and water bodies and when practiced on steep slopes without terracing, erosion and landslides. The Kigali City Master Plan proposes to continue allowing agriculture in arable lands along wetlands and unbuildable zones and it promotes high value-added agriculture and agro-based industries and the creation of innovative types of urban agriculture suitable for slopes of over 20%. This has the potential to reduce the wetland's capacity to buffer flooding events, resulting in worsened flooding impacts. The City Master Plan also proposes conserving arable land on slopes below 15%,

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[365] REMA. 2017. Rwanda State of Environment and Outlook Report: Achieving Sustainable Urbanization.
[366] NISR. 2012. Fourth Population and Housing Census, Rwanda, 2014. Thematic report: Migration and spatial mobility. Kigali: National Institute for Statistics of Rwanda (NISR).
[367] REMA. 2017. Rwanda State of Environment and Outlook Report: Achieving Sustainable Urbanization.
[368] UNHCR Rwanda. 2013. UNHCR Rwanda, interview by Lindsey Harriman. Kigali: United Nations High Commission for Refugees (UNHCR), Rwanda.
[369] REMA. 2017. Rwanda State of Environment and Outlook Report: Achieving Sustainable Urbanization.
[370] NISR. 2017. Poverty Mapping Report, 2013/14. Kigali: National Institute of Statistics of Rwanda (NISR).
[371] NISR. 2016. Integrated Household Living Conditions Survey 2013/2014. Thematic report - Economic Activity. Kigali: National Institute of Statistics of Rwanda (NISR).
[372] REMA. 2017. Rwanda State of Environment and Outlook Report: Achieving Sustainable Urbanization.

limiting mechanized agriculture on steep slopes, promoting forestry on slopes above 25% and supporting sustainable irrigation and fertilisation methods[373].

Land tenure arrangements

The site lies partly within both Kicukiro and Gasabo Districts. The political and technical support of these districts is essential for the long-term success of the project's EbA interventions. The already existing partnership between REMA and the Rwanda Development Board (RDB), City of Kigali (CoK), Kicukiro and Gasabo Districts will boost the implementation of this project.

Article 29 of the Land Organic Law gives the state complete control over swamps and wetlands. The law calls for an inventory of all swamps and their boundaries, the structure of the swamps, their use, and how they can be organised. According to Article 29 of the Land Organic Law, swamp land belongs to the state and no person can use the reason that he or she has spent a long time on it to justify the definitive takeover of the land.

In order for the swamp land to be efficiently managed and utilised, a Minister having 'Environment' in his or her title must give an order that shall determine a list of swamps and their boundaries. The law further requires that such a list shall clearly indicate the structure of the swamps, their use, and how they can be organised so that they can be beneficial to Rwandan nationals on a sustainable basis[374].

Community organisations and structures

In Kigali City, the District Environment Protection Officer reports to the Director of the Health and Environment Unit. The responsibility of the Environment Protection Officer is to ensure the implementation of Organic Law N° 04/2005 of 08/04/2005 determining the modalities of protection, conservation and promotion of the environment and other environmental laws in Rwanda[375].

Reliance on ecosystem services

Residents living around the Nyandungu Wetland, as well as residents of Kigali City in general, rely on ecosystem integrity and biodiversity for various regulatory, provisioning and other ecosystem services. Loss of ecosystem integrity and biodiversity can make ecosystems unable to provide these services, with impacts on human and economic wellbeing. For example, Kigali City is dependent on wetlands to provide clean water and flood protection services. However, upstream mining and development of quarries is causing sedimentation and pollution downstream. Wastes and industrial effluents from Kigali City, due to poor sewage and waste- treatments systems, are also adding to the pollution load[376].

Infrastructure and services available at the site

Access to improved sanitation

The revised Vision 2020 target for sanitation stipulates that Rwanda achieve 60% coverage by 2015 and 100% access by 2020[377]. Additionally, the Economic Development and Poverty Reduction Strategy 2 (EDPRS 2) set a target of 100% of urban households with access to improved sanitation

[373] REMA. 2017. Rwanda State of Environment and Outlook Report: Achieving Sustainable Urbanization.
[374] REMA. 2012. Study for Establishing Urban Wetland Recreation and Eco-Tourism Park in Nyandungu Valley, Kigali City (Rwanda): Final Report.
[375] REMA. 2017. Rwanda State of Environment and Outlook Report: Achieving Sustainable Urbanization.
[376] REMA. 2017. Rwanda State of Environment and Outlook Report: Achieving Sustainable Urbanization.
[377] MINIRENA. 2012. Cabinet Paper for Revised Vision 2020 Indicators and Targets. Kigali: Ministry of Natural Resources, 2012, http://www.minirena. gov.rw/fileadmin/user_upload/Documents/ENR_Sector_EDPRS_2_ Elaboration/Revised_vision_2020_indicators_and_targets.pdf.

by 2017–2018[378]. Currently, access to improved sanitation facilities for all three Districts in Kigali has exceeded the 2015 Vision 2020 goal and continues to improve access to all areas of the city (both urban and non-urban)[379]. In addition, with efforts to attract investors and tourists, additional public sanitation facilities will need to be made available for visitors, including tourists to the Nyandungu Urban Wetland Eco-Tourism Park.

Improved sanitation facilities are defined as facilities that hygienically separate human waste from human contact (WHO and UNICEF 2010). Such facilities include composting or flush toilets that empty to a piped sewer system, septic tank or pit latrine, ventilated improved pit latrine, and pit latrines with a solid slab. A pit latrine without a solid slab is considered an unimproved sanitation facility since it can have many health and household consequences[380]. More than 70% of residents in Gasabo District and over 85% of residents in the Kicukiro and Nyarugenge Districts have access to improved sanitation[381]. The primary type of improved facility in these Districts is a pit latrine with solid slab, but some households have access to flush toilets. Very few households — 2% or less — in each District surveyed were found to have no available toilet facility. The percentage of households with flush toilets or improved pit latrines has risen since 2005, a sign that households are working towards increasing the quality of their own sanitation[382].

Sewerage systems in Kigali are primarily individualised, leaving it up to households to inform themselves about proper sanitation procedures and take responsibility for them. Housing developments as well as large institutional and business facilities tend to have their own sewage treatment plants. City plans are underway to develop centralised District sewerage systems in the foreseeable future. Establishments that are currently developing individualised systems must plan and design them to support current and future plans, bearing in mind how their system might eventually connect to a centralised one[383].

Improved stormwater management could contribute to more sanitary conditions in and around the city of Kigali. Methods include stormwater retention strategies and harvesting excess water for non-potable uses, such as landscape irrigation and general washing purposes; this would lower water purification costs and help to reduce flood risks[384]. The Kigali Conceptual Master Plan (KCMP)[385] proposes instituting improved stormwater management policies and taking actions such as rehabilitating and cleaning the existing drainage network. In addition, infrastructure planning in the long-term (to 2040) includes plans for stormwater harvesting for non-potable water, household water saving devices and fittings, building artificial wetlands and constructing downstream flow paths to catch overflows from sewage treatment plants[386].

Access to clean drinking water

Improved water sources refer to water that is piped directly into a yard or dwelling; provided by a public fountain, protected spring, drilled well, or public utility; or is purchased. Access to improved water in Kigali declined slightly, from 84.8% to 82.7% between 2005–2006 and 2010–2011. However, other sources of drinking water, not specified by the survey, increased, which could possibly explain the decline. Access to clean drinking water is an important complement to proper sanitation for

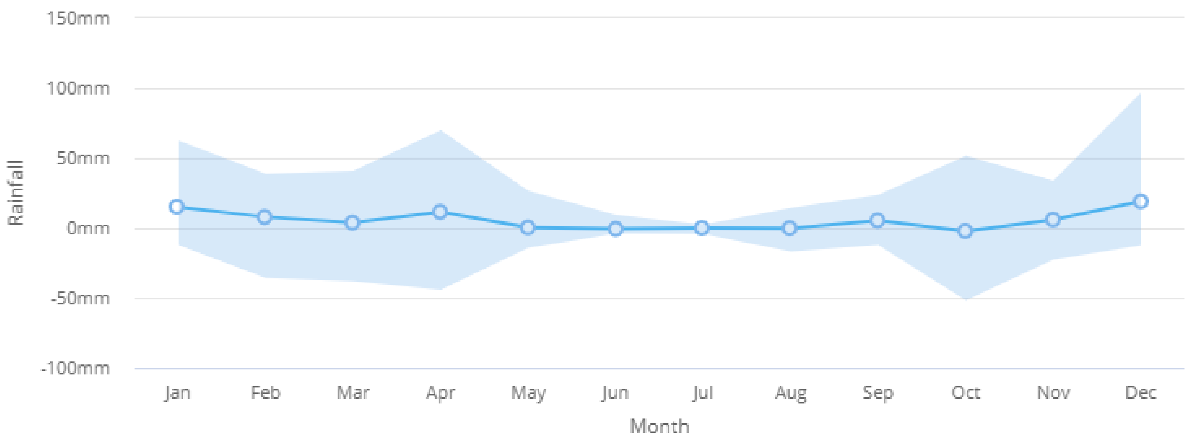
[378] MINECOFIN. 2013. Economic Development and Poverty Reduction Strategy 2013–2018. Kigali: Ministry of Finance and Economic Planning.
[379] REMA. 2013. Kigali State of Environment and Outlook Report 2013.
[380] REMA. 2013. Kigali State of Environment and Outlook Report 2013.
[381] NISR. 2012. EICV Thematic Report - Utilities and Amenities. Kigali: National Institute of Statistics Rwanda.
[382] REMA. 2013. Kigali State of Environment and Outlook Report 2013.
[383] RURA. 2012. Regulations on Decentralized Wastewater Treatment Systems. Kigali: Rwanda Utilities Regulatory Authority.
[384] Surbana. 2012. Detailed District Physical Plans for Kicukiro and Gasabo Kigali, Rwanda: Vision Report. Draft: May 2012, Surbana International Consultants PTE Ltd.
[385] City of Kigali. 2013. Kigali City Master Plan Report: Detailed Physical Plan for Gasabo and Kicukiro, Kigali.
[386] Surbana. 2013. “Gasabo and Kicukiro - Infrastructure stakeholders meeting.” Kigali: Surbana, 13 March 2013.

maintaining clean and safe households and optimal health. The EDPRS 2 has outlined goals for Rwanda to improve water quality and access to improved water sources. The target for 2017–2018 was for 100% of urban households to be within 200 metres of an improved water source[387].

Despite Kigali's increased water production capacity, demand is exceeding supply. Water supply to Kigali is strained as a result of the burgeoning number of people residing in the city and the fact that the installed water infrastructure was originally designed to serve 350,000 people, not the current ~1.2 million people that now live in the city[388]. The city government has been working to reduce the supply gap, including a Water Purchase Agreement (WPA) with Kigali Water Limited to provide an extra 40,000 m^3 per day in 2015 in addition to the expansion of Nzove II Water Treatment Plant[389, 390]. There is also a new Water Supply Policy 2016 in place. In addition, Rwanda won the Global Water Leaders Award in 2016 for the fastest reform to the water sector globally[391].

Climate change problems that the EbA interventions will address

Given projected climate change under a RCP8.5 scenario, monthly precipitation will increase by 15 mm in the short rainy season (March to May) and 28 mm in the long rainy season (September to December) between 2040–2059 in the area where the Nyandungu pilot site is situated (Figure 87). This change is predicted to increase to 36 mm in the short rainy season and 115 mm in the long rainy season between 2080–2099 (Figure 88). Along with an overall increase in rainfall, the range in rainfall between months will also increase under climate change by 34 mm between 2040–2059 and 70 mm between 2080–2099 (Figure 89). In addition to this change in monthly rainfall range, the amount of rainfall on very wet days (those that fall within the top 5% heaviest rainfall days) will increase by 12% between 2040–2059 and 53% between 2080–2099 (Figure 90). This increase in rainfall on already very wet days suggests that there will be more intense extreme rainfall events, which will increase the probability of damaging flooding events in the area. As the area is already being negatively impacted by flooding, increases in the frequency and intensity of flooding events will further increase the vulnerability of urban communities and increase the degradation of the wetland itself.



[387] MINECOFIN. 2013. Economic Development and Poverty Reduction Strategy 2013–2018. Kigali: Ministry of Finance and Economic Planning.
[388] REMA. 2017. Rwanda State of Environment and Outlook Report: Achieving Sustainable Urbanization.
[389] RURA. 2016. Key statistics in water and sanitation as of March 2016. Kigali: Rwanda Utilities Regulation Authority (RURA).
[390] WASAC. 2017. Nzove Water Treatment Plant. Media Centre. From http://www.wasac.rw/index.php/mediacentre/news/357-nzove-water-treatment-plant.
[391] REMA. 2017. Rwanda State of Environment and Outlook Report: Achieving Sustainable Urbanization.

Figure 87. Projected change in monthly precipitation (mm) for the Nyandungu pilot area from 2040–2059 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[392] (GCMs)[393].

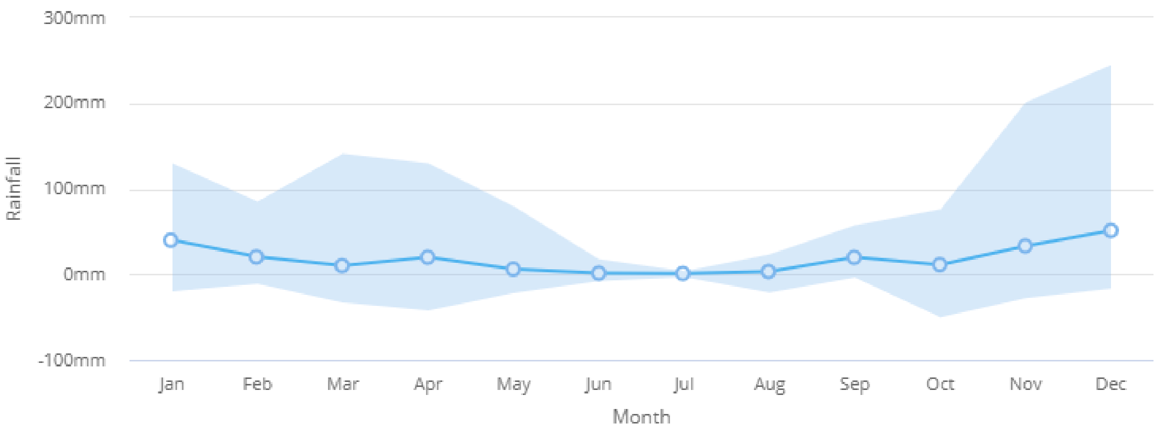


Figure 88. Projected change in monthly precipitation (mm) for the Nyandungu pilot area from 2080–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[394] (GCMs)[395].

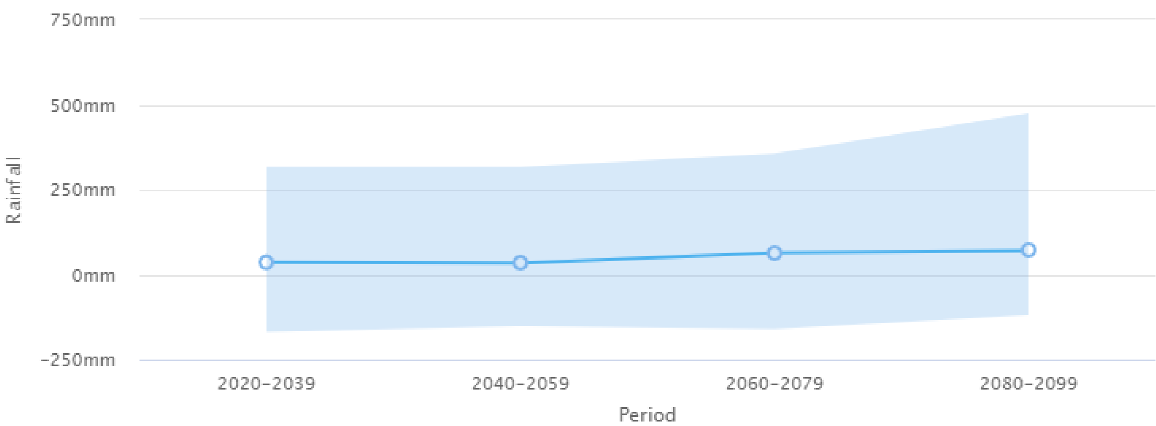


Figure 89. Projected change in monthly rainfall range (mm) for the Nyandungu pilot area from 2020–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[396] (GCMs)[397].

[392] IPCC. 2014. Fifth Assessment Report.
[393] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#
[394] IPCC. 2014. Fifth Assessment Report.
[395] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#
[396] IPCC. 2014. Fifth Assessment Report.
[397] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

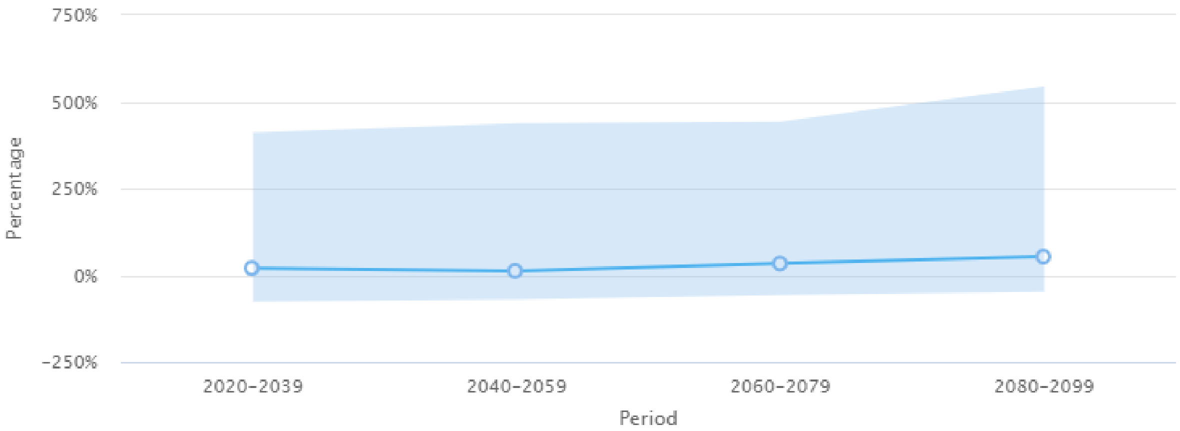


Figure 90. Projected change in the amount of rainfall on very wet days (%) for the Nyandungu pilot area from 2020–2099 under a RCP8.5 scenario compared with historic values from 1986–2005, indicating the median and range values for an ensemble of global circulation models[398] (GCMs)[399].

Detailed description of interventions

Overview of Nyandungu Urban Wetland Eco-Tourism Park project

The Nyandungu Urban Wetland Eco-Tourism Park (NUWEP) project is a REMA-led programme to create a sustainable, urban park in the Nyandungu wetland complex in Kigali. Climate change adaptation aspects of the project include the restoration of 130 ha of wetland, savanna and forest vegetation within the complex, as well as the establishment of a sustainable urban drainage system (SUDS) within the park, to mitigate flooding impacts on surrounding communities. The NUWEP project, which began implementation in 2016 and remains ongoing, is funded by Rwanda's National Climate Change and Environmental Fund (FONERWA). Its estimated total cost is US$2,434,119 (~2.4 billion RWF). Additional partner institutions implementing the project include the district authorities for the Gasabo District (Ndera Sector) and Kicukiro District (Nyarugunga Sector), as well as the City of Kigali and Rwanda Development Board (RDB). A general layout plan for the site is presented in Figure XX below.

[398] IPCC. 2014. Fifth Assessment Report.
[399] World Bank Group. 2020. Climate Change Knowledge Portal: Rwanda climate data projections. Available at: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections#

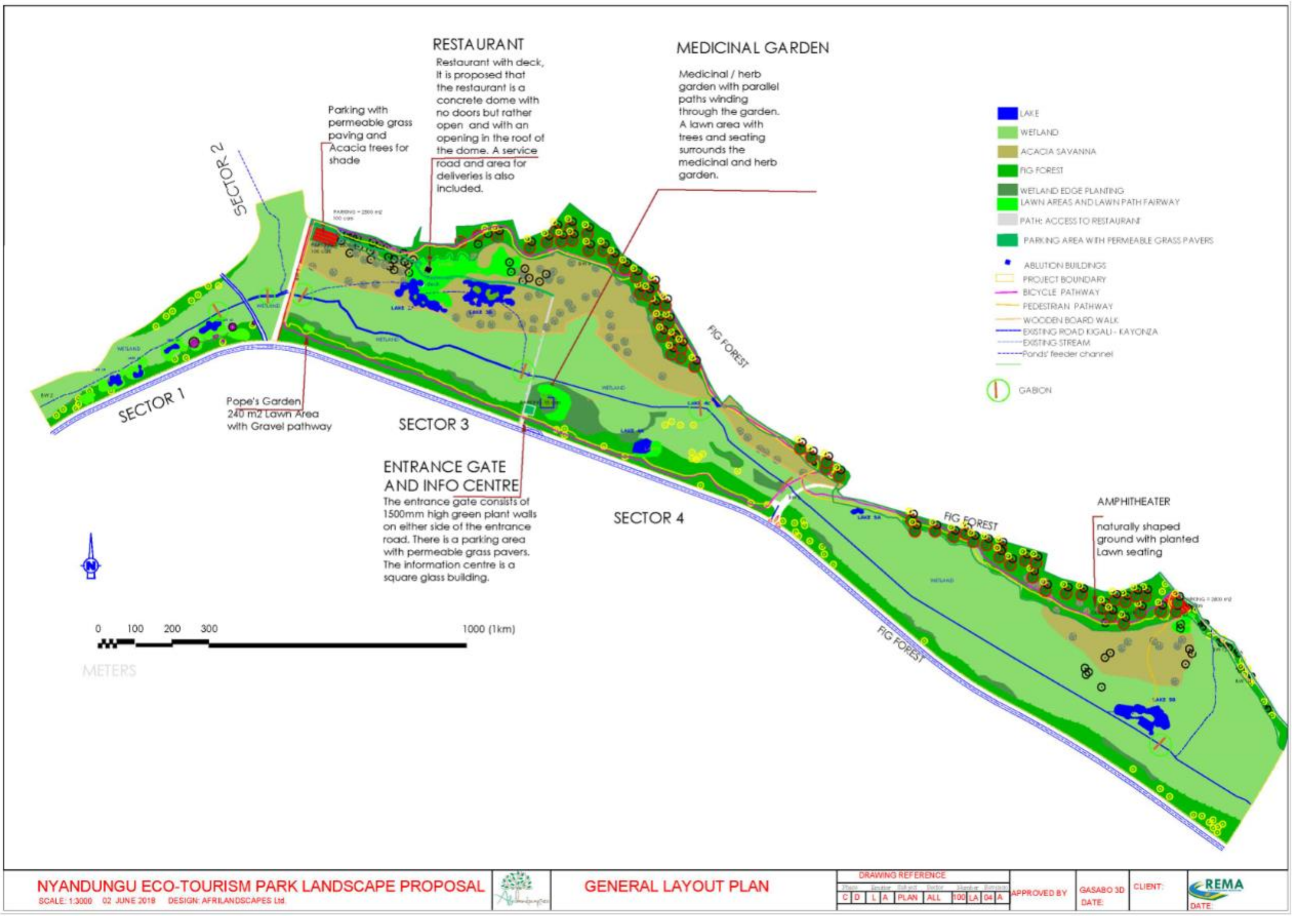


Figure 91. General layout plan for the Nyandungu Eco-tourism park.

The SUDS intervention will be EbA-based, using vegetated swales, check dams and bioretention basins, in conjunction with the aforementioned restored wetland vegetation. While the primary function of these structures will be to reduce flooding impacts, co-benefits include the reduction in river sedimentation and improvement of water quality for downstream communities. The proposed NAP project will co-finance these EbA interventions.

The SUDS intervention will have the objective of mimicking natural drainage systems by:

- storing runoff and releasing it slowly (attenuation);
- harvesting and using the rain close to where it falls;
- allowing water to soak into the ground (infiltration);
- slowly transporting (conveying) water on the surface;
- filtering out pollutants; and
- allowing sediments to settle out by controlling the flow of the water[400].

The sections below detail the different types of SUDS systems — other than the restoration of the wetland vegetation itself — that will be established at the Nyandungu pilot site.

Vegetated swales and check dams

A vegetated swale is a graded and engineered landscape feature appearing as a linear, shallow, open channel with trapezoidal or parabolic shape. The swale is vegetated with flood-tolerant, erosion-resistant plants. The design of vegetated swales promotes the conveyance of storm water at a slower,

[400] https://www.susdrain.org/delivering-suds/using-suds/suds-principles/suds-principals.html

controlled rate and acts as a filter medium removing pollutants and allowing stormwater infiltration. When properly designed to accommodate a predetermined storm event volume, a grassed swale results in a significant improvement over the traditional drainage ditch in both slowing and cleaning of water. Swales are therefore a beneficial, cost-effective EbA intervention for the flood-prone Nyandungu wetland complex.

The vegetated swales can contain the strategic placement of simple check dams (see Figure 92[401] below) that encourage ponding and infiltration into the soil, filtration of the water, and sedimentary deposition. Collected stormwater is expected to drain away through the soil within several hours or days. Alternatively, swales can be connected to bioretention basins, which are explained in more detail in the following section, or they can be connected to storm drains, as is depicted in

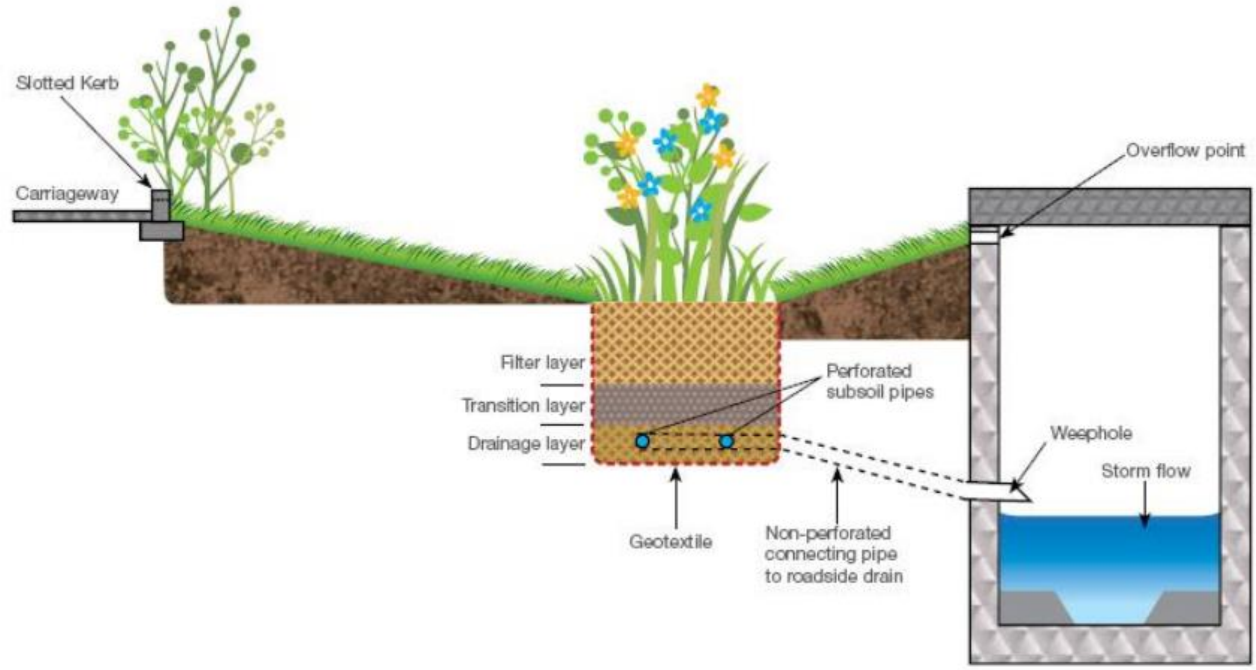


Figure 93[402].

401 https://www.lakesuperiorstreams.org/stormwater/toolkit/swales.html
402 REMA. 2015. Resilient Habitats: Detailed Landscape Guide — Nyandungu Urban Wetland Eco-tourism Park. Available: https://www.yumpu.com/en/document/read/56720118/resilient-habitats-nyandungu-urban-wetland-eco-tourism-park

Figure 92. Design of a vegetated swale connected to a stormwater drain.

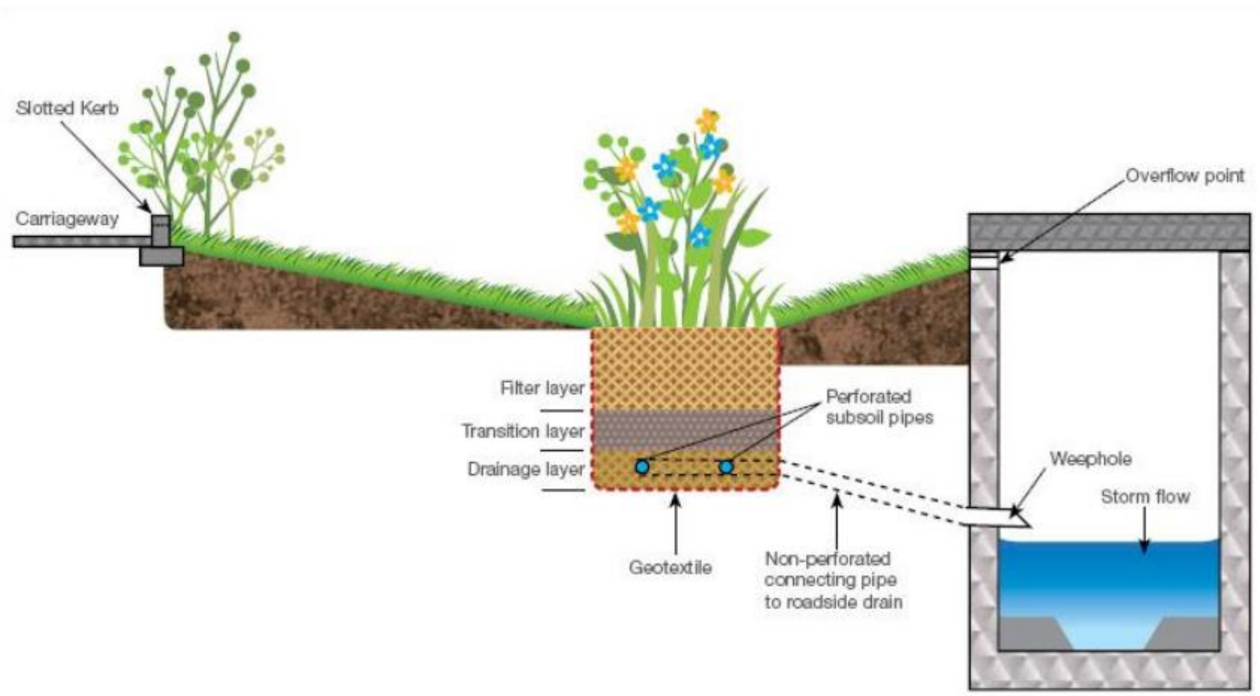


Figure 93. Example of a vegetated swale with simple check dams to encourage ponding.

Bioretention basins/ponds

Bioretention basins are landscaped depressions or shallow basins used to slow and treat on-site stormwater runoff. Stormwater is directed to the basin and then percolates through the system where it is treated by a number of physical, chemical and biological processes. The slowed, cleaned water is allowed to infiltrate native soils or directed to nearby stormwater drains or receiving waters[403]. In the case of Nyandungu, the water that does not infiltrate into the soil will be directed into the wetland, where it will then drain into the Mwanana and Kabagenda streams.

Bioretention basins are usually composed of seven elements, with each element serving a specific function[404]. These are listed below.

1. Grass buffer strip: reduces runoff velocity and removes suspended solids.
2. Vegetation (such as reeds and herbaceous plants): helps remove water through the process of evapotranspiration, and removes excess nutrients through nutrient cycling.
3. Shallow ponding area: provides storage of excess stormwater flows and its subsequent evaporation, also aids in the additional settlement of particulate matter.
4. Mulch: an organic layer that encourages microbiological degradation of petroleum-based pollutants, aids in pollutant filtration and reduces soil erosion.
5. Engineered soils[405]: to support vegetation growth along with nutrient uptake and provision for water storage. Soils should include some clay to adsorb pollutants such as hydrocarbons, heavy metals and nutrients.
6. Sand bed: provides drainage and aeration of planting soil as well as an aid in flushing pollutants.
7. Underdrain system: removal of excess treated water to storm drain system to the wetland stream. The cleansed water can be collected through a perforated pipe at the drainage layer.

[403] https://www.lakesuperiorstreams.org/stormwater/toolkit/bioretention.html
[404] https://www.lakesuperiorstreams.org/stormwater/toolkit/bioretention.html
[405] These are soils that are modified, blended or processed to solve specific slope, bioretention, biodetention and ditch stability problems. Such soils are mixed from compost and mineral aggregates in specific quantities to meet required soil quality and depth requirements and perform to a standard of permeability, stability and fertility.

Figure 94 from the Detailed Landscape Guide for the Nyandungu Park[406] below provides a schematic representation of the design of the bioretention basins that will be built within the park.

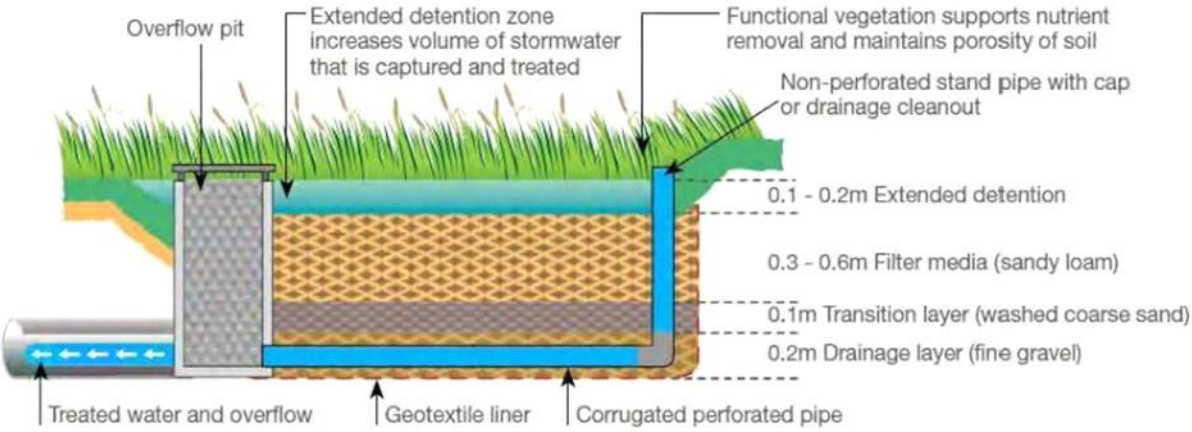


Figure 94. Schematic diagram of the design of a bioretention basin to be used at Nyandungu Wetland.

The selection of plant species to be used in the bioretention ponds will be aligned with the filtration vegetation that is already planned to be planted on the verges of ponds in the Nyandungu Wetland, namely *Cyperus alternifolius* (umbrella grass), *Cyperus papyrus* (paper reed), *Zantedeschia aethiopica* (arum lilies) and *Iris pseudacorus* (yellow irises). The land just beyond the bioretention ponds will be planted with species planned to be introduced in the meadow sections of the Nyandungu complex. These species include natural grasses interspersed with *Agapanthus* spp. (white and blue varieties), *Dietes granfiflora*, *Kinpfofia* spp., *Hemerocallis* spp., *Aloe* spp., *Crocosmia* spp., *Strelitzia reginae*, *Cymbopogon nardus*, *Heliconia* spp., *Hedychium aurantiacum*, *Plumbago auriculata, Hypoestes* spp., *Brilliantasia* spp., *Clerodendron* spp., *Tecomaria capensis* and *Kalanchoe laterite*[407].

Restoration of wetland and savanna vegetation

Another major intervention planned under the NUWEP project is the restoration of native vegetation, which will have benefits including improved biodiversity (including nesting habitats for indigenous birds), flood attenuation, erosion control, sedimentation reduction and establishment of eco-tourism. This LDCF-funded NAP project will co-finance this intervention, which has already been designed in detail[408].

Intervention risks and mitigation measures

Table 35. Potential risks and mitigation measures of each proposed intervention for the Nyandungu Wetland site.

Intervention	Risk category	Risk	Mitigation measure
Establishing vegetated swales and check dams	Environmental	Base of swales and check dams not permeable to water, causing them to flood	Swales and check dams will be designed to allow maximum infiltration into the subsurface

[406] REMA. 2015. Resilient Habitats: Detailed Landscape Guide — Nyandungu Urban Wetland Eco-tourism Park. Available: https://www.yumpu.com/en/document/read/56720118/resilient-habitats-nyandungu-urban-wetland-eco-tourism-park
[407] Afrilandscapes. N.d. Nyandungu Urban Wetland Ecotourism Park: Pond 3b landscaping site plan.
[408] REMA. 2015. Resilient Habitats: Detailed Landscape Guide — Nyandungu Urban Wetland Eco-tourism Park. Available: https://www.yumpu.com/en/document/read/56720118/resilient-habitats-nyandungu-urban-wetland-eco-tourism-park

Establishing bioretention basins	Environmental	Limited management can lead to harmful algal blooms and growth of weedy plant species	Under NUWEP a stormwater management team should be established to organise maintenance guidelines and arrangements. Regular inspections, maintenance and monitoring are necessary to mitigate negative ecological impacts[409]
Restoration of wetland and savanna vegetation	Environmental	Continued consumptive use and degradation of wetland resources	Access to the NUWEP will be restricted

Summary budget

The REMA-led '*Nyandungu Urban Wetland Eco-Tourism Park*'[410] (hereafter 'NUWEP') project has funding gaps for EbA interventions. The EbA interventions implemented through the NAP project will therefore support the NUWEP project, covering funding gaps, while still providing a model for the implementation of EbA in other urban wetlands across Rwanda. The NAP project will focus on the sustainable urban drainage activities of the wetland's development, including EbA flood attenuation techniques.

Below (Table 36) is an approximate breakdown of how the budget for the Nyandungu wetland site could be spent. Costs of training and workshops are based on values of costs obtained from the 'LDCF2 project' ('*Building resilience of communities living in degraded forests, savannas and wetlands of Rwanda through an ecosystem-based adaptation approach*')[411]. Detailed budgets are provided in Annex 7.

Table 36. Summary budget for interventions to be implemented at the Nyandungu wetland site.

Intervention	**Input/activity**	**Estimated cost (US$)**
Sustainable Urban Drainage Systems (SUDS)	Establishing vegetated swales and check dams	170,000
	Establishing bioretention basins	271,800
Restoration of wetland and savanna vegetation in Nyandungu complex	Training on wetland restoration techniques[412]	6,000
	Co-financing the restoration of wetland and surrounding vegetation	464,018
All	Contributions to nursery costs at the Nyandungu nursery	50,000
Total		**961,818**

Implementation workplans and timetables

Implementation timetables for the selected interventions are presented in Annex 3.

[409] Taguchi VJ, Weiss, PT, Gulliver JS, Klein MR, Hozalski RM, Baker LA, Finlay JC, Keeler BL & Nieber JL. 2020. It Is Not Easy Being Green: Recognizing Unintended Consequences of Green Stormwater Infrastructure. *Water* 12: 522. Available: https://www.mdpi.com/2073-4441/12/2/522/pdf
[410] http://www.fonerwa.org/sites/default/files/NYANDUNGU%20URBAN%20WETLAND%20.pdf
[411] https://www.thegef.org/project/building-resilience-communities-living-degraded-forests-savannahs-and-wetlands-rwanda
[412] Three training days will be organised at the wetland restoration site including one day to establish each nursery and two days to explain the restoration techniques through planting the first generation of trees. US$1,000 is allocated to each training day.

Implementation arrangements

The implementation of the EbA interventions at the Nyandungu site will be overseen by the NUWEP's project management unit (PMU) and implementation structures at the site. This will ensure coherence with ongoing activities. The PMU of the NAP project will work closely with their counterparts to ensure that the disbursement of funds, as well as the implementation of activities are carried out as planned. An MoU will be signed between the two projects to formalise the agreed implementation approach.

3 Recommended approach to the cost-benefit analysis of interventions

This section outlines the approach recommended for the cost-benefit analyses (CBA) which will be carried out during project evaluation. The first part provides general guidance around conducting CBA of EbA interventions. This includes key steps to be carried out when conducting CBA of EbA interventions, with a focus on how to quantify and value costs and benefits using the ecosystem services framework. This is followed by more detailed considerations for conducting CBA at each of the sites, given each of their unique profiles of costs, benefits and climate change impacts.

Indicative budgeting for the ongoing collection and analysis of the costs, benefits and impacts associated with the interventions outlined in the Feasibility Study is provided in Annex 6. Introduction to Cost-Benefit Analysis (CBA). The CBA will be integrated into the LTRP for the project's pilot sites, providing a model to be used at other sites that will be included under the LTRP.

CBA is a method used to analyse the costs and benefits associated with a project or policy intervention. This method uses inter-temporal discounting to allow estimation of the net present value of a series of incurred or anticipated costs and benefits.

The nature of EbA interventions presents a unique set of challenges for the use of CBA as a method of appraisal and assessment[413]. A defining feature of CBA is the requirement for all costs and benefits to have been quantified in monetary terms. This is relatively straightforward where grey-infrastructure interventions are considered. Both the costs and the benefits of these interventions are relatively well defined, and therefore more easily expressed in monetary terms. Many of the costs and benefits of EbA interventions accrue through changes in ecosystems and their ability to support the livelihoods of those who rely on them. To better understand this dynamic, the concept of ecosystem services is used to establish theoretical links between changes in biophysical parameters and resulting changes in societal welfare.

To generate optimal information for decision-making around adaptive management, replication and upscaling, the cost-benefit analysis of EbA interventions should include the following steps[414]:

1. Define the aim of the cost-benefit analysis. Outline the study site, including its current land uses, ecosystems and the communities and sectors that rely on their ecosystem services.

[413] Emerton, L. 2017. Valuing the benefits, costs and impacts of ecosystem-based adaptation measures: a sourcebook of methods for decision-making. Bonn/Eschborn: GIZ. Available at https://www.adaptationcommunity.net/wp-content/uploads/2017/12/EbA-Valuations-Sb_en_online.pdf

[414] Emerton, L. 2017. Valuing the benefits, costs and impacts of ecosystem-based adaptation measures: a sourcebook of methods for decision-making. Bonn/Eschborn: GIZ. Available at https://www.adaptationcommunity.net/wp-content/uploads/2017/12/EbA-Valuations-Sb_en_online.pdf
UNEP-WCMC and UNEP, 2019. Developing the economic case for EbA. Briefing note 5. Available at https://wedocs.unep.org/bitstream/handle/20.500.11822/28178/Eba5.pdf?sequence=1&isAllowed=y
Verdone, M. 2015. A cost-benefit framework for analysing forest landscape restoration decisions. IUCN, Gland; Emerton, L. 2017. Valuing the benefits, costs and impacts of ecosystem-based adaptation measures: a sourcebook of methods for decision-making. Bonn/Eschborn: GIZ. Available at https://www.adaptationcommunity.net/wp-content/uploads/2017/12/EbA-Valuations-Sb_en_online.pdf; GIZ, UNEP-WCMC and FEBA (2020) Guidebook for Monitoring and Evaluating Ecosystem-based Adaptation Interventions. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Bonn, Germany.

2. Describe the intervention's theory of change (ToC). Define a 'with intervention' scenario that describes this ToC. Define a 'without intervention' scenario. Describe the ways in which this scenario differs from the 'with intervention' scenario.
3. Identify the costs, benefits and potential impacts associated with the intervention.
4. Measure and quantify in monetary terms, where possible, intervention costs and benefits. Use ecosystem services valuation methods.
5. Perform sensitivity analysis to determine which parameters are most critical to ensuring optimal net benefits for each intervention.
6. Using both quantified and unquantified costs and benefits, determine the distributional impacts of the intervention between user groups and over time.
7. Where unequal distributions of costs and benefits exist, or where project outcomes are not aligned with strategic priorities, explore potential solutions for correction.

The steps outlined here are described in more detail below, followed by specific guidance for conducting CBA at each of the intervention sites identified.

3.1 Defining the aim of the cost-benefit analysis and outlining the study site

A clearly defined aim will ensure that the CBA is structured in a way that best generates the specific information required. Given the time- and data-intensive nature of conducting CBA, scarce project evaluation resources should be spent on answering the most relevant questions to inform project management.

In the case of the Rwanda NAP pilot EbA interventions, the aim of conducting CBA will be to understand and quantify the economic impact of the project interventions on different sectors of Rwandan society. Specific questions to be addressed using CBA include the following:

- What are the costs and benefits to society of implementing the EbA interventions being considered?
- How are these costs and benefits spread between different stakeholders and across time?
- Which factors are important determinants for the optimisation of net benefits resulting from the interventions?

The above aims should be tailored to each of the project sites, with specific ecosystems and communities identified and outlined. With EbA interventions, the assessment of costs and benefits should include an assessment of key ecosystem services user groups and dynamics. This adds a layer of complexity to the analysis, reflected in the additional questions below[415]:

- How does the intervention plan (including associated economic activities and livelihoods) depend on and impact ecosystem services?
- Which stakeholders stand to be affected by the intervention plan and by changes in ecosystem services?

Answering these questions is a multidisciplinary pursuit that should include consultation of a wide range of experts including those from biophysical and socio-economic backgrounds.

3.2 Describing a Theory of Change and outlining scenarios

Describing a Theory of Change (ToC) is critical to determining impact evaluation criteria, including those used in CBA. The costs and benefits measured as part of the CBA need to reflect these evaluation criteria, so as to ensure that the structure of the CBA is detailed enough to measure the

[415] Emerton, L. 2017. Valuing the benefits, costs and impacts of ecosystem-based adaptation measures: a sourcebook of methods for decision-making. Bonn/Eschborn: GIZ. Available at https://www.adaptationcommunity.net/wp-content/uploads/2017/12/EbA-Valuations-Sb_en_online.pdf

key impacts expected to result from the intervention, as well as the influence of key parameters affecting project outcomes.

The ‘with project’ scenario should be defined according to the ToC, with an explicit focus on outlining the expected changes in economic evaluation criteria. For the Rwanda NAP interventions, this detail is provided in the M&E framework associated with this Feasibility Study Report. This information, along with the detailed descriptions of project interventions in Section 2, allows for the definition of key costs, benefits and expected impacts resulting from the interventions. These are further outlined in the following section.

Defining the ‘without project’ scenario can be done using the same information referred to above. The ‘without project’ scenario should describe the counterfactual of the ‘with project’ scenario, in a similar level of detail. This scenario is hypothetical, as it is ultimately impossible to predict what would have happened in the absence of the intervention. In some cases, a control site will be selected to act as a proxy for the ‘without project’ scenario. Where adequate data exist, this control site can be selected using the statistical matching technique.

Defining the ToC and defining scenarios can be done with varying degrees of accuracy, from outlining high-level, general scenarios with easily obtainable impact evaluation criteria, to the application of rigorous statistical methods, informed by detailed field-level data and stakeholder engagement. More information about this process is provided in the Impact Evaluability Toolkit produced by the Abdul Latif Jameel Poverty Action Lab (J-PAL) and Clear South Asia[416], as well as in the Guidebook for Monitoring and Evaluating Ecosystem-based Adaptation Interventions, produced by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) and Friends of Ecosystem-based Adaptation (FEBA)[417].

When being applied to EbA interventions, ToCs should seek to incorporate environmental, economic and social values. Table 37 outlines the ecosystem services classification developed as part of The Economics of Ecosystems and Biodiversity initiative in 2012 and recently updated to include existence and bequest values. Understanding the delivery of ecosystem services requires an analysis of both the ecosystems that produce them as well as the sectors of society to which they accrue.

Table 37. Ecosystem services classification[418].

Ecosystem service type	Ecosystem service
Provisioning	Food
	Water
	Raw materials
	Genetic resources
	Medicinal resources
	Ornamental resources
Regulating	Air quality regulation
	Climate regulation
	Moderation of extreme events
	Regulation of water flows
	Waste treatment

[416] Jetha, Q. Kanan, H. Escueta, M. 2017. "Impact Evaluability Toolkit." J-PAL South Asia and CLEAR South Asia.
[417] GIZ, UNEP-WCMC and FEBA (2020) Guidebook for Monitoring and Evaluating Ecosystem-based Adaptation Interventions. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Bonn, Germany.
[418] De Groot, R. Brander, L. Solomonides, S. 2020. Ecosystem Services Valuation Database (ESVD) Version June 2020. www.es-partnership.org/esvd

	Erosion prevention
	Maintenance of soil fertility
	Pollination
	Biological control
Habitat	Maintenance of life cycles of migratory species
	Maintenance of genetic diversity
Cultural	Aesthetic information
	Opportunities for recreation and tourism
	Inspiration for culture, art and design
	Spiritual experience
	Information for cognitive development
	Existence and bequest values

3.3 Identification of benefits, costs and impacts associated with the interventions

The identification of benefits, costs and impacts to be included in the CBA should be done with the use of the ToC associated with interventions and the scenarios outlined in the previous section. Key categories of benefits, costs and impacts to be defined are outlined in Table 38.

Benefits

EbA interventions have been shown to result in improved health, wellbeing and prosperity of local communities. Where markets exist for the benefits resulting from EbA measures, the value of these benefits can be expressed in financial terms. Where benefits are more social in nature, accruing to people outside of markets, these will be measured either in non-monetary, but still quantitative, ways (e.g. Avoided lives lost due to flooding) or expressed in qualitative terms (e.g. Increased recreation value for local residents).

Economic valuation of these benefits will be conducted with varying points of focus, depending on the context as revealed through planned stakeholder consultations and following a review of literature and data. This will further ensure integration with: i) the project's monitoring and evaluation process; ii) existing Monitoring and Evaluation initiatives and datasets which may be encountered during stakeholder engagement; and iii) the long-term research programme (LTRP).

Costs

As outlined in Table 38, there are four categories of costs that can be considered as part of cost-benefit analysis of EbA interventions. Direct implementation expenses will be reviewed periodically through a project expenditure review, which should include both financial and in-kind project-related costs including the finances and labour required for staffing, equipment, transport, infrastructure and maintenance. In addition to these direct expenses, other categories of costs to be considered include core institutional and enabling costs, opportunity costs and social and environmental losses where applicable.

Impacts

The assessment framework, outlined in Table 38, requires that impacts be considered in terms of their temporal and spatial dimensions, as well as in terms of their distribution along key socio-economic parameters such as between gender groups and between income groups. Following the assessment of project costs and benefits, these flows will be considered along these dimensions to inform project management.

Table 38. Framework used in the identification of costs, benefits and impacts to be considered as part of the economic assessment of EbA interventions[419].

BENEFITS

Primary adaptation benefits
i.e. the benefit of reducing climate change related risk, e.g. sustained agricutlural productivity

Additional adaptation benefits
e.g. mitigation of storms and flood damages, year-round water supplies, sustained farmland productivity in the face of drought, maintenance of species habitat, etc.

Co-benefits
e.g. improved health, better food supplies, new and diversified income opportunities, disaster risk reduction, watershed protection, enhanced biodiversity, etc.

COSTS

Direct implementation expenses
e.g. staff, equipment, transport, infrastructure, maintenance, etc.

Core institutional & enabling costs
e.g. training, development of plans, laws, policies, incentives, etc.

Opportunity costs
e.g. foregone income and output due to land use restrictions, etc.

Social & environmental losses
e.g. negative impacts on women, downstream communities, etc.

IMPACTS

Temporal impacts
When do costs and benefits fall over time? e.g. rate at which habitat recovery restores ecosystem services, when intervention costs are incurred, interests of future generations, etc.

Spatial impacts
Where do costs and benefits fall spatially? e.g. gains and losses for upstream and downstream communities, costs and benefits to ecosystem providers and users, effects across borders, etc.

Distributional impacts
Where do costs and benefits fall demographically? e.g. changes in resource access or income opportunities between women and men, rich and poor, urban and rural, regions, sectors, communities, etc.

3.4 Valuation of costs and benefits generated through ecosystem services

The nature of EbA interventions presents a unique set of challenges for the use of CBA as a method of appraisal and assessment[420]. EbA interventions have been shown to result in improved societal health, wellbeing and prosperity. This occurs both through enhanced opportunities to develop sustainable livelihoods as well as through averted risk to the impacts of climate change. In some cases, the benefits generated by EbA can be measured in monetary terms. The theoretical foundations of ecosystem services valuation lie mostly in neoclassical microeconomics, and a list of valuation methods is outlined in Table 39. Each of these methods provides a unique opportunity to understand some aspect of value associated with improvements in EbA.

Of the methods outlined in Table 39, the majority fall within the category of revealed preference methods. These methods use market prices, net factor incomes, production functions or replacement costs to infer the value from transactions which have been made around ecosystem services. These methods vary in the degree to which the use of econometrics is required, and therefore in their cost to undertake.

Stated preference methods entail direct elicitation of the value of a resource from its users, through the use of surveys or participatory knowledge generation. Choice Modelling, Contingent Valuation and Group Valuation fall within this category.

Table 39. Ecosystem Services valuation methods[421].

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[419] UNEP-WCMC and UNEP, 2019. Developing the economic case for EbA. Briefing note 5. Available at https://wedocs.unep.org/bitstream/handle/20.500.11822/28178/Eba5.pdf?sequence=1&isAllowed=y; Emerton, L. 2017. Valuing the benefits, costs and impacts of ecosystem-based adaptation measures: a sourcebook of methods for decision-making. Bonn/Eschborn: GIZ. Available at https://www.adaptationcommunity.net/wp-content/uploads/2017/12/EbA-Valuations-Sb_en_online.pdf

[420] Emerton, L. 2017. Valuing the benefits, costs and impacts of ecosystem-based adaptation measures: a sourcebook of methods for decision-making. Bonn/Eschborn: GIZ. Available at https://www.adaptationcommunity.net/wp-content/uploads/2017/12/EbA-Valuations-Sb_en_online.pdf

[421] Brander, L.M., van Beukering P., Balzan, M., Broekx, S., Liekens, I., Marta-Pedroso, C., Szkop, Z., Vause, J., Maes, J., Santos-Martin F. and Potschin-Young M. (2018). Report on economic mapping and assessment methods for ecosystem services. Deliverable D3.2 EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007

Valuation method	Approach
Choice Modelling (Discrete Choice Experiment; Conjoint Analysis)	Ask people to make trade-offs between ES and other goods or income to elicit willingness to pay
Contingent Valuation	Ask people to state their willingness to pay for an ES through surveys
Damage Cost Avoided	Estimate damage avoided due to ecosystem service
Defensive Expenditure	Expenditure on protection of ES
Group Valuation (Participatory Valuation)	Ask groups of stakeholders to state their willingness to pay for an ES through group discussion
Hedonic Pricing	Estimate influence of environmental characteristics on price of marketed goods
Input-Output Modelling	Quantifies the interdependencies between economic sectors in order to measure the impacts of changes in one sector to other sectors in the economy. Ecosystems can be incorporated as distinct sectors.
Market Prices (Gross Revenue)	Prices for ES that are directly observed in markets
Net Factor Income (Residual Value; Resource Rent)	Revenue from sales of ecosystem-related good minus cost of other inputs
Opportunity Cost	The next highest valued use of the resources used to produce an ecosystem service
Production Function	Statistical estimation of production function for a marketed good including an ES input
Public Pricing	Public expenditure or monetary incentives (taxes/subsidies) for ES as an indicator of value
Replacement Cost	Estimate the cost of replacing an ES with an artificially generated service
Restoration Cost	Estimate cost of restoring degraded ecosystems to ensure provision of ES
Social Cost of Carbon	The monetary value of damages caused by emitting one tonne of CO_2 in a given year. The social cost of carbon (SCC) therefore also represents the value of damages avoided for a one tonne reduction in emissions.
Travel Cost	Estimate demand for ecosystem recreation sites using data on travel costs and visit rates
Value Transfer (Benefits Transfer)	Estimate the ES value for a "policy site" using existing information from a different "study site(s)".

Caution is required when inferring values from markets. Asymmetric information on or access to markets has been shown to distort prices so as not to reflect societal-level demand for ecosystem services[422]. Disruptions to financial markets can affect commodity prices, creating a distortion in the market's ability to reveal value. Values generated using market prices should be validated by stakeholders and adjusted where market failures and distortions are present. To avoid the use of markets, stated preference methods can be used to gather information on value through explicit consultation with stakeholders. This is a more costly exercise, requiring careful survey design to avoid the introduction of bias.

[422] Kumar M & Kumar P. 2008. Valuation of the Ecosystem Services: A Psycho-Cultural Perspective. *Ecological Economics*, 64. 10.1016/j.ecolecon.2007.05.008

In some cases, the benefits from EbA interventions will accrue in ways which are not easily expressed in monetary terms, even through the use of stated preference methods[423], but which are important for consideration in any economic analysis. These benefits include, for example, avoided lives lost to drought or flooding, or the psychological benefits associated with immersion in green spaces[424]. Although methods exist to determine the value of these benefits, the accuracy of these methods is poorly understood. Cultural ecosystem services are especially less amenable to monetisation[425], and few studies have quantified cultural ecosystem services in Africa[426]. Costs and benefits that remain unquantified should be presented in qualitative terms alongside the results of the CBA, to allow decision-makers to take both quantitative as well as qualitative information into account when determining which interventions to scale up and how additional interventions might be used to adjust for disproportional welfare effects.

Choice of the Discount Rate

The choice of discount rate can have a critical impact on whether an intervention generates favourable results under CBA. Discount rates should be set at the opportunity cost of capital. For projects generating a social impact, this is reflected in society's rate of social time preference. Valentim and Prado estimated Rwanda's rate of time preference to be 6%[427].

Where EbA interventions are concerned, costs are often borne up front while benefits accrue over longer timeframes. Higher discount rates favour projects that deliver benefits earlier. Given that responding to climate change entails the consideration of inter-generational equity, there exists a strong argument for the use of lower discount rates and longer timeframes in analysis than have conventionally been used in CBA's in, for example, built infrastructure[1].

Internal Rate of Return

An intervention's internal rate of return (IRR) reflects the discount rate at which the present value of all costs and benefits are equal. Higher IRRs are generally considered favourable, although the parameter should be interpreted with caution, given its tendency to result in unstable estimates under certain patterns in the distribution of net benefits in time1. IRRs are sometimes measured against a 'hurdle-rate', which is determined by the opportunity cost of the investment being considered. Projects which produce a high return relative to this hurdle rate can be considered favourable investments, provided that they also meet additional environmental, social and economic criteria.

3.5 Sensitivity analysis

CBA relies on the construction of simplified models of reality. These models are useful to the extent that they reflect key real-world dynamics in simulated scenarios. The ability of a CBA to produce useful results is dependent on the accurate specification of key model assumptions and parameters. Sensitivity analysis involves the testing of key assumptions and parameters used in the CBA. These can be changed manually where a plausible higher or lower-bound of the parameter exists, and the impact on NPV, IRR and other results gauged. Alternatively, this can be done with the use of a repeated random sampling technique such as Monte Carlo simulation. By assuming a distribution in

[423] UNEP-WCMC and UNEP, 2019. Developing the economic case for EbA. Briefing note 5. Available at https://wedocs.unep.org/bitstream/handle/20.500.11822/28178/Eba5.pdf?sequence=1&isAllowed=y
[424] Fuller, R. A., Irvine, K. N., Devine-Wright, P., Warren, P. H., & Gaston, K. J. (2007). Psychological benefits of greenspace increase with biodiversity. Biology letters, 3(4), 390–394. https://doi.org/10.1098/rsbl.2007.0149
[425] Daniel, TC. A. Muhar, A. Arnberger, A. Aznar, O. Boyd, JW. Chan, et al. 2012. Contributions of cultural services to the ecosystem services agenda. Proceedings of the National Academy of Sciences, 109 (23) (2012), pp. 8812-8819
[426] Wangai, P.W., Burkhard, B. and Müller, F., 2016. A review of studies on ecosystem services in Africa. International journal of sustainable built environment, 5(2), pp.225-245.
[427] Valentim, J. Prado, M. 2008. Social Discount Rates. SSRN. Available: https://ssrn.com/abstract=1113323 or http://dx.doi.org/10.2139/ssrn.1113323

the pattern of variation of results, this method allows for the construction of confidence intervals, as well as a visual representation of the distribution of likely benefits under the variation in parameters[428].

3.6 Distributional analysis

To generate information on the distributional impact of an intervention, the analysis should explicitly consider the scales at which scales costs and benefits accrue to society. In some cases, a relatively large share of benefits will be captured by local communities. Where the costs of EbA interventions are incurred to a disproportionate degree by local communities, in the form of opportunity costs or increased social and environmental risk, while the benefits accrue to society more broadly, a mechanism to redistribute costs and benefits should be considered[429]. The sustainable development and diversification of livelihoods which rely on ecosystem services generated through EbA is one such mechanism, and if carried out well, can contribute to both the social and economic feasibility of EbA interventions. These measures, analysed further in the discrete sections below, should be targeted towards addressing disproportionate net benefits as identified in the CBA of EbA interventions.

Cost and benefit data should be analysed according to gender, class, and other critical social parameters to inform the extent to which project interventions are addressing poverty or improving the lives of women and girls. In some cases, analysis may reveal that marginalised members of society are not equipped with the necessary land or labour needed to benefit from EbA interventions. Where CBA reveals disproportionate benefits to certain sectors of society, this information can be used to justify efforts to increase participation of marginalised sectors and, in doing so, the impact of interventions.

The following sub-sections provide guidance on finalising criteria that can be used to quantify the costs and benefits associated with the interventions proposed. Changes in these criteria should be measured over time and net changes in monetary values incorporated into the CBA for each of the project years.

3.7 Site 1: Ibanda-Makera Natural Forest, Kirehe District, Eastern Province

The following list provides a summary of the finalised interventions identified for Ibanda-Makera Natural Forest, including a list of EbA interventions and a list of complementary interventions to address degradation drivers. This is followed by a more detailed overview of the costs and benefits associated with each, and information on how to measure these costs, benefits, and the resulting geographical, temporal and distributional impacts.

EbA interventions

- Demarcation and establishment of a buffer zone around the forest, using drought-resilient, multi-use tree species
- The promotion of agroforestry in surrounding agricultural land
- Introducing highly productive drought-resistant crop species

Complementary interventions to address baseline degradation drivers

- Provision of fuel wood, fruit, timber and NTFPs from agroforestry and buffer zone trees

[428] Verdone, M. 2015. A cost-benefit framework for analysing forest landscape restoration decisions. IUCN, Gland
[429] Hockley, NJ. Razafindralambo, R. 2006. A Social Cost-Benefit Analysis of Conserving the Ranomafana-Andringitra-Pic d'Ivohibe Corridor in Madagascar. Available online: http://www.bangor.ac.uk/~afpe5d/SCBA.html

Benefits

The benefits associated with interventions at Ibanda-Makera Natural Forest are outlined in Table 40 and the text below provides guidance around their measurement.

Demarcation and establishment of buffer zone

The demarcation and establishment of the forest will be done using multi-use tree species. Species will be selected based on their ability to provide fruit, fodder and fuelwood to communities. Harvesting of fuelwood and NTFPs should be tracked over time to determine whether the intervention provides a notable increase in the quantity of fuelwood and NTFPs. The value of fuelwood and NTFPs can be quantified using local market prices. In this way, the annual value of fuelwood and NTFPs can be determined and included in the CBA.

Successful protection and restoration of the remaining natural parts of Ibanda-Makera forest will result in the improved potential for ecotourism in the area. According to Damascène Gashumba, the Director of Rwanda's Rural Environment Development Organisation (REDO), promotion of tourism in Ibanda-Makera could result in the area attracting 10% of the visitors to Akagera National Park. This park attracted 49,000 visitors in 2019, meaning that Ibanda-Makera could attract around 4,900 visitors per year if this was to happen[430]. This tourism, if developed in a way that results in a high degree of local beneficiation, has the potential to play an important role in the diversification of livelihoods and the reduction of poverty. Household surveys should be used to gather information on the amount of income generated through tourism-based livelihoods.

Both the buffer zone and the natural forest within will likely serve to improve infiltration of water during rainfall events, leading to soil conservation, hillside stabilisation, improved groundwater recharge and a reduction in the severity of flooding and landslides. Quantifying and valuing this benefit will require the tracking of parameters in the area of disaster losses. This is currently being done by Rwanda's Ministry in charge of Emergency Management (MINEMA). In accordance with United Nations Office for Disaster Risk Reduction (UNDRR)'s Sendai Framework, the database held by MINEMA documents the number of deaths resulting from disasters in the country, including from flooding and landslides. The database also has information on the number of houses damaged and the number of hectares of crops damaged or lost to flooding and landslides[431]. Through the use of household surveys, MINEMA data can be validated to most accurately measure the parameters associated with flooding and landslide-related damages. The surveys can also be used to gather additional information to be used in valuing the damages. Crucial in this regard is the determine the value of agricultural losses incurred, by determining the exact crop types, levels of maturity, and proportion of the yield lost during flooding or landslides.

Promotion of agroforestry

Agroforestry provides a wide spectrum of ecosystem services including provisioning, regulating, habitat and cultural services[432]. Delivery of provisioning services is most straightforward in terms of measurement and quantification. Detailed farm budgets should be recorded for each of the

[430] De Dieu Nsabimana, J. 2020. Plans underway to transform Kirehe's Ibanda-Makera forest into a tourist venue. The New Times, 17 November 2020. Available: https://www.newtimes.co.rw/news/plans-underway-transform-kirehes-ibanda-makera-forest-tourist-venue

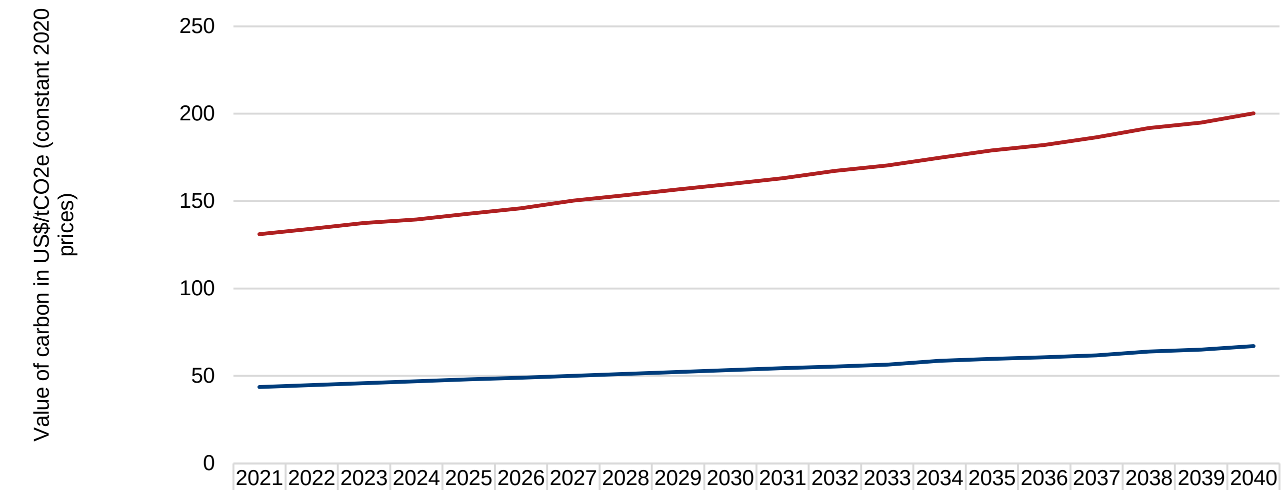
[431] MINEMA. 2020. Disaster Management. Ministry in charge of Emergency Management. Available: https://www.minema.gov.rw/disaster-management

[432] Sileshi, G. Akinnifesi, FK. Ajayi, OC. Chakeredza, S. Kaonga, M. Matakala, PW. 2007. Contributions of agroforestry to ecosystem services in the miombo eco-region of eastern and southern Africa. African Journal of Environmental Science and Technology, 1(4); Buchelli, VJP, Bokelmann, W. 2017. Agroforestry systems for biodiversity and ecosystem services: the case of the Sibundoy Valley in the Colombian province of Putumayo. International Journal of Biodiversity Science, Ecosystem Services and Management, 13(1); Brown, S.E., Miller, D.C., Ordonez, P.J. et al. Evidence for the impacts of agroforestry on agricultural productivity, ecosystem services, and human well-being in high-income countries: a systematic map protocol. Environ Evid 7, 24 (2018). https://doi.org/10.1186/s13750-018-0136-0

participants taking part in the development of agroforestry. These should include records of the harvesting of fuelwood, crops, fodder and other forms of NTFPs.

Agroforestry provides regulating ecosystem services in the form of i) carbon sequestration, ii) biodiversity conservation, iii) soil enrichment and iv) air and water quality[433]. While some of these benefits will be reflected in farm budgets (through enhanced productivity, pollination and pest management), others will require estimation through hydrological and atmospheric modelling.

Carbon sequestration can be quantified using remote sensing data, and a value attached to this quantity according using the Shadow Pricing method. This is relatively straightforward given readily available estimates for an appropriate shadow price in the form of the social cost of carbon (SCC). Recent World Bank guidance suggests that the assessment of an intervention's mitigation benefits should rely on an SCC value that steadily rises over time, as is shown in Figure 95.



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
High estimate	87	89	92	93	95	97	100	102	104	107	109	112	114	116	119	121	125	128	130	133
Low estimate	44	45	46	47	48	49	50	51	52	53	54	55	56	59	60	61	62	64	65	67

Figure 95. Recommended shadow price of carbon[434].

Once annualised values of the tons of the CO2 equivalent has been estimated, this can be multiplied by both a low and a high estimate for the SCC to create a range of the likely value of climate change mitigation associated with the intervention in each year. Alternatively, a conservative value can be generated using only the low estimate.

Introducing highly productive drought-resistant crop species

The use of drought-resistant crop species has been shown to produce more consistent yields under conditions of high rainfall variability relative to conventional varieties[435]. However, in some cases these varieties have been found to result in the same or even lower yields than their conventional counterparts during average rainfall years[436]. The returns to the introduction of new crop species and varietals should be measured during project implementation through the recording of detailed farm budgets. These budgets should be recorded both for farms participating in this project's activities as well as for those farms which do not. The sample of respondents forming part of the assessment

[433] Jose, S. 2009. Agroforestry for ecosystem services and environmental benefits: an overview. Agroforest Syst 76, 1–10. https://doi.org/10.1007/s10457-009-9229-7
[434] Figures taken from World Bank, 2017. Shadow price of carbon in economic analysis: Guidance note, updated for inflation to reflect 2020 constant prices
[435] Cacho, O.J., Moss, J., Thornton, P.K. et al. 2020. The value of climate-resilient seeds for smallholder adaptation in sub-Saharan Africa. Climatic Change 162, 1213–1229.
[436] Michler, JD. Baylis, K. Arends-Kuenning, M. Mazvimavi, K. 2019. Conservation agriculture and climate resilience. Journal of Environmental Economics and Management, 93. https://doi.org/10.1016/j.jeem.2018.11.008.

should therefore be divided into two groups: a treatment group and a control group. Aside from the one group's receiving the treatment, the groups should be as similar as possible in other respects. This will allow for the generation of comparable data and robust information from which to draw inferences.

Table 40. Benefits of interventions at the Ibanda-Makera site.

Intervention	Primary adaptation benefits	Additional adaptation benefits	Co-benefits
Demarcation and establishment of a buffer zone around the forest, using drought-resilient, multi-use tree species	enhanced household incomes from sale of fruit, timber, poles, fuelwood and NTFPs; reduced demand on natural forests for resources and reduce deforestation rates (conservation)	Reduced forest fragmentation; improved ecosystem connectivity and biodiversity; enhanced potential for the development of eco-tourism, including associated jobs and incomes; potential for enhanced indirect and induced impacts of tourism spending; potential to generate income for conservation and promotion of cultural heritage;	Enhanced regulation of ecosystem services such as flood and soil erosion control; disease and pest control; carbon sequestration; improved soil quality and nutrient cycling; improved water quality
The promotion of agroforestry with drought-resilient trees in surrounding agricultural land	Optimisation of usage of space in a country limited by land resources and facing high population density pressures; enhanced household incomes from sale of fruit, timber, poles, fuelwood and NTFPs; reduced demand on natural forests for resources and reduce deforestation rates (conservation)	Enhanced regulation of ecosystem services such as flood, wind and soil erosion control, disease and pest control, carbon sequestration, improved soil quality and nutrient cycling, and improved water quality, as a result of decreased pressure on natural forest for resources	Improved diets through the provision of fruits from fruit trees
Introducing highly productive drought-resistant crop species	More dependable, consistent levels of agricultural productivity	Reduced water use	Reduced pressure on water sources; reduced encroachment into forest and therefore enhanced regulation of ecosystem services it provides

Costs

The costs associated with EbA interventions at Ibanda-Makera have been identified and outlined in Table 41. The types of costs which need to be considered for Ibanda-Makera are similar across all of the interventions, given similarities in the inputs required. Direct implementation expenses are detailed in the project budgets in Annex 7. These include the provision of seedlings and other inputs for implementation. Also included in this cost category is the labour required for planting and maintaining seedlings during establishment. Core institutional and enabling costs include those associated with enforcement of conditions around resource-use, which will be required to ensure sustainable harvesting of fuelwood and NTFPs from the buffer zone.

The opportunity cost of land to be used in this buffer zone should be ascertained as part of the CBA. This can be done by determining the most productive form of sustainable utilisation of the land and estimating the value per hectare of this land-use type. In the case of Ibanda-Makera, the value of agriculture in terms of productivity and associated returns should be used to estimate the opportunity cost of land.

Table 41. Costs of interventions at Ibanda-Makera site.

Intervention	Direct implementation costs	Core institutional and enabling costs	Opportunity costs, including social and environmental losses
Demarcation and establishment of a buffer zone around the forest, using drought-resilient, multi-use tree species	Seedlings; labour for planting and maintenance of seedlings during establishment	Enforcement costs; development of laws/plans/policies	Loss of land owned by surrounding communities in a land-scarce region
The promotion of agroforestry with drought-resilient trees in surrounding agricultural land	Seedlings; labour for planting and maintenance of seedlings during establishment	Training expenses	Training time cost for foresters/farmers
Introducing highly productive drought-resistant crop species	Seedlings; labour for planting and maintenance of seedlings during establishment	Training expenses	Training time cost for foresters/farmers; possible shift away from community crop preferences

Impacts

Once the above costs and benefits have been quantified and annual figures estimated, the net present value (NPV) of the interventions should be determined. This NPV should be disaggregated between different user groups. The NPV should be computed for male-headed households and for female-headed households and these figures compared. The NPV should also be compared between households earning lower and higher incomes, allowing the project team to determine which income classes are benefiting from the interventions the most. This will provide information on the interventions' impacts on societal equity. Evidence surrounding the uptake of sustainable land management in Malawi and Tanzania suggests that higher-income households are more likely to be able to absorb the indirect costs associated with the activities, and therefore benefit to a greater degree from their uptake. Similarly, male-headed households in the areas studied were found to be more likely to own land and other assets, and more likely to benefit from sustainable land management practices[437]. The impacts associated with EbA interventions at Ibanda-Makera have been identified and outlined in Table 42.

Table 42. Impacts of interventions at Ibanda-Makera site.

[437] Emerton L. 2016. Assessing the economic costs, benefits and drivers of sustainable land management for farmers in Ntcheu District, Malawi & Lushoto District, Tanzania. CIAT Working Paper. International Center for Tropical Agriculture (CIAT). Cali, Colombia. 77 p.

Intervention	Temporal impacts	Spatial impacts	Distributional impacts
Demarcation and establishment of a buffer zone around the forest, using drought-resilient, multi-use tree species	Extended timeframe for planted species in the buffer zone to provide benefits (food, firewood, forage, etc.)	Displacement of land owned by surrounding communities	-
The promotion of agroforestry with drought-resilient trees in surrounding agricultural land	Longer timeframe for delivery of benefits (food, firewood, forage, etc.)	Displacement of land that could be used for crop cultivation	May not benefit farmers with less space to implement agroforestry
Introducing highly productive drought-resistant crop species	Potentially long timeframe for new species/cultivars to grow to maturity		

3.8 Site 2: Muvumba River, Nyagatare District

The following list provides a summary of the interventions proposed for the Muvumba River.

EbA interventions

- Demarcation and establishment of a buffer zone along river, using riparian vegetation restoration, as well as multi-use trees (e.g. fodder and fruit trees), and the possible extension of the buffer zone beyond 10 m around certain gallery forests
- Reforestation of catchment areas upstream from water intake and treatment plants
- Using ditches and grasses for soil erosion control

Complementary interventions to address baseline degradation drivers

- Provision of fuel wood, fruit, timber and NTFPs from multi-use tree species planted in buffer zone and in reforested areas

<u>Benefits</u>
The anticipated benefits associated with interventions at Muvumba River are outlined in Table 43, and the text below provides guidance around their measurement and valuation.

Demarcation and establishment of a buffer zone

The buffer zone is expected to stabilise the riverbank and reduce erosion and sedimentation of the river. This would have the effect of improving the river's water quality. Field consultations and a desktop review revealed that the Muvumba River, and the water abstracted from it, is used for the following purposes:

- Direct domestic use;
- Irrigated agriculture (rice);
- Coffee washing stations;
- Hydropower plants;
- Water treatment plants;
- Mineral extraction sites;
- Dams;
- Fishing grounds; and

- Multipurpose dam (planned).

Siltation of the river related to erosion of exposed riparian areas and riverbanks decreases water intake of the pumping stations on the river, through the clogging of pumps and the reduced intake capacity during the necessary cleaning, negatively affecting the supply to the above uses and increasing maintenance costs. The activity will have benefits to the extent that it reduces the costs of water treatment facilities and to the extent that it reduces the amount of time in a given period when these facilities are not able to deliver water to their users. This can be quantified in relatively simple ways by keeping track of the number of days in a year that water treatment facilities are able to supply water to their users. Conversely, the number of hours spent on maintenance can be tracked as a proxy for the costs of treating water with a high sediment load.

Establishing the value of this benefit will require additional steps and therefore be a more costly exercise. There are two potential approaches to this exercise, both of which are based on the Production Function method outlined in Section 3.4:

- By determining the quantity of water used in for the various purposes, and then estimating the value of the water for each of these purposes. The loss of water due to reduced operation of water treatment facilities, during times when they are unable to operate due to high siltation rates, can be estimated. The value of this water can be inferred using either the Market Prices method or Replacement Cost method (Section 3.4).
- By determining the increase in the direct costs of water treatment under different levels of siltation, the intervention's impact of reducing siltation can be quantified in monetary terms. Ongoing monitoring of both siltation levels and treatment costs could be used to establish evidence for the causal link between improved management of the riparian zone, as well as water quality parameters such as turbidity, and treatment costs.

Rwanda's Natural Capital Accounts present an important source of data for the measurement of soil erosion in the Muvumba catchment and elsewhere in Rwanda[438]. The study estimates that the Muvumba catchment has lost between 6.7 million and 11 million tons of soil per year since 1990, with estimates for 2015 suggesting the loss of 8.7 million tons per annum.

With both of these approaches, it should be noted that demonstrating the causal link between the intervention and improved water quality will be challenging. Gathering data at every stage of the causal chain in the Theory of Change will ensure a relatively robust outcome in the absence of control sites.

Additional adaptation benefits associated with this intervention will include the reduced impact of flooding on communities adjacent to and downstream of the project site. This can be done through a consideration of the project's impacts on losses in life and assets experienced due to flooding, as was described for bank stabilisation interventions in Ibanda-Makera.

Reforestation

Reforestation catchment areas is likely to result in the improved delivery of a wide spectrum of ecosystem services. A systematic review across the tropics found that afforestation resulted in an average of a three-fold increase in the infiltration capacity of soils across the sites considered[439]. The implications of this improved infiltration are considerable for groundwater recharge and flood

[438] NISR, MINECOFIN, MoE. 2019. Rwanda Natural Capital Accounts – Ecosystems. Version 1.0, National Institute of Statistics of Rwanda, Ministry of Finance and Economic Planning, Ministry of Environment with assistance from the World Bank and the WAVES Global Partnership
[439] Ilstedt, U. Malmer, A. Verbeeten, E. Murdiyarso, D. 2007. The effect of afforestation on water infiltration in the tropics: A systematic review and meta-analysis. Forestry Ecology and Management, 251. https://doi.org/10.1016/j.foreco.2007.06.014

attenuation. The value of these reforestation activities can be measured through considering the changes in landscape processes which accompany reforestation.

Reduced runoff improves soil conservation, and the averted loss of soil constitutes one benefit which should be tracked during implementation. This can be done by measuring soil depth at key points in the landscape and tracking change over time. If this soil is being used in a productive way, the value of productivity can be tracked over time to see if there is correlation with soil depth. Using the Production Function approach described in Section 3.4, the value of the soil can be inferred and attached to the quantity of soil being conserved through the intervention, to estimate annual benefits.

Improved infiltration would lead to groundwater recharge, and increased availability during times of lower rainfall. This increased resilience can be quantified using hydrological modelling and verified with primary data from the project catchment. Where the increased availability in water can be quantified, the value of this additional water can be ascertained, either by inferring its value directly from the market price of water for residential and industrial purposes, according to the demand profile in the study site.

Additional co-benefits that may be generated through this intervention include the provision of fuelwood and NTFPs, as well as recreational benefits.

Using ditches and grasses for soil erosion control

Using ditches and grasses for soil erosion control would result in improved infiltration, soil conservation and flood attenuation. Measurement of these impacts should be carried out as described above for the Reforestation intervention.

Table 43. Benefits of interventions at the Muvumba River site.

Intervention	Primary adaptation benefits	Additional adaptation benefits	Co-benefits
Demarcation and establishment of a buffer zone along river, restoring riparian vegetation	Reduced sedimentation of rivers; bank stabilisation; soil conservation; reduced erosion of riverbanks; reduced cost of water treatment; improved water quality for irrigation and fisheries	Reduced impact of flooding; shade for aquatic species; enhanced household incomes from sale of fruit, timber, poles, fuelwood and NTFPs	Recreational
Reforestation of catchment areas upstream from water intake and treatment plants with drought-resistant tree species	Reduced sedimentation of rivers; bank stabilisation; soil conservation; reduced erosion of riverbanks	Reduced impact of flooding; shade for aquatic species; reduced cost of water treatment; Improved water quality for irrigation and fish	Recreational; possible provision of fruit, fuelwood and NTFPs depending on tree species used
Using ditches and grasses for soil erosion control	Soil conservation; flood attenuation	Improved groundwater recharge	Fodder production

<u>Costs</u>

The anticipated costs associated with interventions at Muvumba River are outlined in Table 44. Interventions at Muvumba would include direct implementation costs, as detailed in Section 2, as well as core institutional and enabling costs and opportunity costs.

The demarcation and establishment of a buffer zone along the river entails enforcement costs, as well as costs related to the establishment of governance and usage rules for the buffer zone. Some of these costs may be difficult to quantify, especially where community governance structures are used. Where these are found to be substantial they should be quantified where possible or expressed qualitatively.

The reforestation of catchment areas, as well as the use of ditches and grasses for soil erosion control will require labour. The value of this labour can be assumed equivalent to its opportunity cost – that is, the average wage rate or otherwise most productive use of time for the participants. The opportunity cost of the time required for training and other forms of stakeholder engagement should also be factored in, using the same method as for labour.

The opportunity cost of land should be considered where relevant, once final areas are demarcated and allocated to either the buffer zone or an area of reforestation or soil erosion control. This opportunity cost can be expressed as the next most productive use of that land available. The productive value of agriculture is an appropriate opportunity cost to consider given its prominence as a form of land use in the project sites, and given generally available information on the average yield per hectare and market price for crops produced.

Table 44. Costs of interventions at the Muvumba River site.

Intervention	Direct implementation costs	Core institutional and enabling costs	Opportunity costs, including social and environmental losses
Demarcation and establishment of a buffer zone along river, restoring riparian vegetation	Infrastructure (demarcation materials); seedlings; labour for planting and maintenance of seedlings during establishment	Enforcement costs; development of laws/plans/policies	Current land uses, potentially productive
Reforestation of catchment areas upstream from water intake and treatment plants with drought-resistant tree species	Seedlings; labour for planting and maintenance of seedlings during establishment	Staffing and administrative costs to finalise land tenure arrangements	Training time cost for participants; potential displacement of productive activities, e.g. agriculture
Using ditches and grasses for soil erosion control	Seedlings; Labour for digging ditches, planting and maintenance of seedlings during establishment		Training time cost for participants

Impacts

The interventions at Muvumba River have the potential to result in the impacts outlined in Table 45. In terms of temporal impacts, the benefits from reforestation in particular have been shown to materialise over relatively long timeframes. If CBA is to accurately reflect the benefits as well as the costs of these interventions, longer timeframes should be used in analysis. The use of ditches and grasses for soil erosion control, by comparison, results in benefits which accrue over shorter timeframes. Fast growing grasses can provide fodder within months as opposed to years in the case of trees. These strategies are complimentary and when used together will ensure fast returns as well as potentially higher value but longer term benefits.

In terms of spatial impacts, the nature of catchment topography and hydrological cycles determines results in downstream water users benefiting from improved catchment management upstream. In some cases, Payments for Ecosystems Services (PES) has been used as a financial solution to incentivise sustainable land management in the catchments of a valuable water source, and as a means to distribute the benefits from downstream water users to upstream land users. These payments can be results-based, varying according to the improvement in key parameters such as soil depth and infiltration rates.

Table 45. Impacts of interventions at the Muvumba River site.

Intervention	Temporal impacts	Spatial impacts	Distributional impacts
Demarcation and establishment of a buffer zone along river, restoring riparian vegetation	Long timeframe for riparian vegetation to establish and for benefits to materialise	Loss of agricultural land along river	Unequal cost:benefit profile favouring communities downstream of demarcation zone
Reforestation of catchment areas upstream from water intake and treatment plants with drought-resistant tree species	Long timeframe for forest vegetation to establish and for benefits to materialise	Loss of agricultural land on hills in catchment	The activity has a high opportunity cost given the requirement for less intensive forms of cultivation to be practiced. This cost is borne locally. The benefits of the intervention, however, are experienced both locally as well as on a larger scale, with carbon and bequest values for the preservation of biodiversity being of global relevance. Depending on magnitudes, this potential mismatch in costs and benefits can be addressed through sustainable, locally-driven tourism or other forms of livelihood diversification.
Using ditches and grasses for soil erosion control	Relatively short timeframes for returns from the use of grasses	Benefits will be experienced both on site, downhill from the interventions and further downstream in the catchment, with improved water quality. Costs will be incurred locally, but the benefits in the form of fodder production and soil	

		conservation may prove to be substantial.	

3.9 Site 3: Eastern Savannas, Nyagatare District

The recommended EbA interventions to be piloted in the eastern savannas would promote silvopastoralism to strengthen livestock production and increase forest cover. The following list provides a summary of the interventions proposed to achieve these outcomes.

EbA interventions

- Fencing off paddocks with drought-tolerant trees
- Planting drought-resistant trees in rangelands
- Planting fodder and medicinal plants for use by livestock and humans, respectively

Complementary interventions to address baseline degradation drivers

- Provision of fuel wood, fruit, timber and NTFPs from multi-use tree species planted in all three EbA interventions

Benefits

The benefits of EbA interventions at the eastern savanna site are given below in Table 46. The fencing off of paddocks with drought-tolerant trees is intended to result in increased physical capacity for sustainable livestock management among project participants. This measure, if accompanied by sustainable governance of communal grazing areas, has the potential to facilitate improved rangeland management and a reduction of grazing pressure during recovery of the savanna ecosystem to a more optimal and productive state. The benefits are therefore improved productivity as well as improved consistency of supply of ecosystem services in the form of fodder production. The quantity of fodder produced can be measured using remote-sensing and other ways of detecting changes in biomass. The value of this increased fodder can then be inferred through the use of market prices, as well as through choice experiment techniques where markets are not available to the key sectors of society under consideration[440].

The use of ecological infrastructure for the paddocks will provide additional adaptation benefits in the form of improved soil health and nutrient cycling, as well as improved water infiltration and groundwater recharge.

Additional important co-benefits include carbon sequestration from the improved condition of savannas, and potential emissions reductions due to improved enteric fermentation of livestock. Reduced sedimentation of rivers, and improved disease and pest control have also been shown to result from the use of live fences[441].

Table 46. Benefits of interventions at the eastern savannas site.

[440] Myint, M.M., & Westerberg, V. (2015). An economic valuation of a large-scale rangeland restoration project through the Hima system in Jordan. Report for the ELD Initiative by International Union for Conservation of Nature, Nairobi, Kenya. Available from: www.eld-initiative.org
[441] ScienceDirect, 2020. Live Fences. Available: https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/live-fences

Intervention	Primary adaptation benefits	Additional adaptation benefits	Co-benefits
Fencing off paddocks with drought-tolerant trees	Restoration of rangeland systems to a more productive state, and benefit of sustainably managed livestock production	Improved soil health and nutrient cycling; improved water infiltration and groundwater recharge	Carbon sequestration; flood attenuation; reduced sedimentation of rivers; disease and pest control
Planting drought-resistant trees in rangelands	Additional fodder and shade for livestock in a warming and drying environment; Wood for communities; Enhanced soil protection	Optimisation of usage of space in a country limited by land resources and facing high population density pressures; Enhanced household incomes from sale of fruit, timber, poles, fuelwood and NTFPs; Enhanced regulation of ecosystem services such as flood, wind and soil erosion control, disease and pest control, carbon sequestration, improved soil quality and nutrient cycling, water infiltration and water quality	Improved access to plants with medicinal uses; Reduced degradation on savannas and pressure on remaining natural tree species
Planting fodder and medicinal plants for use by livestock and humans, respectively	Improved access to plants with medicinal uses, fruit, fuelwood, timber and NTFPs	Reduced demand on natural forests for resources and reduced deforestation rates (conservation)	Improved nutrition through the provision of fruits from fruit trees; Enhanced household incomes from sale of fruit, timber, poles, fuelwood and NTFPs

Costs

Costs related to the implementation of interventions in the eastern savannas will include direct implementation costs, largely in the form of seedlings and other inputs as described in Section 2 and presented in Table 47. Other direct costs include the labour used for planting and maintenance of drought-resistant trees, as well as fodder and medicinal plants.

Enabling costs include the training expenses also incurred as part of the project. Opportunity costs consist of the time invested by farmers in attending training and other forms of stakeholder engagement. It is possible that other costs will be incurred where livestock farmers change grazing regimes to allow for rangeland rehabilitation. These costs should be monitored during implementation and quantified where possible.

Table 47. Costs of interventions at the eastern savannas site.

Intervention	Direct implementation costs	Core institutional and enabling costs	Opportunity costs, including social and environmental losses
Fencing off paddocks with drought-tolerant trees	Seedlings; labour for planting and maintenance of seedlings during establishment; labour	Training expenses	Training time cost for farmers; changes to grazing regimes?
Planting drought-resistant trees in rangelands	Seedlings; labour for planting and maintenance of seedlings during establishment; labour	Training expenses	Training time cost for farmers
Planting fodder and medicinal plants for use by livestock and humans, respectively	Seedlings; Labour for planting and maintenance of seedlings during establishment; labour	Training expenses	Training time cost for farmers

Impacts

Potential impacts from the eastern savanna site EbA interventions are presented in Table 48. The impacts of these interventions may take several years to be felt, given the long timeframes required for rangeland restoration. Planting fodder and medicinal plants is likely to provide returns over shorter timeframes, and these strategies should ideally be implemented alongside one another.

Stakeholder consultations revealed that farmers with smaller rangelands may be less likely to have the available space to accommodate the planting of trees or additional crops. Similarly, farmers without access to water may be less successful in the uptake of these interventions. During implementation, intervention benefits should be measured according to plot size, as well as according to the different levels of access to water for irrigation among participants.

Table 48. Impacts of interventions at the eastern savannas site.

Intervention	Temporal impacts	Spatial impacts	Distributional impacts
Fencing off paddocks with drought-tolerant trees	Longer timeframe for delivery of benefits	Changes to grazing regimes to allow for rangeland rehabilitation	
Planting drought-resistant trees in rangelands	Longer timeframe for delivery of benefits		May preference farmers with larger rangelands and access to water for irrigation
Planting fodder and medicinal plants for use by livestock and humans, respectively	Relatively shorter timeframe for delivery of benefits		May preference farmers with larger rangelands to accommodate crop-planting, and access to water for irrigation

3.10 Site 4: Shagasha Tea Estate, Rusizi District, Western Province

The following list provides a summary of the interventions identified for the Shagasha tea estate.

EbA interventions

- Reducing water stress and soil moisture loss through the planting of drought-tolerant tree species as a form of agroforestry
- Plantation of grasses on the verges of tea plots for erosion control
- Conservation of remaining natural forests and restoring degraded forests around the plantation to increase shade and water infiltration
- Conservation and restoration of riparian vegetation along streams and wetlands to prevent channelisation of headwater streams

Complementary interventions to address baseline degradation drivers

- Provision of fuel wood, fruit, timber and NTFPs from multi-use tree species planted in agroforestry intervention
- Plantation of forest trees in available land of 200 ha specifically for use in the tea-making process by the tea factory

Benefits

Benefits for the interventions proposed for Shagasha Tea Estate are given in Table 49. The introduction of agroforestry at Shagasha Tea Estate has the potential to result in enhanced household incomes from the sale of timber, fuelwood and NTFPs. These benefits should be tracked through the recording of detailed farm budgets before, during and after the interventions. These budgets should include both the financial costs as well as in-kind costs such as the amount of labour used in agriculture. Production, home consumption and sales of a wide variety of crops and NTFPs should be tracked. The use of a control group would allow for a more robust method of comparing the with-project scenario to the without-project scenario, improving the quality of evidence generated for evaluation.

Table 49. Benefits of interventions at the Shagasha Tea Estate site.

Intervention	Primary adaptation benefits	Additional adaptation benefits	Co-benefits
Reducing water stress and soil moisture loss through the planting of drought-tolerant tree species (agroforestry)	Enhanced household incomes from sale of fruit, timber, fuelwood and NTFPs; shade, reducing soil moisture loss and ambient temperatures, as well as erosion and runoff; Reduce frost on tea plants in lower elevation plantations	Enhanced regulation of ecosystem services such as flood, wind and soil erosion control, disease and pest control, carbon sequestration, improved soil quality and nutrient cycling	Improved nutrition through the provision of fruits from fruit trees
Plantation of grasses on the verges of tea plots	Hill stabilisation; soil conservation; Maintained or enhanced agricultural productivity	Reduced erosion and rainwater runoff (erosion and flood control)	Livestock fodder generation
Conservation of remaining natural forests and restoring degraded forests around the plantation	Reduced forest fragmentation; improved ecosystem connectivity and biodiversity; enhanced potential for the development of eco-tourism, including associated jobs and incomes; potential for	Enhanced regulation of ecosystem services such as flood and soil erosion control; enhanced disease and pest control	Carbon sequestration; improved soil quality and nutrient cycling; improved water quality

	enhanced indirect and induced impacts of tourism spending; potential to generate income for conservation and promotion of cultural heritage;		
Conservation and restoration of riparian vegetation along streams and wetlands to prevent channelisation of headwater streams	Reduced sedimentation of rivers; bank stabilisation; soil conservation; reduced erosion of riverbanks; reduced cost of water treatment; improved water quality for irrigation	Reduced impact of flooding; shade for aquatic species; enhanced household incomes from sale of fruit, timber, poles, fuelwood and NTFPs	Recreational

Costs

The costs associated with interventions at Shagasha Tea Estate would include direct implementation costs, core institutional and enabling costs as well as opportunity costs (Table 50). Direct implementation costs include project costs as reflected in Section 2 as well as labour costs incurred by project participants. Institutional and enabling costs include training expenses incurred by the project. The opportunity cost of the project includes time spent training, incurred by participants, as well as the foregone income from the next most feasible form of land-use.

The plantation of grasses on the verges of tea plots was not deemed to have a substantial opportunity cost in terms of land. This cost can be estimated by determining the proportion of land-cover occupied by verges and allocating an amount per hectare. However, this land is relatively inaccessible, and the viability of an alternative use is therefore questionable.

Table 50. Costs of interventions at the Shagasha tea estate site.

Intervention	Direct implementation costs	Core institutional and enabling costs	Opportunity costs, including social and environmental losses
Reducing water stress and soil moisture loss through the planting of drought-tolerant tree species (agroforestry)	Seedlings; labour for planting and maintenance of seedlings during establishment	Training expenses	Training time cost for farmers; opportunity cost of land
Plantation of grasses on the verges of tea plots	Seedlings and seeds; labour for planting and maintenance of seedlings during establishment	Training expenses	Training time cost for farmers
Conservation of remaining natural forests and restoring degraded forests around the plantation	Seedlings; labour for planting and maintenance of seedlings during establishment	Enforcement costs; development of laws/plans/policies	Loss of land owned by surrounding communities in a land-scarce region; foregone provisioning services in the forest including wood, NTFPs
Conservation and restoration of riparian vegetation along streams and wetlands to	Infrastructure (demarcation materials); seedlings; labour for planting and maintenance of	Enforcement costs; development of laws/plans/policies	Current land uses, potentially productive

prevent channelisation of headwater streams	seedlings during establishment		

Impacts

The impacts of interventions at Shagasha Tea Estate should be measured with gender and income used to disaggregate the results of the CBA (Table 51). The costs and benefits identified above should be measured alongside data on household socio-economic status, as well as composition. Evidence from research into agriculture and gendered time use at the global scale suggests that[442]:

- "women play a key role in agriculture, and this is reflected in their time commitments to these activities, whether as farmers or as farmworkers;
- women are important actors in the uptake and response to agricultural interventions; and
- agricultural interventions tend to increase women's, men's, and children's time burdens."

The rate of uptake among participants can be considered according to the different models of agriculture practiced under different cooperatives, with inferences drawn from consultations with participants. Information from engagements should be used to inform the cost-benefit analysis and explain variations in costs and benefits between different user groups. Engagements should prioritise seeking input from people in marginalised positions within society.

Table 51. Impacts of interventions at the Shagasha tea estate site.

Intervention	Temporal impacts	Spatial impacts	Distributional impacts
Reducing water stress and soil moisture loss through the planting of drought-tolerant tree species	Improved drought resilience of agriculture over time	Improved drought resilience of farms where agroforestry is implemented	All smallholder farmers within cooperatives should benefit equally
Plantation of grasses on the verges of tea plots		Improved erosion control for farms downhill from grass verges	
Conservation of remaining natural forests and restoring degraded forests around the plantation	Extended timeframe for planted species in the buffer zone to provide benefits (tourism)	Displacement of resource extraction; displacement of land owned by surrounding communities	Reduced access to resources, potentially for poorer households
Conservation and restoration of riparian vegetation along streams and wetlands to prevent channelisation of headwater streams		Benefits for communities downstream in the form of reduced impact of flooding and reduced sedimentation of waterways	

3.11 Site 5: Nyandungu Wetland, Gasabo and Kicukiro Districts, Kigali City

The following interventions have been proposed, to complement the existing projects focused on the Nyandungu Wetland:

- Establishing vegetated swales and check dams
- Establishing bioretention basins

[442] Johnston, D. Stevano, S. Malapit, H. Hull, E. Kadiyala, S. 2015. Agriculture, Gendered Time Use, and Nutritional Outcomes: A Systematic Review. International Food Policy Research Institute Discussion Paper 01456.

These interventions are anticipated to result in the benefits, costs and impacts outlined below.
Benefits

Benefits from interventions at this site would include reduced erosion and rainwater runoff, as well as increased water availability from both of the interventions (Table 52). The establishment of bioretention basins would provide waste treatment which can be valued using the Replacement Cost method outlined in Section 3.4.

Table 52. Benefits of interventions at the Nyandungu wetland site.

Intervention	Primary adaptation benefits	Additional adaptation benefits	Co-benefits
Establishing vegetated swales and check dams	Reduced erosion and rainwater runoff (erosion and flood control); increased water availability during variable rainfall	Hill stabilisation; soil conservation; Maintained or enhanced agricultural productivity	Livestock fodder generation
Establishing bioretention basins	Waste treatment	Enhanced regulation of water flows, improved access to water during low rainfall periods	Reduced incidence of disease

Costs

Costs associated with activities at Nyandungu Wetland include direct implementation costs in the form of project costs, as well as the labour required to construct and maintain vegetated swales and check dams, as well as bioretention basins (Table 53). Core enabling costs include training expenses associated with setting up nursery operations. Opportunity costs are associated with the land required for the interventions as well as the labour required for attending training and other forms of stakeholder engagement.

Table 53. Costs of interventions at the Nyandungu wetland site.

Intervention	Direct implementation costs	Core institutional and enabling costs	Opportunity costs, including social and environmental losses
Establishing vegetated swales and check dams	Labour for construction and maintenance of vegetated swales; seedlings	Training expenses	Training time cost for farmers; opportunity cost of land
Establishing bioretention basins	Construction costs, including labour	Training expenses	Opportunity cost of land

Impacts

The establishment of vegetated swales and check dams is expected to improve the consistency in availability of water during times of variable rainfall (Table 54). This increase in the adaptive capacity of communities will improve access to water for domestic and agricultural purposes. Water use should be monitored in the surrounding area, along with key water quality parameters to determine the impact of the intervention.

Table 54. Impacts of interventions at the Nyandungu wetland site.

Intervention	Temporal impacts	Spatial impacts	Distributional impacts
Establishing vegetated swales and check dams	Improved consistency in the availability of water during times of variable rainfall; more consistent income from agriculture	Reduced soil loss leads to reduced river turbidity downstream	
Establishing bioretention basins	Relatively short timeframe for benefits of wastewater treatment		

4 Linkages between interventions and past and ongoing projects and initiatives

The proposed EbA interventions to be implemented under the LDCF-funded project will be closely aligned with other initiatives previously and currently implemented at the project sites and elsewhere in Rwanda. This will include strengthening existing linkages and determining new linkages between ongoing projects and the LDCF-funded project's EbA pilot interventions. The importance of identifying such linkages is based on the need for the project to contribute to the broader goal of increased climate resilience in Rwanda. By complementing existing initiatives, the LDCF-funded interventions will form part of the broad suite of initiatives aimed at reducing vulnerability in the country. Ultimately, the consideration of linkages will ensure that the proposed interventions are not implemented in isolation, and that they are sustainable within the local context of their implementation.

The identification of linkages with past and ongoing initiatives is also important to ensure that the project's EbA interventions build on the successes of and learn from the failures of relevant initiatives. This has informed the: i) accurate selection of implementation sites; ii) identification and avoidance of potential risks to the success of interventions, as well as mitigation measures as necessary; iii) design of interventions according to local socioeconomic conditions — what is appropriate and successful, and what is not; iv) cost-effective design and implementation of interventions; v) identification of successful interventions that can be replicated or upscaled by the project; and vi) design of interventions to ensure that community needs are prioritised. Table 55 below shows a list of past and ongoing baseline and climate change adaptation projects in Rwanda, and their potential linkages with the LDCF-funded project's proposed EbA interventions.

Table 55. Past and ongoing baseline and climate change adaptation projects in Rwanda, and their potential linkages with the LDCF-funded project's proposed EbA interventions.

Project title	Funder	Project area	Summary of project	Potential linkages to LDCF-funded project	Implementation period
Strengthening Climate Resilience of Rural Communities in Northern Rwanda[443]	GCF	Muvumba catchment (Muvumba River, eastern savannas)	The project will restore and enhance ecosystem services in one of the sub-catchments of the degraded Muvumba watershed, increase the capacity of communities to renew and sustainably manage forest resources and support smallholders to adopt climate-resilient agriculture. The project will also invest in climate-resilient settlements for vulnerable families currently living in areas prone to landslides and floods and support community-based adaptation planning and livelihoods diversification. Knowledge and capacity developed during implementation will be mainstreamed at the local and national level.	Activities under this project include: stabilising riverbanks, roads and steep slopes with protective forestry; integrating agroforestry into farming systems; supporting smallholder crop-livestock farmers to adopt agro-ecological approaches to increase climate resilience; increasing sustainable forest management; and establishing, restoring and managing degraded woodlots. All of these can be aligned with the LDCF-funded project's proposed interventions. The proposed LDCF-funded project will complement the activities of the GCF-funded project through the development of catchment-level CCA plans, promoting the sustainability of adaptation interventions and the long-term climate resilience of local communities. Furthermore, the pilot site established at the Muvumba River under the proposed project's LTRP will focus on the restoration of riverbank buffer zones, attenuating floods downstream of the catchments that will be restored through the GCF project.	2018–2025
Muvumba Catchment Management Plan	GoR	Muvumba catchment (Muvumba River, eastern savannas)	Specific objectives of Muvumba Catchment Management Plan are the following: 1. Improve water quality and quantity in water bodies taking into account resilience to climate change in the	As the proposed LDCF-funded project will enhance the climate resilience of the Muvumba River, there will be direct complementarity between the proposed project and the Muvumba Catchment Management Plan. While the latter is	2018–2024

[443] https://www.greenclimate.fund/project/fp073

			catchment; 2. Reduce the pressure on natural resources by diversifying livelihoods; 3. Ensure equitable allocation of available water resources for all users of current and future generations in the catchment; and 4. Strengthen the water governance framework and transboundary cooperation to ensure effective implementation of integrated catchment management.	focussed on the catchment areas of the river, the proposed LDCF-funded project will be focussed on areas downstream. Therefore, the improved management of the catchment areas will improve the sustainability of the interventions implemented under the proposed LDCF-funded project.	
Lake Victoria Water Supply and Sanitation (LVWATSAN II)[444]	African Development Bank	Nyagatare District (eastern savannas)	This project took place in the Lake Victoria basin, part of which includes the Nygatare District. The major outputs of this project included: rehabilitation and expansion of water supply systems; capacity building; improved hygiene and environmental sanitations; and urban drainage improvement.	This project included the development of basic water infrastructure and the building of capacity in the water sector in the Nyagatare District. Two of the LDCF-funded project's pilot sites, Muvumba River and eastern savannas, fall within this district. This project is therefore an important baseline project that the LDCF-funded project can build on and complement, particularly in terms of climate-proofing the LVWATSAN II project's interventions through EbA. Lessons learned from this project can also be incorporated into the design of interventions in the Nyagatare District, as well as in the Nyandungu wetland, given that the project had a sustainable urban drainage component.	2010–2014
The Gishwati Water and Land Management Project	LDCF	Gishwati region, a forest ecosystem in the Western Province	The project's objectives are to: i) promote the sustainable co-existence of agrarian communities with the Gishwati Forest ecosystem; and ii) maximise the sustainable economic contribution of the Gishwati ecosystem to surrounding local communities. Specific activities of the	The proposed LDCF-funded project will complement the Gishwati Water and Land Management Project through EbA interventions implemented at several of its EbA pilot sites. Relevant EbA interventions will include: i) forest rehabilitation at Ibanda-Makera Natural	2014–2019

[444] https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Multinational__Lake_Victoria_Basin_-_East_African_Community__-_AR_-_Lake_Victoria_Water_Supply_and_Sanitation_Programme_Phase_II_.pdf

			project include: i) the promotion of water and land husbandry technologies to the local communities; ii) implementation of land husbandry in croplands and rangelands of the Gishwati ecosystem; iii) development and rehabilitation of rangeland; iv) forest plantation and ecosystem restoration in the Gishwati project area; and v) rehabilitation and construction of roads in the project area.	Forest; ii) agroforestry at Shagasha Tea Estate and alongside Ibanda-Makera Natural Forest; and iii) silvopastoralism in the degraded savannas of the Nyagatare District. This will further promote the co-existence of agrarian communities with forest ecosystems as well as strengthen the capacity of forest ecosystems to supply ecosystem services. Lessons learned and best practices developed from the restoration components of the Gishwati project (objectives iii, iv and v) can be incorporated into the design and implementation of the proposed project.	
Nyandungu Urban Wetland Eco-Tourism Park[445]	National Climate Change and Environment Fund (FONERWA)	Nyandungu wetland	Rwanda Environment Management Authority (REMA) has started the process of designing the Nyandungu Wetland into an urban wetland recreation and eco-tourism park. The project will not only provide social and economic benefits to the communities but also support innovative approaches to restore and conserve wetland ecosystems on 130 ha, promote the sustainable management of natural resources and support livelihood diversification to enhance incomes for local communities.	One of the pilot sites for EbA interventions under the proposed LDCF-funded project is the Nyandungu Wetland. There will be overlap in the design of the two projects, and lessons learned could inform the design of the EbA interventions under the proposed project. Specifically, the proposed NAP project will implement Sustainable Urban Drainage System interventions to complement the restoration activities in the park, and together these will reduce local communities' risk to flood impacts.	2015–2020
Reducing Vulnerability to Climate Change by Establishing Early Warning and Disaster Preparedness Systems and Support for Integrated Watershed	LDCF	Gishwati region, a forest ecosystem	The project's Final Terminal Evaluation found that the project outputs had been satisfactorily delivered within the planned budget and timeframe. These outcomes included: i) establishing a modern and fully functional Early Warning System (EWS) to deliver climate information and early warnings under Component 1; ii) building human and institutional capacity to effectively utilise the hydro-meteorological network and conduct	The proposed project will build on and upscale the activities of this LDCF-funded project through implementing and promoting CCA (including EbA) practices. Similar rehabilitation interventions that were implemented in the Gishwati region will take place in this project's restoration interventions. Best practices and lessons learned from LDCF1 will be incorporated into the design of the proposed interventions. Point v) in the adjacent cell	2010–2015

[445] http://www.fonerwa.org/portfolio/nyandungu-urban-wetland-eco-tourism-park

Management in Flood Prone Areas (LDCF1)			climate risk assessments and forecasting under Component 1; iii) developing climate-sensitive land-use plans and climate-proofing DDPs for the four pilot districts of Nyabihu, Ngororero, Rubavu and Rustiro under Component 2; iv) developing climate change mainstreaming guidelines for the agriculture, energy and infrastructure, environment and natural resources, and health sectors under Component 2; v) implementing climate-resilient land-use practices in the Gishwati region under Component 3, which included the rehabilitation of ~1,300 ha of degraded land through tree planting, agroforestry, terracing and the promotion of alternative livelihoods; vi) training and knowledge-sharing about climate-resilient adaptation practices was implemented under Component 4 (this included the development of a climate change portal and the development of a climate change vulnerability index).	in particular will be complemented by the proposed project.	
National Adaptation Readiness and Preparatory Support for Building Flood Resilience Capacities in Rwanda[446]	GCF	National	The objective of the GCF NAP Readiness project is to coordinate different government agencies and targeted stakeholders for effective flood and landslide planning and prevention in Rwanda's most vulnerable zones. Outcomes of the project include: i) enhancing capacity and coordination of stakeholders to mitigate the impacts of floods and to prevent landslides; ii) prioritising and identifying technical studies, and strengthening of climate finance strategies and project pipeline for	As both the GCF NAP and GEF NAP processes are aimed at enhancing the country's capacity to adapt to the impacts of climate change, there is inherent alignment between the two. Direct linkages between the GCF NAP Readiness project and the proposed LDCF project will particularly be aligned through the implementation of flood-management interventions, as well as the stabilisation of soil through reforestation. In addition, the lessons learned and best practices generated from these	2020–Ongoing

[446] https://gggi.org/gcf-nap-national-adaptation-plan-project-on-building-flood-resilience-capacities-in-rwanda/#:~:text=The%20National%20Adaptation%20Readiness%20and,flood%20and%20landslide%20planning%20and

			effective stormwater and landslide management in Kigali and other rapidly growing urban areas; iii) management of knowledge, sharing of information, and strengthening of communication for flood and landslide management; and iv) developing mechanisms for reporting, monitoring and reviewing of adaptation and resilience planning progress to inform future management practices.	interventions will be directly aligned with the GCF NAP Readiness project's focus on knowledge management, and the use of information generated under the project to inform future adaptation interventions.	
Landscape Approach to Forest Restoration and Conservation (LAFREC)	World Bank	Gishwati-Mukura landscape (forest ecosystems)	The project aimed to restore the degraded Gishwati-Mukura landscape to enhance both its productive and environmental values. Specifically, the project aimed to: i) rehabilitate forests within the Gishwati and Mukura Forest Reserves; ii) enhance sustainable land management in the agricultural lands between these forest reserves; and iii) introduce silvopastoral approaches in the rangelands of the Gishwati Reserve. These objectives were to be achieved through two components that include: i) forest-friendly and climate-resilient restoration of Gishwati-Mukura landscape (Component 1); and ii) research, monitoring and management (Component 2).	Under the proposed project, EbA interventions such as silvopastoralism, agroforestry and the strengthening of buffer zones around natural forests at pilot sites in other parts of the country both complement and align with the interventions of LAFREC — in terms of forest restoration and conservation. Consequently, the proposed project will build on the knowledge generated through the EbA interventions of LAFREC. This will occur under the project's LTRP where research on the effectiveness of EbA interventions such as those implemented under LAFREC will be conducted in the long-term, informing adaptation planning in Rwanda and the upscaling of EbA interventions across the country's varied landscapes under the NAP process.	2014–2019
Building Resilience of Communities Living in Degraded Wetlands, Forests and Savannas of Rwanda through an Ecosystem-based Adaptation Approach Project (LDCF2)	LDCF	Wetlands, forests and savannas around Rwanda	The overall objective of LDCF2 is to increase the capacity of Rwandan authorities and local communities to adapt to climate change by implementing EbA interventions in wetlands, forests and savannas. The project is focused on vulnerable communities living adjacent to these ecosystems and has three main components, namely: i) increasing the capacity and awareness of national and	The proposed project aligns with numerous activities of LDCF2 project and will be implemented alongside it, drawing from its lessons learned and upscaling several of its activities. Two of the proposed project's EbA pilot sites are located alongside LDCF2 intervention sites, namely; Nyandungu Wetland and Ibanda-Makera Natural Forest. Sustainable Urban Drainage System	2015–2020; delayed by two years

			local institutions to implement EbA; ii) strengthening policies, strategies and plans for climate change adaptation; iii) implementing EbA interventions that restore wetlands, forests and savannas to be climate resilient while diversifying local communities' livelihoods.	(SUDS) interventions that will be implemented under the proposed project at Nyandungu Wetland will complement the restoration work planned under LDCF2 at Kimicanga Wetland, which is also in Kigali. Flood attenuation will promote effective regrowth of wetland vegetation, while the revegetation of the site will broaden restoration at Nyandungu Wetland. In terms of the Ibanda-Makera Natural Forest, LDCF2's restoration activities will be supported by the re-establishment of a buffer zone around the forest.	
Increasing the Capacity of Vulnerable Rwandan Communities to Adapt to Adverse Effects of Climate Change: Livelihood Diversification and Investment in Rural Infrastructures	LDCF	National	The project's objective is to increase the adaptive capacity of vulnerable Rwandan communities to adapt to the adverse effects of climate change through livelihood diversification and investment in rural infrastructure. The project components include: i) enhancing and diversifying climate-resilient rural livelihoods; ii) strengthening awareness and ownership of adaptation and climate risk reduction processes; iii) climate-resilient small-scale rural infrastructure; and iv) monitoring and evaluation.	The proposed project will upscale CCA awareness, enhance and diversify climate-resilient rural livelihoods through the implementation of EbA interventions at pilot sites as summarised below. • Agroforestry (alongside Ibanda-Makera Natural Forest in the Kirehe District) using drought-resistant tree species with strong root systems. Agroforestry will protect exposed lands from wind and rain erosion, through canopy cover and the binding of soils. The planted trees will also provide fruit, fodder and wood fuel for local people. This is also in alignment with the Department of Forestry's plan to plant 10,000 fruit trees across the Eastern Province. • Silvopastoralism (in the degraded savannas of the Nyagatare District) using climate-resilient tree species which will strengthen livestock production through the provision of food and promotion of vegetation regrowth in degraded savannas.	2015–2019
Forest Landscape	GEF Trust	Mayaga	The project objective is to conserve	The proposed project is aligned with and	2016–2021

Restoration in the Mayaga Region	Fund	region (forest ecosystem)	biodiversity and sequester carbon while strengthening the resilience of livelihoods through forest landscape restoration and upscaling clean technologies. This objective will be achieved through three components, namely: i) developing decision-support tools for planning of forest landscape rehabilitation; ii) increasing skills and capacity for the implementation of forest landscape restoration plans; and iii) creating incentives for the adoption of energy efficient technologies to reduce pressure on forest resources, while securing household access to energy and reducing emissions.	complements the Forest Landscape Restoration in the Mayaga Region project through several EbA interventions. These interventions include: i) the re-establishment of forest buffer zones, including the implementation of agroforestry around Ibanda-Makera Natural Forest to reduce deforestation and stimulate forest regrowth; ii) the implementation of agro-forestry at Shagasha Tea Estate and savannas of Nyagatare; and iii) the promotion of silvopastoralism in the degraded savannas of Nyagatare. These interventions will add to the Forest Landscape Restoration project's objective of conserving biodiversity and sequestering carbon.	
Climate Mainstreaming Pilot for Rwanda's Tea and Coffee Sectors	FONERWA	Tea and coffee plantations (e.g. Shagasha)	The project is being implemented by MINAGRI with funding provided by FONERWA. Other key stakeholders in this project include the National Agricultural Export Development Board (NAEB) and the Rwanda Agricultural Board (RAB). The objective of this pilot project is to mainstream climate change into the agricultural sector development investment plan of MINAGRI, with a focus on the tea and coffee sectors as important export crops that are sensitive to climate change. The project's five outputs include: i) environmental and climate change issues mainstreamed into the MINAGRI development plan; ii) climate information and knowledge on climate change impacts improved; iii) sustainable adaptation options implemented in the coffee and tea sector; iv) sustainable wood fuel used for low carbon tea production; and v) capacity	The proposed LDCF-funded project will upscale the project's adaptation interventions to include EbA. This will include agroforestry, intercropping and the stabilisation of plantation verges, which will strengthen the resilience of associated livelihoods against the negative effects of climate change (at the Shagasha Tea Estate).	2015–2019

			building to enhance government staff and the private sector's capacity on climate change mainstreaming.		
Muvumba Multipurpose Dam project	African Development Bank Group	Nyagatare District, Muvumba catchment	Muvumba multipurpose dam project is a government project that intends to construct a dam of 30.5 m high and will impound 35 million m^3 of water in Karama, Gatunda and Rukomo Sectors and will supply water for domestic use to Karangazi, Rwimiyaga and Nyagatare Sectors. The dam will impound water to be used for domestic water supply, water for irrigation of 7,380 ha (net command area) and water for 16 reservoirs for livestock watering, the project aims to increase the productivity and commercialisation of agriculture and livestock products through the implementation of integrated watershed management practices, water-harvesting in main and valley dams, marshland and hillside irrigation. It will also help to increase the quality and quantity of water to supply as it was observed that Nyagatare District suffers from recurrent dry spells resulting in the imbalance between water supply and demand. This project will therefore help to provide water to meet the demand of different water users.	The dam will help address drought impacts in the eastern savannas in the Nyagatare District, which will complement the EbA interventions implemented under the proposed LDCF-funded project that will enhance and diversify climate-resilient rural livelihoods in the district.	Unknown
Gabiro Agribusiness Hub Project (GAHP)[447]	GoR and Netafim	Eastern savannas	The GAHP is a commercially-oriented farming project initiated through a joint venture between the GoR (with 90% shares — equity) and the global leader of the irrigation sector, Netafim Ltd (with 10% shares — in kind). The Gabiro project is expected to provide a new impetus to the green revolution of	The proposed LDCF project will involve the implementation of agroforestry and silvopastoralism in the savannas of Nyagatare District. These interventions will complement the initiatives implemented under the GAHP project, as they will be directly linked to the enhancement of agricultural livelihoods in	Unknown

[447] https://www.netafim.africa/blog/rwanda-gabiro-project/

			Rwanda. The GAHP aims to create a holistic and commercial agricultural ecosystem by developing an advanced agricultural ecosystem and modern value chain over a total of approximately 15,600 ha of arable land with advanced water infrastructure, cutting-edge irrigation systems, high-value agro-processing operations and other ag-tech activities across the value chain. This project will significantly enhance private sector investments in Rwanda's agricultural sector, mitigate the risks of climate change and food security, contribute to job creation, increase export of value-added products and enhance rural community development and livelihoods. The project will support the production of crops for local consumption (staple crops), export crops (high-value crops) and agriculture-generated, value-added products (paste, powder, oil, etc.) intended mostly for international markets. It will also support livestock especially in the community irrigation part of the project. A total of 1,402 households will benefit from the project by benefiting from lease fees, and allocation of irrigated land.	the area.	
Rwanda Urban Development Project II (RUDP II)[448]	The World Bank	City of Kigali and six secondary cities	The objective of the project is to improve basic services, to enhance resilience and to strengthen urban management in the cities targeted under the project. The project's interventions include the implementation of flood risk-reduction interventions, and wetland rehabilitation in the city of Kigali and the development	The proposed LDCF-funded project will align with the RUDP II project, as it will complement interventions focussed on the rehabilitation of wetlands in the city of Kigali through its EbA interventions at the Nyandungu pilot stie.	2021–2025

[448] https://projects.worldbank.org/en/projects-operations/project-detail/P165017

			of detailed area plans for secondary cities to enhance their sustainability and resilience to climate change.		
African Improved Cookstoves and Clean Water Programme: Ibanda – Makera Forest Cook Stove Project III	Gold Standard for the Global Goals	Ibanda-Makera Forest, Kirehe District	This Micro-Scale Voluntary Project Activity for the PoA African Improved Cookstoves and Clean Water Programme involves the distribution of approximately 6,000 domestic fuel-efficient cook stoves to households around Ibanda-Makera forest within the district Kirehe, Rwanda, which previously have had no access to improved cookstoves. Ibanda – Makera Forest Cook Stove Project currently includes three VPAs. The project owner Likano Project Development GmbH will work closely with the in-country partner Rural Environment and Development Organization (REDO) in the preparation and implementation of the project.	The project will reduce the reliance of surrounding communities on Ibanda-Makera Forest for woodfuel, therefore contributing to addressing baseline drivers of forest degradation and complementing the NAP project's efforts to protect the forest.	2020/2021

Annexes

Annex 1: Rapid options analysis

For each pilot site, a full list of potential EbA interventions was generated to ensure that all options were considered. The potential interventions were identified through consultations with relevant stakeholders, including the Government of Rwanda (GoR) staff (national and district level), academics, experts, representatives from EbA-related initiatives and local communities. This was supplemented by identifying additional options through a review of relevant local and international EbA best practices. Once lists were developed for each of the sites, a rapid options analysis was undertaken to ensure that the EbA interventions proposed in the project document were still appropriate/viable. This included the need for explicit links to identified climate change problems to be present, the conferring of relevant benefits, as well as an alignment with national and local priorities. Where the results of the rapid options analysis indicated that any of the proposed interventions were not appropriate, alternatives were selected from the relevant sites list. In this way, the rapid options analysis served as the first “filter” in the viability assessment of the project’s proposed EbA interventions. The methodology for the rapid options analysis is further detailed below.

Review of the evidence base for EbA

To establish a full list of options (including those already proposed), the readily available information base on relevant EbA projects and interventions was consulted for an indication whether they would be successful in the context of the project’s pilot sites. Examples of the tools and resources used to review the EbA knowledge base included:

- UN-REDD Benefits & Risks Tool (BeRT);
- the EbA Valuation Sourcebook[449];
- weADAPT website[450];
- ‘EbA Tools Navigator’[451];
- EbA Guidelines for the climate-resilient restoration of savannah, wetland and forest ecosystems of Rwanda[452];
- the ALivE tool[453]; and
- other readily available local and international knowledge bases and tools found by or brought to the attention of the project team.

Table 56 below provides the outcome of the rapid options analysis.

Table 56. The outcome of the rapid options analysis.

449 https://www.adaptationcommunity.net/wp-content/uploads/2017/12/EbA-Valuations-Sb_en_online.pdf

450 https://www.weadapt.org/

451 https://www.iied.org/tools-for-ecosystem-based-adaptation-new-navigator-now-available

452 http://wedocs.unep.org/bitstream/handle/20.500.11822/32704/EbaG.pdf?sequence=1&isAllowed=y

453 https://www.iisd.org/sites/default/files/publications/alive-tool-manual-full.pdf

Ecosystem	EbA intervention	Reference document	Potential costs of intervention (direct implementation costs; core institutional and enabling costs; opportunity costs; social and environmental losses)	Potential benefits of intervention	What tends to be measured/valued (regarding benefits)?
Forest; agro-ecosystems	Modernisation of agriculture and soil protection	REDD+ Readiness Proposal [referred to in Forest Investment Program for Rwanda, 2017]	Input costs (equipment required for soil protection, seeds/seedlings); Institutional and enabling costs through strengthening supply-chains; short-term opportunity cost in foregone revenue from high-yield varieties	Soil health improvements, enhanced nutrient cycling leading to increased productivity. Improved soil fertility, and therefore reduced fertiliser costs	Increases in water infiltration; increases in soil fertility
				Improved regulating services including erosion control and flood control (through increased rainwater infiltration), and averted damages/pollution to water courses from fertiliser and pesticide runoff	Production losses avoided; infrastructure damage avoided; losses of life prevented; improvement in water quality of rivers/watercourses
Forest; agro-ecosystems	Promotion of bee-keeping in agro-ecological zones of the country	REDD+ Readiness Proposal [referred to in Forest Investment Program for Rwanda, 2017]	Input costs of bee-keeping infrastructure; environmental risk	Livelihood diversification, leading to increased income and employment	Avoided reductions in incomes as a result of climate change
				Enhanced delivery of pollination services	Increases in agricultural productivity
Eastern savannas	Intensive afforestation	REDD+ Readiness Proposal [referred to in Forest Investment Program for Rwanda, 2017]	Foregone grazing benefits; Loss of shade-intolerant plant species used for both human foraging/medicinal purposes and for animal feed; Potential decline in biodiversity; Climatic conditions likely not suitable to sustain dense forests.	Improvement in provisioning services—multi-use species could provide various NTFPs; livelihood diversification, employment and income impacts; alternative sources of income that are less prone to climate risk	Avoided reductions in incomes as a result of climate change; number of new NTFP types and income opportunities created
				Improved soil health, nutrient cycling	Increases in water infiltration; increases in soil fertility

				Regulating services including wind, erosion and flood control	Production losses avoided; infrastructure damage avoided; losses of life prevented; improvement in water quality of rivers/watercourses
Eastern savannas	Development of agroforestry and silvopastoralism	REDD+ Readiness Proposal [referred to in Forest Investment Program for Rwanda, 2017]	Longer timeframe for delivery of benefits; training costs for improved rainwater harvesting techniques; seedling supply/supply-chain intervention costs	Livelihood diversification through improved provisioning services in the form of agricultural produce, timber and NTFP harvesting	Avoided reductions in incomes as a result of climate change; number of new NTFP types and income opportunities created
				Improved quality and quantity of milk through reduced heat stress and increased fodder supply	Increases in milk production and quality; increases in fodder production and quality
				Regulating services including erosion control, flood mitigation, enhanced consistency in the regulation of water supply for agriculture	Production losses avoided; infrastructure damage avoided; losses of life prevented; improvement in water quality of rivers/watercourses
				Improved soil health, leading to improved supporting services such as nutrient cycling	Increases in water infiltration; increases in soil fertility
				Opportunities for education, recreation and other cultural services	Increases in number of opportunities for educational, recreational and cultural services; increases in well-being of community members?

Savannas	Conservation and management of existing natural relic forests	REDD+ Readiness Proposal [referred to in Forest Investment Program for Rwanda, 2017]	Foregone provisioning services including wood, NTFPs, depending on land-use rules; enforcement costs	Enhanced potential for the development of eco-tourism, including associated jobs and incomes; cultural services including education and recreation.	Avoided reductions in incomes due to climate change; increases in number of opportunities for educational, recreational and cultural services; increases in jobs
				Enhanced regulation of ecosystem services such as flood and soil erosion control, disease and pest control, carbon sequestration, improved soil quality and nutrient cycling	Production losses avoided; infrastructure damage avoided; losses of life prevented; improvement in water quality of rivers/watercourses
Eastern savannas	Good management of existing manmade forests	REDD+ Readiness Proposal [referred to in Forest Investment Program for Rwanda, 2017]	Foregone provisioning services including wood, NTFPs	Enhanced regulation of ecosystem services such as flood and soil erosion control, disease and pest control, carbon sequestration, improved soil quality and nutrient cycling	Production losses avoided; infrastructure damage avoided; losses of life prevented; improvement in water quality of rivers/watercourses
Eastern savannas	Improvement of existing eco-tourism	REDD+ Readiness Proposal [referred to in Forest Investment Program for Rwanda, 2017]	High initial cost in the form of capital investment	Enhanced potential for the development of eco-tourism, including associated jobs and incomes; Potential for enhanced indirect and induced impacts of tourism spending; potential to generate income for conservation and promotion of cultural heritage.	
Eastern savannas	Development of non-timber products	REDD+ Readiness Proposal [referred to in Forest Investment Program for Rwanda, 2017]	High initial cost in the form of capital investment	Reduced deforestation for timber; enhanced potential for the development of non-timber industries, including associated jobs and incomes; Potential for enhanced indirect and induced impacts from tourism	Avoided reductions in incomes as a result of climate change; number of new NTFP types and income opportunities created

				spending; Potential for exports.	
Eastern savannas	Development of efficient wood energy use; Development of alternative sources of energy; Large utilisation of improved charcoal and wood cook stoves	REDD+ Readiness Proposal [referred to in Forest Investment Program for Rwanda, 2017]	Job and income losses for wood harvesters, charcoal producers and traditional cook stove producers	Reduced fuel demand, leading to a reduction in time spent harvesting wood, reduced spending on wood, and reduced deforestation rate.	Decreases in deforestation rates
Agricultural	Introduction and development of agroforestry	The Agroforestry Strategy. Ministry of Agriculture (MIINAGRI) Rwanda 2017 [referred to in FIP document]	Initial costs of sourcing and growing tree seedlings, of labour to plant and take care of the seedlings until trees are self-sufficient, fertiliser/compost costs	Improved diets through the provision of fruits from fruit trees	Increases in dietary options
				Optimisation of space usage in a country limited by land resources and facing high population density pressures	Avoided reductions in incomes as a result of climate change
				Enhanced household incomes from selling of fruit, timber, poles, fuelwood and NTFPs	Avoided reductions in incomes as a result of climate change; number of new NTFP types and income opportunities created
				Reduced demand on natural forests for resources and reduced deforestation rates (conservation)	Decreases in deforestation rates
				Enhanced regulation of ecosystem services such as flood, wind and soil erosion control, disease and pest control, carbon	Production losses avoided; infrastructure damage avoided; losses of life prevented; improvement in water

				sequestration, improved soil quality and nutrient cycling	quality of rivers/watercourses
Forest	Match species and varieties to current and projected site and climatic conditions. In planted forests, use species and varieties that are adapted to new and anticipated conditions. In natural and semi-natural forests, favour varieties and species that are adapted to current and predicted future climatic conditions by selecting and retaining seed trees and through enrichment planting.	FAO. Climate change guidelines for forest managers.	Foregone short-run production and revenue from established varieties; Conflict with local tastes and preferences	Climate-resilient forests deliver a more consistent, dependable supply of ecosystem services	Production losses avoided and production increases obtained; infrastructure damage avoided as a result of flood and erosion control; decreases in water losses (including more efficient use and less evaporation)
Forest	Modify silvicultural/forest management treatments	FAO. Climate change guidelines for forest managers.	Time costs for foresters/farmers	Improved productivity; enhanced regulation of water cycle	Increases in productivity

	(such as thinning, pruning and vine-cutting)				
Forest	Invest in measures to improve soil structure and reduce water stress (including to reduce grazing and maintain organic matter)	FAO. Climate change guidelines for forest managers.	Reduced grazing capacity and associated jobs and income in the short-run (can be mitigated through increased fodder provision depending on budget and local market conditions). Increased forest fire risk as grass biomass and organic matter builds up	Improved productivity; enhanced regulation of water cycle	Increases in water stored (for example through harvesting and increased filtration of rain water into ground water); Decreases in water losses (including more efficient use and less evaporation)
Forest	Manage vegetation (for example control weeds and understorey vegetation) to reduce competition with target species	FAO. Climate change guidelines for forest managers.	Biodiversity loss; Loss of habitat for species that could potentially control pests; Increased erosion and flood likelihood	Improved productivity; reduced water stress; reduced forest fire risk; less competition for desired species (for water, space, light, nutrients); restored soil properties to natural state; restored natural nutrient cycling processes, fire regimes and hydrology	Increases in productivity; decreases in wildfire impacts (frequency and severity)
Forest	Plant or promote the use of climate-adapted species and varieties	FAO. Climate change guidelines for forest managers.	Foregone short-run production and revenue from established varieties; Conflict with local tastes and preferences	More consistent, dependable supply of ecosystem services; reduced scarcity of water	Decreases in water losses (such as more efficient use and less evaporation); Increases in water stored (including through increased infiltration of rainwater into groundwater); Production losses avoided and production increases obtained

Forest	Put measures in place to detect and control invasive species	FAO. Climate change guidelines for forest managers.	Labour costs associated with invasive species removal/ time costs for farmers and foresters	Improved indigenous biodiversity; reduced spending on pest management; improved pollination services; less competition for desired species (for water, space, light, nutrients); restore soil properties to natural state; restore natural nutrient cycling processes, fire regimes and hydrology	Decreases in water losses (through more efficient use and less evaporation); Increases in water stored (through increased infiltration of rainwater into groundwater); Production losses avoided and production increases obtained
Forest, riparian	Maintain or increase shade in riparian zones where increased temperatures pose a risk to aquatic species (for example by increasing tree cover and favouring fruit-bearing species)	FAO. Climate change guidelines for forest managers.	Land-use change	Shade for aquatic species, reduced sedimentation of rivers, stabilisation of river banks, fruit	Increases in water quality and ecosystem health (such as increased fish population numbers); decreases in erosion impacts (severity and/or frequency)
Riparian	In areas of reduced rainfall, maintain connections between waterways to avoid drying up	FAO. Climate change guidelines for forest managers.	Land-use change	Improved water security; flood management	Decreases in flood impacts (production losses avoided, infrastructure damage avoided, losses of life prevented); increases in water availability

Forest, riparian	Implement measures to ensure proper drainage and erosion control in areas subject to waterlogging (such as adjusting the construction and maintenance of roads and stream crossings and providing drainage channels to ensure proper drainage)	FAO. Climate change guidelines for forest managers.	Financial costs	Flood mitigation, reduced sedimentation of rivers	Decreases in flood impacts (production losses avoided, infrastructure damage avoided, losses of life prevented); increases in river/watercourse water quality
Forest	Maintain landscape connectivity and establish corridors through restoration and reforestation	FAO. Climate change guidelines for forest managers.	Land-use change	Reduced forest fragmentation; improved ecosystem connectivity and biodiversity	Increases in pollination services; decreases in erosion impacts
Forest, riparian, savanna	Sustainably manage water resources to ensure water storage, the regulation of water flow and the provision of water to downstream users (for	FAO. Climate change guidelines for forest managers.	Reduced grazing capacity and associated jobs and income in the short-run (can be mitigated through increased fodder provision depending on budget and local market conditions)	Reduced scarcity of water; Enhanced drought resilience and adaptive capacity for households and key sectors; Reduced cost of water treatment for residential, commercial, industrial and agricultural water users downstream.	Increases in water stored (including through harvesting and increased filtration of rainwater into groundwater); Decreases in water losses (more efficient use and less evaporation)

	example through the protection of forest catchment areas, water harvesting and the protection of streams)				
Forest, riparian, savanna	Promote water infiltration of the soil, the water-storage capacity of soils and watertrapping in catchments, storage lakes and irrigation channels (for example using check dams, retention ditches and contour and strip cropping)	FAO. Climate change guidelines for forest managers.		Reduced scarcity of water	Increases in water stored (through harvesting and increased filtration of rainwater into groundwater); Decreases in water losses (more efficient use and less evaporation)
				Reduced erosion of soil	Reduced impact of sedimentation of rivers and dams; Avoided greenhouse gas emissions from degraded soils; Avoided losses in agricultural productivity
Forest, riparian, savanna	Select water-efficient and drought-resistant species and varieties for afforestation and reforestation	FAO. Climate change guidelines for forest managers.	Trade-offs in terms of yield quantity or cultural preferences	Drought resilience/reduced water stress; reduced scarcity of water	Decreases in water losses (more efficient use and less evapotranspiration); increases in soil and groundwater infiltration
Forest, savanna	Reduce evapotranspiration and competition for	FAO. Climate change guidelines for forest managers.	Potential loss of tree species preferred by communities	Drought resilience/reduced water stress; reduced scarcity of water	Decreases in water losses (more efficient use and less evapotranspiration);

	water by vegetation management (e.g. thinning, pruning and planting deciduous species)				increases in soil and groundwater infiltration
Forest, savann a	Maintain forests on ridge tops to promote mist and fog interception, reduce surface runoff and increase water infiltration of the soil	FAO. Climate change guidelines for forest managers.	Planting costs	Drought resilience/reduced water stress, flood control	Decreases in water losses (more efficient use, less evapotranspiratio); increases in soil and groundwater infiltration
				Flood and erosion control	Production losses avoided; infrastructure damage avoided; losses of life prevented; improvement in water quality of rivers/watercourses
Forest, savann a	Promote afforestation and reforestation to protect against wind erosion (for example establish windbreaks)	FAO. Climate change guidelines for forest managers.	Planting costs; Increased water use	Drought resilience/reduced water stress; reduced scarcity of water	Decreases in water losses (more efficient use and less evapotranspiration)
				Reduced wind damage to crops	Production losses avoided
Forest, riparian	Adjust harvesting schedules to reduce erosion and siltation, taking into consideration the terrain, forest cover, road networks,	FAO. Climate change guidelines for forest managers.	Change in harvesting schedules could conflict with other agricultural work	Reduced soil erosion and sedimentation of rivers	Reduced impact of sedimentation of rivers and dams; Avoided greenhouse gas emissions from degraded soils; Avoided losses in agricultural productivity

	the type of machinery used and the presence of streams and other waterways				
Forest, riparian	Maintain or increase vegetation cover in erosion-prone and flood-prone areas (for example using contour and strip cropping)	FAO. Climate change guidelines for forest managers.	Planting costs; Increased water use	Reduced erosion and sedimentation of rivers	Reduced impact of sedimentation of rivers and dams; Avoided greenhouse gas emissions from degraded soils; Avoided losses in agricultural productivity
				Flood control	Production losses avoided; infrastructure damage avoided; losses of life prevented; improvement in water quality of rivers/watercourses
Forest, riparian	Consider excluding harvesting in areas subject to waterlogging	FAO. Climate change guidelines for forest managers.	Foregone harvesting benefits	Flood control	Production losses avoided; infrastructure damage avoided; losses of life prevented; improvement in water quality of rivers/watercourses
				Reduced erosion and sedimentation of rivers	Reduced impact of sedimentation of rivers and dams; Avoided greenhouse gas emissions from degraded soils; Avoided losses in agricultural productivity

Forest	Plant or encourage species and varieties capable of benefiting from or withstanding increased rainfall and waterlogging	FAO. Climate change guidelines for forest managers.	Trade-offs with community preferences; Limited technical/scientific knowledge of flood-resilient cultivars/ lack of flood-resilient cultivars developed	Reduced flooding impacts on production	Production losses avoided
Forest	Support the development of policies and plans for forest fire management	FAO. Climate change guidelines for forest managers.	Out of scope of project	Forest fire mitigation: decreased impact (severity or likelihood) of wildfires	Production losses avoided; infrastructure damage avoided; losses of life prevented
Forest	Employ an integrated fire management approach that emphasizes landscape planning	FAO. Climate change guidelines for forest managers.	Limited technical capacity/knowledge	Forest fire mitigation: decreased impact (severity or likelihood) of wildfires	Production losses avoided; infrastructure damage avoided; losses of life prevented
Forest	Modify landscape structure to impede fire spread (such as to establish networks of fire breaks; manage for a mix of stand ages and stocking densities; thin stands; create mosaics of controlled burns; select	FAO. Climate change guidelines for forest managers.	Potential loss of agricultural/forestry land to fire breaks	Forest fire mitigation: decreased impact (severity or likelihood) of wildfires	Production losses avoided; infrastructure damage avoided; losses of life prevented

	fire-tolerant species)				
Forest	Maintain and restore appropriate fire regimes to increase forest resistance to severe fire. Use prescribed burns and "let burn" policies in fire-maintained ecosystems for fuel management and to achieve ecological management objectives	FAO. Climate change guidelines for forest managers.	Potential training of community members in fire management and safety	Forest fire mitigation: decreased impact (severity or likelihood) of wildfires	Production losses avoided; infrastructure damage avoided; losses of life prevented
Forest	Undertake salvage logging to remove dead or damaged trees that pose a fire risk	FAO. Climate change guidelines for forest managers.	Logging costs	Forest fire mitigation: decreased impact (severity or likelihood) of wildfires	Production losses avoided; infrastructure damage avoided; losses of life prevented
Forest	Promote fire-smart landscapes (for example by planting fire-resistant tree species as firebreaks)	FAO. Climate change guidelines for forest managers.	Loss of land for plant species preferred by communities	Forest fire mitigation: decreased impact (severity or likelihood) of wildfires	Production losses avoided; infrastructure damage avoided; losses of life prevented

Forest	In areas where slash-and-burn agriculture poses a fire risk, encourage the modification of burning practices (for example restrict burning to seasons where the risk of fire is low)	FAO. Climate change guidelines for forest managers.		Forest fire mitigation: decreased impact (severity or likelihood) of wildfires	Production losses avoided; infrastructure damage avoided; losses of life prevented
Forest	Employ integrated pest management to prevent and suppress attacks	FAO. Climate change guidelines for forest managers.	Implementation costs; technical capacity/knowledge barriers	Mitigation against increased outbreaks of insects, pathogens and invasive native and exotic plant species	Production losses avoided
Forest	Minimize damage to trees during harvesting, silvicultural interventions and fires to minimise the risk of pest outbreaks	FAO. Climate change guidelines for forest managers.	Potential changes to harvesting techniques, potentially slowing down the process and reducing production	Mitigation against increased outbreaks of insects, pathogens and invasive native and exotic plant species	Production losses avoided
Forest	Encourage the introduction and maintenance of mixed-species stands to increase resistance to pest invasion and resilience	FAO. Climate change guidelines for forest managers.	Trade-offs with community preferences	Mitigation against increased outbreaks of insects, pathogens and invasive native and exotic plant species	Production losses avoided

Forest	In forest stands, introduce and retain genotypes and varieties that are resistant and resilient to pest attacks	FAO. Climate change guidelines for forest managers.	Trade-offs with community preferences	Mitigation against increased outbreaks of insects, pathogens and invasive native and exotic plant species	Production losses avoided
Forest, riparian	Maintain natural vegetation in riparian zones and avoid the channelisation of headwater streams	FAO. Climate change guidelines for forest managers.	Foregone agriculture revenue	Flood control	Production losses avoided; infrastructure damage avoided; losses of life prevented; improvement in water quality of rivers/watercourses
				Reduced erosion and sedimentation of rivers	Reduced impact of sedimentation of rivers and dams; Avoided greenhouse gas emissions from degraded soils; Avoided losses in agricultural productivity
Forest, riparian	Avoid soil compaction to maintain infiltration rates and the water-storage capacity of the soil	FAO. Climate change guidelines for forest managers.	Change in livestock grazing regimes	Flood control	Production losses avoided; infrastructure damage avoided; losses of life prevented; improvement in water quality of rivers/watercourses
				Reduced erosion and sedimentation of rivers	Reduced impact of sedimentation of rivers and dams; Avoided greenhouse gas emissions from degraded soils; Avoided losses in agricultural productivity

				Reduced scarcity of water	Increases in water stored through infiltration; decreases in water losses (less soil evaporation)
Forest, riparian	Maintain or increase species and structural diversity in ecosystems to promote resistance to storm damage and resilience following damage	FAO. Climate change guidelines for forest managers.	Trade-offs with community preferences	Decreased impact (severity or likelihood) of extreme events such as droughts/flash floods	Production losses avoided; infrastructure damage avoided; losses of life prevented
Forest	Select wind-resistant species and promote the development of multi-layered canopies	FAO. Climate change guidelines for forest managers.	Trade-offs with community preferences	Improved storm and wind resilience	Production losses avoided
Forest and agriculture, particularly on slopes	Promote multi-layered root systems by encouraging growth (for example through natural regeneration or planting) of deep-rooted and shallow-rooted species	FAO. Climate change guidelines for forest managers.	Trade-offs with community preferences	Reduced landslide and erosion risk	Production losses avoided; infrastructure damage avoided; losses of life prevented

Forest and agriculture, particularly on slopes	Practice contour planting	FAO. Climate change guidelines for forest managers.	Not all land is utilised, so agricultural produce loss	Reduced landslide and erosion risk	Production losses avoided; infrastructure damage avoided; losses of life prevented
Forest	Adjust forest management plans to increasingly provide for local community needs – for example, by promoting the planting of multipurpose trees, incorporating wood fuel production in planning, and promoting agroforestry and aquaculture systems	FAO. Climate change guidelines for forest managers.	Implementation costs	Food security; livelihoods; alternative sources of income that are less prone to climate risk	Avoided reductions in incomes as a result of climate change
Forest	Establish buffer zones around forests for multiple uses by communities	FAO. Climate change guidelines for forest managers.	Foregone agricultural benefits, harvesting of trees in forests	Food security; livelihoods; alternative sources of income that are less prone to climate risk; conservation of relic natural forest ecosystems	Avoided reductions in incomes as a result of climate change; decreases in deforestation rates
Forest	Invest in local development to improve climate change adaptation in	FAO. Climate change guidelines for forest managers.	Financial costs	Reduced deforestation rates	Decreases in deforestation rates

	communities (for example improved efficiency in the use of wood energy)				
Forest	Protect water sources within forests (such as lakes, creeks and rivers) to prevent outbreaks of water-borne diseases among forest workers and local communities	FAO. Climate change guidelines for forest managers.	Financial costs; Implementation costs of conservation/protection	Reduced impacts of water-borne diseases; better water quality for consumption and irrigation	Losses of life prevented; increases in water quality
All ecosystems where farming occurs on slopes	Utilising resource recovery and reuse through organic waste composting and wastewater irrigation	INDC (2015).	Infrastructural costs if wastewater/ grey water treatment plant established; health concerns if no water treatment used	Increased soil fertility following high rainfall and associated erosion (through compost)	Production losses avoided
				Reduced scarcity of water in drought periods/ reduced pressure on water sources	Decreases in water usage from natural water sources (rivers, dams, groundwater)
Riparian (Muvumba River in particular)	Catchment restoration	Muvumba Catchment Management Plan (2018-2024). https://waterportal.rwb.rw/sites/default/files/2019-04/Muvumba%20Catchment%20Plan_0.pdf	Implementation costs (planting, growing, establishment of seedlings, etc.); foregone agricultural uses of land	Reduced erosion and sedimentation, improved soil quality, lower water treatment plant costs	Decreases in river sedimentation/increases in river water quality; Avoided greenhouse gas emissions from degraded soils; Avoided losses in agricultural productivity because of erosion; Decreases in water treatment costs

All	Use adequate and cost effective mechanical, physical, chemical, biological, habitat management or any combination of the most appropriate methods to remove all individuals of target invasive alien species	REMA. Study To Assess The Impacts Of Invasive Alien Species (Flowering Plants, Fish And Insects) In Natural Forests, Agro-- Ecosystems, Lakes And Wetland Ecosystems In Rwanda And Develop Their Management Plans.	Research costs; Implementation costs. Biodiversity loss. Loss of habitat for species that could potentially control pests. Increased erosion and flood likelihood	Improved productivity; reduced water stress; reduced forest fire risk; less competition for desired species (for water, space, light, nutrients); restore soil properties to natural state; restore natural nutrient cycling processes, fire regimes and hydrology	Increases in productivity; decreases in water losses
Forest	Collective management of forested landscapes that promotes social learning to conserve forest function and structure, biodiversity and habitat connectivity, and climate-smart agriculture with agroforestry systems.	WeADAPT		More resilient ecosystems, improved ecosystem services	Increases in ecosystem connectivity and biodiversity; production losses avoided; alternative sources of incomes created through agroforestry
Forest	Using multiple sources of forest foods to support food security during	WeADAPT		Improved food security; alternative sources of income that are less prone to climate risk	Avoided reductions in incomes as a result of climate change

	periods of low agricultural productivity caused by severe drought in tropical forested landscapes.				
Forest	Fire prevention through fire breaks, prescribed burning, reducing fuel loads and fire suppression	Locatelli B, Kanninen M, Brockhaus M, Colfer CJP, Murdiyarso D & Santoso H. 2008. Facing an uncertain future: How forests and people can adapt to climate change. Forest perspectives no.5, CIFOR, Indonesia	Loss of land that could be used for agriculture to fire breaks	Reduced wildfire risk	Decreases in fire extent (severity and frequency); production losses avoided; infrastructure damage avoided; losses of life prevented
Forest	Managing invasive species, insects and diseases (including the removal of invasive species, prevention of the migration of invasive species, phytosanitary treatments)	Locatelli B, Kanninen M, Brockhaus M, Colfer CJP, Murdiyarso D & Santoso H. 2008. Facing an uncertain future: How forests and people can adapt to climate change. Forest perspectives no.5, CIFOR, Indonesia	Implementation costs. Biodiversity loss. Loss of habitat for species that could potentially control pests. Increased erosion and flood likelihood	Improved local biodiversity and ecosystem resilience; restore soil properties to natural state; restore natural nutrient cycling processes, fire regimes and hydrology	Increases in productivity; decreases in water losses

Forest	Managing post-disturbance phases through restoration and revegetation	Locatelli B, Kanninen M, Brockhaus M, Colfer CJP, Murdiyarso D & Santoso H. 2008. Facing an uncertain future: How forests and people can adapt to climate change. Forest perspectives no.5, CIFOR, Indonesia	Implementation costs (including planting, growing and establishment of seedlings)	Improved ecosystem health and ecosystem services (such as soil fertility and reduced soil erosion)	Reduced impact of sedimentation of rivers and dams; Avoided greenhouse gas emissions from degraded soils; Avoided losses in agricultural productivity
Forest	Enhancing landscape connectivity (for example corridors and buffers) and assisting indigenous species migrations	Locatelli B, Kanninen M, Brockhaus M, Colfer CJP, Murdiyarso D & Santoso H. 2008. Facing an uncertain future: How forests and people can adapt to climate change. Forest perspectives no.5, CIFOR, Indonesia	Foregone agriculture revenue through conservation corridors	Improved ecosystem health/functioning and ecosystem services; improved pollination services; improved pest control	Increases in ecosystem connectivity and biodiversity; production losses avoided
Forest	Conservation of biodiversity hotspots and enhancing genetic diversity in natural forests	Locatelli B, Kanninen M, Brockhaus M, Colfer CJP, Murdiyarso D & Santoso H. 2008. Facing an uncertain future: How forests and people can adapt to climate change. Forest	Implementation costs of conservation	Improved ecosystem health/functioning and ecosystem services	Increases in ecosystem health (e decreases in tree mortality due to drought, disease, waterlogging, herbivory)

		perspectives no.5, CIFOR, Indonesia			
Forest	Modifying management practices in forest plantations (including species and genotype selection, species mixes, thinning and harvest and age structure)	Locatelli B, Kanninen M, Brockhaus M, Colfer CJP, Murdiyarso D & Santoso H. 2008. Facing an uncertain future: How forests and people can adapt to climate change. Forest perspectives no.5, CIFOR, Indonesia	Technical capacity and knowledge of genotype selection may be limited	Increased climate-resilience of forests	Avoided losses in agricultural productivity/increases in agricultural productivity
Forest	Maintaining natural disturbance regimes	Locatelli B, Kanninen M, Brockhaus M, Colfer CJP, Murdiyarso D & Santoso H. 2008. Facing an uncertain future: How forests and people can adapt to climate change. Forest perspectives no.5, CIFOR, Indonesia	Training costs; extension services required; research/M&E need	Improved ecosystem functioning and resultant services	Reduced impacts of disasters (such as fires)

Forest	Natural forest management based on selective logging. Measures for facilitating adaptive capacity include maximising juvenile and reproductive population sizes, maintaining interpopulation movement of pollen and/or seeds (by minimising harvesting impacts on forest structure and by maximising landscape connectivity), maximising genetic variation of planted seedlings when enriching logging gaps and the use of translocated material in enrichment planting	Locatelli B, Kanninen M, Brockhaus M, Colfer CJP, Murdiyarso D & Santoso H. 2008. Facing an uncertain future: How forests and people can adapt to climate change. Forest perspectives no.5, CIFOR, Indonesia	Training costs; extension services required; research/M&E need	More climate-resilient crops and forests	Production losses avoided

Forest	Tree plantations that use measures such as planting a range of genotypes that tend to perform acceptably in a range of environments, implementing appropriate species selection (particularly in transitional zones) and using seed sources adapted to expected future conditions	Locatelli B, Kanninen M, Brockhaus M, Colfer CJP, Murdiyarso D & Santoso H. 2008. Facing an uncertain future: How forests and people can adapt to climate change. Forest perspectives no.5, CIFOR, Indonesia	Community preferences; seedling supply/supply-chain intervention costs; training costs	More resilient forests and crops/plantations, improved ecosystem services	Production losses avoided
Wetland (Rwanda)	Erosion control structures	Maintenance of hydropower potential in Rwanda through ecosystem restoration (https://www4.unfccc.int/sites/nwpstaging/pages/item.aspx?ListItemId=23190&ListUrl=/sites/NWPStaging/Lists/MainDB)		Reduced soil erosion; improved soil fertility; reduced sedimentation of rivers and water sources, improving the quality and reducing water treatment plant costs; reduced landslide risk	Reduced impact of sedimentation of rivers and dams; Avoided greenhouse gas emissions from degraded soils; Avoided losses in agricultural productivity

Wetland (Rwanda)	Bamboo and grass buffer belt	Maintenance of hydropower potential in Rwanda through ecosystem restoration (https://www4.unfccc.int/sites/nwpstaging/pages/item.aspx?ListItemId=23190&ListUrl=/sites/NWPStaging/Lists/MainDB)		Reduced degradation of wetlands?	Decreases in extent of wetland degradation
Wetland (Rwanda)	Tree planting on surrounding hillsides and distribution of improved cooking stoves to reduce fuelwood removal from wetland areas	Maintenance of hydropower potential in Rwanda through ecosystem restoration (https://www4.unfccc.int/sites/nwpstaging/pages/item.aspx?ListItemId=23190&ListUrl=/sites/NWPStaging/Lists/MainDB)	Planting costs; loss of potential living area	Reduced degradation of wetlands for fuelwood collection	Decreases in extent of wetland degradation
Wetland (Rwanda)	Sustainable agricultural measures in neighbouring communities such as bee-keeping	Maintenance of hydropower potential in Rwanda through cosystem restoration (https://www4.unfccc.int/sites/nwpstaging/pages/item.aspx?ListItemId=23190&ListUrl=/sites/NWPStaging/Lists/MainDB)	Training costs	Alternative sources of income that are less prone to climate risk	Avoided reductions in incomes as a result of climate change

Forest	Alternative livelihood options including agroforestry, crop diversification, eco-agricultural practices such as bee-keeping, grazing management, and keeping livestock that are better adapted to the harsher climate.	Kikuyu escarpment forest (https://www4.unfccc.int/sites/nwpstaging/pages/item.aspx?ListItemId=23205&ListUrl=/sites/NWPStaging/Lists/MainDB)		Alternative sources of income that are less prone to climate risk	Avoided reductions in incomes as a result of climate change

Potential benefits of the identified EbA options

Once the full list of potential EbA options was developed, they were characterised based on the potential benefits they will generate. This further characterisation aimed to capture the full range of benefits that could be delivered by each specific EbA option on a case-by-case basis at the relevant pilot sites. In addition to the use of the information sources listed above ('Review of the evidence base for EbA'), this characterisation was supported through the examination of relevant case studies and projects where a case for the benefits of EbA has been made. Any knowledge gaps that exist were targeted for research under the LTRP.

Guiding questions for the rapid options analysis to determine the viability

Based on the list of EbA options for the project sites, benefit characterisation activities and the associated evidence base, a set of guiding questions was developed to identify potentially viable site-specific EbA interventions. These guiding questions were used in the multi-criteria analysis to assess the viability and feasibility of the full set of EbA intervention options identified in the rapid options analysis. The guiding questions were developed from the description of pilot sites provided in the project document as well as the outcomes of the situation analysis. They focussed on how the key characteristics of the site — including local population, direct beneficiaries, potential beneficiaries from future scale-up, ecosystems, land use and livelihoods, as well as the change in climate risks anticipated — will drive the overall scale of benefits. In addition, design aspects of each intervention were considered to determine if the interventions can be tailored to increase their resilience to the impacts of the risks identified at each site. A summary of these guiding questions are listed below.

Scale: Is the project likely to deliver the number of beneficiaries and influence across a similar biophysical scale to previously approved LDCF projects?

In terms of scale the questions are relatively straightforward:

- How many people are likely to directly benefit from the investment?
- What size is the area the project will cover?
- Are these figures broadly in line with interventions which benefit around xxxx people and/or xxxx ha land per million $ of investment requested from the LDCF?

Pathway to impact: Do we understand how interventions map to changes that are relevant to people?

The questions above are intended to help understand whether the scale's orders of magnitude are in line with previous LDCF projects. This section reinforces the need to track how the changes that occur as a result of an EbA intervention, inform the differences that can be felt by people.

The questions below are aimed at probing the impact pathway in this context, to connect the linkages between people's livelihoods, wellbeing and the economy for the eventual impacts in a CBA to be more readily identifiable. This will need to build on an understanding of the current situation at the project site — for example, identifying the current economic activities taking place and how they will be affected by climate change. In the context of the project actions, it will then be important to ask:

- How will the intervention deliver benefits to people which will help counter the impacts of the expected changes in the climate in Rwanda? (which sectors / whose livelihoods / what infrastructure will be protected?)

Considering the nature and pattern of benefits over time is necessary, particularly as it will reveal when, as well as how, beneficiaries will start to benefit from different options. For example, it will reveal if there are any lags between the investment in EbA and the delivery of their impacts.

- Are these values likely to deliver a stream of ongoing annual benefits or change the probability of arising negative impacts? What is the profile of benefits over time? How long after the EbA investment will the associated benefits be received (how long will it take for the intervention's benefits to be experienced by local communities)?

EbA options are often promoted for their primary goals, as well as their wider associated benefits, based on the multifunctionality of natural systems. The first column of the table below describes the types of benefits that might arise from EbA and indicates the relevance of considering this broad range as they all reflect returns on the LDCF's investment.

- Beyond the targeted climate adaptation outcomes, are there likely to be wider benefits of the project? What are these co-benefits?

Magnitude of benefits: Does it seem plausible that the project will be able to deliver enough value to be acceptable to the LDCF?

While previous sections have focussed on identifying benefits, beneficiaries and how they would benefit from the proposed intervention, this section focusses on the magnitude of the benefits.

- At this scoping stage — based on the impact pathway and biophysical benefits identified above, does it seem plausible that benefits will be at least three to four times the scale of the costs (including both adaptation benefits and any co-benefits)?
- For example, will restoring a river embankment be enough to reduce flooding impacts, or will the embankment also need to be raised?

Where the benefit is not an annual flow but the avoidance of other periodic climate change-related natural disasters, this can be examined by looking at the costs of previous disasters, to determine their increasing frequency and intensity. A starting point to collect such information is PreventionWeb from the UN Office for Disaster Risk Reduction. Specifically, data for Rwanda is available here: https://www.preventionweb.net/english/countries/africa/rwa/.

Cost-effectiveness: Can we show that the proposed actions are a 'good value' way of delivering the intended changes?

Beyond presenting the economic case, LDCF projects are expected to deliver a legacy beyond project funding. This can be achieved by demonstrating the commercial viability of EbA options when compared with man-made grey infrastructure alternatives. Uptake may currently be slow because of the perceived risks of such investments. In the project appraisal, it can be indicated that the EbA option is likely to deliver similar benefits for similar costs to other investments, which will highlight the potential for the project to be replicated with funding sourced through other routes, if it can be proved successful.

- Can grey infrastructure alternatives be identified and compared with the costs of delivering any elements of the benefits package delivered by the EbA options?

Long-term impacts: Financial sustainability post-project funding

Beyond cost effectiveness, other elements of financial sustainability should be examined. The first relates to costs beyond the project lifetime. If an EbA measure requires ongoing maintenance to continue delivering benefits, it is important to examine how these will be met. Second, if the project is aimed at catalysing action at a greater scale, how might this happen?

Both questions can be examined by focusing on the beneficiaries — it is necessary to identify who benefits from the project. In particular, identifying whether there is a group of beneficiaries who derive sufficient value from the project to the extent that they have an incentive to continue working together to maintain it, or alternatively replicate the project elsewhere if the LDCF-funded work provides a proof of concept. For example, is sufficient additional water likely to be generated for it to be in farmers' (or a collective of farmers') direct interests to employ the EbA measures demonstrated? If so, are they likely to have the resources upfront to do this or would the GoR be required to ensure loans are available for wider EbA measures?

The EbA option may also provide a solution that can be replicated elsewhere, and potentially by other models beyond grants from donor agencies, which allows for significant upscaling possibilities. Targeting these types of options with GEF projects allows them to be transformative, potentially stimulating a widespread uptake of EbA that reaches many potential beneficiaries.

Questions that can help examine these matters include:

- How are benefits distributed across different sectors/groups? Who will benefit from the intervention? For example, replacing tea plantations with forests may help some people, but not the tea farmers. Introducing agroforestry, however, will help the tea farmers.
- Which sector(s) benefit most, and do any gain more than the likely cost of the actions?
- What are the number of potential beneficiaries with similar livelihoods, facing similar climate change threats and in similar ecosystem settings that could also employ EbA measures developed under the LDCF project?
- Will the most vulnerable people in the local communities benefit from the interventions?
- Where do the costs and benefits of the intervention fall demographically? For example, will there be changes in resource access or income opportunities between men and women, rich and poor, urban and rural, regions, sectors and communities?

Additional guiding questions suggested in the IUCN EbA Handbook[454]

- Are the landscape and its land uses capable of delivering sufficient adaptation services?
- Are actors aware of the adaptation services delivered by ecosystems and do they value these?
- Is there a social and institutional framework that can be strengthened and given responsibility in relation to EbA? Examples are institutions in charge of development planning, Disaster Risk Reduction (DRR) or water resources and ecosystem management.
- Within this framework, is there experience and willingness to generate policies and actions to keep the aforementioned ecosystems in good health and able to supply key adaptation services?
- Could the particular role of ecosystems in delivering primary adaptation services be acknowledged and valued in spiritual, aesthetic, ecological and economical terms?
- Are actors and decision-makers willing to strengthen development planning policies with adaptation strategies that take adaptation services into account?

If the answer to the majority of these questions is no, then EbA would not be a suitable option for the site under consideration. If the answer to the majority of these questions is yes, you can proceed with the six steps in the IUCN EbA guide to set up an EbA strategy.

Additional guiding questions

- Is the intervention expected to be climate resilient? Will the intervention be climate proof to the projected climate change trends for the site?

[454] https://www.iucn.nl/files/klimaat_water_voedsel/eba_handbook.pdf

- How easily can the success of the intervention be measured and monitored? How will the success of the intervention be measured? Bear this in mind particularly for the LTRP.

Annex 2: Multicriteria analysis (MCA)

Attached in the Excel file entitled '*Rwanda LDCF_Annex 2_Multicriteria analysis results_7 Dec 2020*' are the results of the MCA carried out for each site, with the exception of Nyandungu Wetland, given that this stie already has a detailed set of EbA interventions planned under the 'Nyandungu Urban Wetland Eco-tourism Park' project. The interventions analysed include those initially proposed in the GEF NAP ProDoc, and additional, alternative solutions proposed by stakeholders during consultations. Scores closest to 1 indicate preferred interventions (and therefore most viable in terms of current and future climate change impacts, and feasible in terms of, *inter alia*, cost-effectiveness, environmental and social safeguards, and ease of implementation).

Annex 3: Intervention implementation workplans and timelines
Attached as a separate document.

Annex 4: Stakeholder consultations guide
Attached as a separate document.

Annex 5: Site Visit and Stakeholder consultations report
Attached as a separate document.

Annex 6: Indicative budget for ongoing cost-benefit analysis
Attached as a separate document.

Annex 7: Interventions Detailed budgets
Attached as a separate document.

Annex 8: Review of bamboo for riparian restoration at the Muvumba River site

Introduction

While bamboo may be seen as a weed or perceived mostly as an invasive species, there are native bamboo species on almost every continent and only a small portion of the entire genera show characteristics of invasiveness[455]. Rwanda has one naturally occurring species of bamboo, *Yushania alpina*[456], which is predominantly found in the north eastern part of Volcanoes National Park[457]. *Yushania alpina* is a useful source of NTFPs for local communities, being commonly used for weaving 70%, construction 20%, furniture 5%, household items 5%[458]. Apart from *Yushania alpina*, there are also naturalised bamboo species which occur commonly in Rwanda. These include *Bambusa vulgaris*, which is dominant in the natural forests of Nyungwe, and *Oxythenanthera abyssinica*. In Kigali, one can find a few clumps of *Bambusa oreobambos*[459]. In terms of watershed protection and riparian restoration, *Bambusa vulgaris, Arundinaria alpine,* and possibly *Yushania alpine*, have been identified as suitable[460].

Potential risks of using bamboo for riparian restoration

Certain species of bamboo, particularly taxa in the genus *Phyllostachys*, have been reported as noxious weeds in both native and non-native ranges. The encroachment of bamboo mono-forests into mixed forests has caused substantial impacts on plant diversity and community structure[461]. This is attributed to the ability of woody bamboos to form fast growing monoculture forests that displace surrounding vegetation, which is detrimental to local biodiversity[462]. Sites need to be monitored to assess spread of species. Consequently, non-invasive, clumping bamboos are used to avoid negative impacts. They are selected for restoration as they have positive impacts on the water table as opposed being high water users. Indeed, there are species of bamboos which are known to grow naturally in Rwanda such as *Bambusa vulgaris* see above) which have been identified as low-risk for restoration purposes in Rwanda[463].

Benefits of using bamboo for restorative purposes

As one of the fastest-growing plants on earth, with an estimated 1,200 to nearly 1,500 species worldwide, bamboo's substitutability provides a key way of dealing with contemporary natural resource deficits. Bamboo reaches maturity within seven years and if managed correctly can be harvested every year thereafter. Moreover, it grows on marginal land, and under this production framework does not compete with food production and requires little fertilizer or water in comparison to traditional sources of fibre[464]. As an alternative fibre, bamboo has the potential to transform major

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[455] Rebelo, C & Buckingham, K. 2015. Bamboo: The opportunities for forest and landscape restoration. *Unasylva*. 66:91-98.
[456] UNEP-WCMC, & INBAR. 2004. Bamboo Biodiversity: Africa, Madagascar and the Americas.
[457] Ministry of Forests and Mines. 2011. National Bamboo Policy.
[458] UNEP-WCMC, & INBAR. 2004. Bamboo Biodiversity: Africa, Madagascar and the Americas.
[459] Ministry of Forests and Mines. 2011. National Bamboo Policy.
[460] IUCN. 2015. Rwanda's Green Wall: Opportunities to engage private sector investors in Rwanda's forest landscape restoration.
[461] Canavan, S., Wilson JR., and Richardson, DM. 2015. Understanding the risks of an emerging local market for cultivating bamboo: considerations for a more responsible dissemination of alien bamboos. 10th World Bamboo Congress, Korea 2015.
[462] Canavan, S., Wilson JR., and Richardson, DM. 2015. Understanding the risks of an emerging local market for cultivating bamboo: considerations for a more responsible dissemination of alien bamboos. 10th World Bamboo Congress, Korea 2015.
[463] Ministry of Forests and Mines. 2011. National Bamboo Policy.
[464] Rebelo, C & Buckingham, K. 2015. Bamboo: The opportunities for forest and landscape restoration. *Unasylva*. 66:91-98.

timber industries, reducing pressure on remaining natural forests and contributing to international restoration goals by using degraded and deforested land to restore critical ecosystem functions[465].

Rapid growth, soil binding and erosion control, adaptive capability, nutrient and water conservation of land and the provision of a continuous and permanent canopy all enable select and carefully chosen bamboo species to act as succession species for the restoration of degraded land. In a nutshell, bamboo provides key ecological benefits for soil, water and carbon sequestration as well as livelihood benefits as detailed below.

Soil

Bamboo can grow on degraded and marginal soils, where many native species, particularly in tropical regions, have difficulty becoming established. In the case of compacted soils, bamboo's extensive interconnected root system can break up soil particles, increasing permeability, reducing compactibility and over time allowing other less competitive species to become established. Similarly, bamboo has the potential to control soil erosion quickly after planting. It grows and establishes itself well on sloping terrains, hill slopes and embankments.

The root system or rhizomes of bamboo form an underground network – the rhizosphere – which helps bind soil while its dense canopy reduces the impact of the elements on exposed soils. Most bamboo rhizomes are present in the top layer of soil (0–30 cm), which enables it to be effective in controlling soil erosion and stabilizing ecosystems[466]. Moreover, bamboo can thrive in soils that are depleted of nutrients and the introduction of bamboo can enrich soil fertility. Because of its fast-growing nature and dense foliage, bamboo is able to rapidly create and maintain a thick layer of litter. This litter layer maintains a microclimate in the understorey and soil moisture – some of the most important factors for the restoration of degraded lands.

In the case of clumping bamboos, the root system does not spread beyond the centre of the plant; it forms an intricate network that has the ability to break up compacted soils and restore permeability and aeration. It also slows the flow of water through the layers of soil. Each individual clump puts up multiple stems or culms each year. These break through the soil and create a multidimensional structure, providing habitat for a range of insects, birds and mammals. In contrast to traditional tree plantations, which generally clear-cut large areas during harvesting, individual culms from each bamboo plant within a plantation can be removed annually, an approach that stimulates growth and ensures a continuous canopy cover. Because these individual culms die naturally, their removal has little effect on forest composition, ensuring minimal disturbance to forest landscapes[467].

A study in India shows how severely degraded soil – the result of an intensive brickmaking industry – staged a remarkable recovery after planting with bamboo. Within 20 years, the groundwater table had increased by 10 metres, and agricultural crops and tree species had been incorporated into a bamboo landscape. In Colombia, planting *guadua* bamboo in degraded soil improved soil quality, decreasing soil compaction by more than half. This more porous soil, with a lower bulk density, quickly restored several crucial ecological functions, including water regulation and nutrient recycling. In Nepal, a similar plantation helped reduce soil erosion and flood damage. Improved water regulation was also a key feature of the study in Chishui, China. A comparison of soil conditions between a bamboo plantation and sweet potato farm found that bamboo plantations had 25 per cent less water runoff. The bamboo plantation also helped to reduce the average soil erosion by 80 per cent, and the established bamboo plantation significantly reduced soil erosion up to 27 t soil/ha/year[468].

[465] Rebelo, C & Buckingham, K. 2015. Bamboo: The opportunities for forest and landscape restoration. *Unasylva*. 66:91-98.
[466] Rebelo, C & Buckingham, K. 2015. Bamboo: The opportunities for forest and landscape restoration. *Unasylva*. 66:91-98.
[467] Rebelo, C & Buckingham, K. 2015. Bamboo: The opportunities for forest and landscape restoration. *Unasylva*. 66:91-98.
[468] FAO, & INBAR. 2018. Bamboo for land restoration. INBAR Policy Synthesis Report 4. INBAR: Beijing, China.

Water

Bamboo has evergreen leaves, a dense canopy and numerous culms, which creates a strong capacity for rainfall interception and moisture retention. In China, more than 90 percent of bamboo forests are found in regions of major rivers and lakes and along riverbanks, where they play an important role in regulating the flow of water through an ecosystem, protecting water sources, and reducing the effects of soil erosion caused by rainfall on bare ground. In other areas, the restoration of degraded land into bamboo forests has been shown to regenerate water tables, securing more regular rainfall patterns and increasing the occurrence of streams, rivers and other water bodies[469].

Wetlands and rivers can be protected by creation of buffer zones, vegetated with suitable species of bamboo and trees, and in-stream and bankside erosion control structures. Many studies have demonstrated the effectiveness of vegetative buffers in reducing the concentration of nitrates, phosphorous, and pesticides from water running off cultivated fields. Concentrations of nitrogen trapped and assimilated by buffer strips or wetlands can be reduced by up to 94% before entering a stream. Phosphorus runoff can be reduced by 25–95 %. The ability of buffers to retain pesticides is variable because each pesticide has unique mobility and soil-binding properties, but they can be especially effective when pesticides are tightly bound to the soil[470].

Carbon sequestration

With their rapid growth rate and high annual regrowth after harvesting, bamboo forests have high carbon storage potential. In contrast to timber plantations under harvest, the long-term average of bamboo's carbon sequestration does not represent a bell curve, but rather a static line. This is attributable the fact that although a portion of bamboo biomass is harvested and removed each year, this is rapidly replaced within a single growing season. The long-term average carbon sequestration and storage of a bamboo restoration project is static, regardless of the end use of the product. This high annual rate of carbon accumulation indicates that the bamboo forest is one of the most efficient types of forest vegetation for carbon fixation[471].

Socioeconomic

Bamboo planting, harvesting and processing have both positive and negative economic effects. Cultivation creates an opportunity for income generation activities for rural people and serves as job creation to those who engage in its activities as well as benefitting small and medium scale enterprises[472]. A bamboo forest or plantation under active management represents a high need for labour. In contrast to timber plantations or managed forests, where these jobs are sporadic due to the intermediate timeframes associated with tree growth and subsequent harvesting, such jobs are permanent and long-term[473].

The promotion of NTFPs in buffers around Rwanda's waterways is a potential opportunity for safeguarding watershed services and improving community livelihoods. A survey regarding knowledge and use of NTFPs around VNP found that bamboo was the single most commonly utilized NTFP, with 44.8% of households producing goods from bamboo, and that NTFPs are most commonly

[469] Rebelo, C & Buckingham, K. 2015. Bamboo: The opportunities for forest and landscape restoration. *Unasylva*. 66:91-98.
[470] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[471] Rebelo, C & Buckingham, K. 2015. Bamboo: The opportunities for forest and landscape restoration. *Unasylva*. 66:91-98.
[472] Akwada, DR & Akinlabi, ET. 2016. Economic, Social and Environmental Assessment of Bamboo for Infrastructure development. International Conference on Infrastructure Development in Africa (ICIDA).
[473] Rebelo, C & Buckingham, K. 2015. Bamboo: The opportunities for forest and landscape restoration. *Unasylva*. 66:91-98.

produced within barriers around waterways. By supporting the creation of fast-growing bamboo buffers in riparian zones, investors also enable the production of a valuable NTFP that has further value when transformed into furniture or other uses. Limited information is available on riparian zone restoration and the use of bamboo in Rwanda[474].

NTFPs differ from traditional agricultural products due to the importance of wild harvesting in the production process, which inherently limits supply for individuals or households. The development of some type of organizing or oversight body is essential to ensuring a volume of supply substantial enough to make subsequent processing and distribution steps economical. In instances where NTFPs are harvested from common land, community organizations are typically well positioned to manage these activities. In instances where NTFPs are harvested primarily from smallholder plots, cooperatives are more likely to form to reduce costs and improve bargaining power. Purchase agreements between ecotourism operators and community groups engaged in the production of NTFPs could provide an income source for households; hotels in Rwanda have already begun sourcing furniture crafted from bamboo, the cultivation of which is being promoted in Rwanda[475]. In a survey of households surrounding VNP, it was found that bamboo, beekeeping and medicinal plants are the most common NTFPs, with 44.8%, 43.3% and 34.3% of respondents benefitting, respectively. One kilogram of honey can command a price of up to RwF 3,500 (US$ 5), while a chair produced from bamboo and sold to a nearby hotel can be worth RwF 5,000 (US$ 7.30). Together, honey and bamboo are responsible for 60% of the value of NTFPs produced in some districts. Most of Rwanda's NTFPs are produced within buffer zones, providing additional benefits when buffers are created and restored around natural forests and national parks. NTFPs are also important during the dry season, when a larger number of poor households use them as an income source[476].

Wildlife or biodiversity

Despite their lack of diversity in Africa, bamboos play an important role in ecology and biodiversity conservation, often providing important shelter and resources for some key species of conservation interest[477]. For example, bamboo improves habitat connectivity and preserves wildlife corridors[478]. Bamboo groves also support important biodiversity, which can be retained as long as sustainable, selective harvesting systems are applied. Because its management requires few inputs of biocides, as few problems with pests and diseases have been reported, bamboo cultivation results in limited negative impacts on local wildlife[479].

Best practices and lessons learned

First, programme developers should actively encourage and plan for local participation. Participatory decision-making and planning processes are particularly crucial for the long-term management of the reclaimed land, after the project has ended. Furthermore, a land restoration approach that incorporates local knowledge and wisdom when developing restoration models with bamboo can result in improved outcomes.

Raising awareness – through local media or via awareness campaigns – is a key element to actively involve local people in projects. Awareness campaigns should make clear the benefits of bamboo

[474] IUCN. 2015. Rwanda's Green Wall: Opportunities to engage private sector investors in Rwanda's forest landscape restoration.
[475] Ministry of Natural Resources. 2014. Forest Landscape Restoration Assessment for Rwanda.
[476] IUCN. 2015. Rwanda's Green Wall: Opportunities to engage private sector investors in Rwanda's forest landscape restoration.
[477] UNEP-WCMC, & INBAR. 2004. Bamboo Biodiversity: Africa, Madagascar and the Americas.
[478] Rebelo, C & Buckingham, K. 2015. Bamboo: The opportunities for forest and landscape restoration. *Unasylva*. 66:91-98.
[479] Akwada, DR & Akinlabi, ET. 2016. Economic, Social and Environmental Assessment of Bamboo for Infrastructure development. International Conference on Infrastructure Development in Africa (ICIDA).

plantations for erosion control and environmental protection, as well as the tangible benefits which bamboo culms provide.

Given the huge income potential of bamboo products, bamboo land restoration projects should also consider integrating bamboo product development into their plans and providing appropriate support and training. Projects should also encourage the establishment of community-driven enterprises, which create employment opportunities, generate income and provide locally available renewable products. Finally, training and capacity building are key to ensuring an intervention's long-term sustainability.

Site-species matching selection is therefore a critical requirement to identify suitable species and appropriate management options. The existing literature on bamboo species and soil matching, planting density, pests and diseases, and plant nutrition is yet to reach some project implementers who are using bamboo for land restoration.

Once a suitable species has been chosen, the establishment of local nurseries can help produce a number of high-quality offset bamboo seedlings for small-scale projects. For larger projects, more research is needed regarding the most cost-effective way to produce a large quantity of planting materials, including bamboo tissue culture and seedlings[480].

Lessons learned and stakeholder considerations from the Muvumba River site

The establishment of a riparian buffer zone on the banks of the Muvumba River was positively received by stakeholders, but the proposed use of bamboo will need to take into consideration the current land use. For example, farmers appealed against having bamboo in the area where they are growing rice. In these areas, farmers are proposing to have other economically useful species like fodder plants, agroforestry trees, fruit trees and sugar cane that do not have negative impacts on river ecosystems. A few farmers have already started planting some fruit trees along the buffer zone. Indigenous species to this riparian vegetation type that also provide resources such as fruit, fodder, fuel wood and medicine, include wild date palm (*Phoenix reclinate*), water berry (*Syzygium cordatum*), swamp hibiscus (*Hibiscus diversifolius*) and Egyptian riverhemp (*Sesbania sesban*)[481] — see Annex 5 for more information.

Riparian buffer zones are already being used within Rwanda, with bamboo often being the preferred crop for demarcating the buffer zone and providing protection from agricultural intrusion[482]. Bamboo is a cash crop that can be used for a number of applications, depending on the selected variety. Moreover, bamboo is listed along with fruit trees and elephant grass as part of agroforestry by the Muvumba Catchment Management Plan[483] as a suitable species for revegetation within buffer zones along the Muvumba River. The catchment management plan notes that a core intervention of catchment restoration is the intensification and diversification of agroforestry techniques; which involve extending the diversity and intensity of agroforestry trees already used to stabilise the slopes of terraces and improve soil fertility, promotion of perennials and tree-crops (including tea, shade coffee, fruit trees, etc), intercropping, planting of in-field trees, shelter-belts or live-fences. Species are to be selected in relation to the local conditions in coordination with farmers to adapt to their needs. The plan suggests planting local species such as *Podocarpus, Polyscias fulva, Entandophragma, Croton megalocarpus, Markhamia Lutea, Vernonia Amygdalina Mytragyna,* and *Syzygium* to enhance biodiversity, in addition to exotic commercial species like *Alnus Acuminata, Acacia Agustima* and *Acacia melanoxylon* to generate revenues. Bamboo is also a crop that can be used in agroforestry[484].

[480] FAO, & INBAR. 2018. Bamboo for land restoration. INBAR Policy Synthesis Report 4. INBAR: Beijing, China.
[481] World Agroforestry Centre. 2015. Useful tree species for astern Africa: Freshwater swamp. Available at: http://maps.vegetationmap4africa.org/docs/X.html.
[482] Rwanda Water Portal. N.d. Buffer strips and gully erosion control. Available at: https://waterportal.rwb.rw/toolbox/468.
[483] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[484] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

Case studies

From a regulatory perspective, case studies show that a combination of attractive subsidies and regulatory policies can speed up the land restoration process and encourage local people to take land management responsibilities seriously. More complicated is the situation regarding land rights. Local people do not want to restore degraded land when land tenure and ownership rights are not clear. Therefore, restoring degraded land in unclear land ownership and land use conflict situations should first settle the land tenure and ownership rights[485].

In most of the case studies, the acceptance and involvement of local people was regarded as an essential component of the project's success. The project organisers for these studies used a participatory approach in the planning, implementation and management of the plantations to encourage locals to participate in land restoration, which was largely successful. In China, local farmers were actively involved in using bamboo for land restoration, under combined approaches from local governments that included awareness raising, subsidies and legal obligations. In Ghana, the rule that 20 per cent of the profit of bamboo plantations was given to workers encouraged participation. In Tanzania, meanwhile, awareness raising about the link between bamboo plantation programmes and bamboo enterprise development led to increased local involvement.

In Anji county, China, the bamboo sector provided jobs for about 100,000 people; in Tanzania, a number of bamboo enterprises were established, creating jobs for almost a thousand villagers. In Tanzania, bamboo enterprise development has proven very successful, with bamboo-related enterprises generating an extra 200 USD each month per household[486].

Ghana

The bamboo species were planted between trees and remnants of forest patches. With the introduction of bamboo, the gaps in the vegetation cover are gradually closing. The bamboo replaced the trees that had been destroyed by bushfires or cut for charcoal burning. The bamboo developed shoots and foliage which have closed the gap between the remaining tree stands, changing the entire vegetation cover to forest. Wildlife and other plant species growth in the forest are gradually being restored. Birds and bush animals that previously lived in the forest are returning to the forest reserve. The bushfires destroy the young bamboo plants and retard the growth of the established bamboo plants. However, unlike many other tree species that are completely destroyed by the fires leaving the land bare, the established bamboo is able to withstand the bushfires; the bamboo shoots stay on the land and rejuvenate when they receive some water. This unique characteristic of the plant compared to the other tree plants makes bamboo useful for maintaining cover in areas with rampant bushfires that destroy vegetation cover. Weed maintenance and the establishment of fire belts around the bamboo is essential but costly. To address this threat and to upscale the project, the Ghana Forestry Commission in collaboration with the local community is adapting the 'taungya' system, where community members in groups of five are allocated land on which to plant and maintain bamboo and plant plantain in-between. These arrangements reduce the cost of weeding and provide land for community members to plant crops to not only supply food for household consumption but also gain income from sales of surplus produce[487].

Bamboo for riparian re-vegetation in Ghana's Northern Savannah Zone

The soils are prone to risk of erosion and have limited capacity to retain and drain water and hold nutrients. Farming practices along the streams and river banks pollute water bodies with agrochemicals and erode river banks. Illegal mining activities, charcoal burning and bushfires have

[485] FAO, & INBAR. 2018. Bamboo for land restoration. INBAR Policy Synthesis Report 4. INBAR: Beijing, China.
[486] FAO, & INBAR. 2018. Bamboo for land restoration. INBAR Policy Synthesis Report 4. INBAR: Beijing, China.
[487] FAO, & INBAR. 2018. Bamboo for land restoration. INBAR Policy Synthesis Report 4. INBAR: Beijing, China.

resulted in severe degradation of vegetation and water bodies. The policy on buffer zone protection indicates recommended buffer zone widths of 15 to 60 m along major rivers and streams; however, farmers plant crops within the buffer zone.

The Sustainable Land and Water Management Program, using bamboo for riparian re-vegetation, started mid-2017. The project is implemented in twelve districts. Bamboo is planted along the river catchments to restore the vegetation cover, reduce soil erosion and stop farmers from farming close to the river banks (Osmani L., personal interview, 2018; E. Yeboah, personal interview, 2018). Community members farming along the river bed were sensitised to the need for river buffer zone protection. Community watershed management committees were formed and interested community members, mostly farmers who farm along river beds were given bamboo saplings and other tree seedlings to plant along the river buffer zone. Farmers were trained on land preparation, planting, mulching, fertiliser application and tree maintenance. Agricultural extension agents and technical experts provided technical advice on the environmental and economic benefits of planting bamboo.

Bamboo grows faster than other trees planted for catchment area protection such as cassia and eucalyptus. Within six months of planting the bamboo along the river banks, stands about 5 m developed. Other conservation trees would take longer to grow to this height. benefits as helping to reduce soil erosion and protect the land. When the culms are matured, the bamboo could be sold to craftsmen who use it for furniture. The bamboo can also be intercropped with other crops such as yellow melon and calabash. Farmers have also mentioned ruminants (grasscutter) feeding on the bamboo leaves and shoots as another co-benefit.

A major challenge is the dry weather conditions in the area, which requires farmers to water the bamboo, especially in the initial stages. Farmers along the river catchment area have pump machines to draw water from the river and irrigate their farmlands. This water is also used for watering the bamboo: farmers' mulch around the bamboo to reduce water evaporation from the soil after watering[488].

Tanzania: Challenges and solutions[489]

[488] FAO, & INBAR. 2018. Bamboo for land restoration. INBAR Policy Synthesis Report 4. INBAR: Beijing, China.
[489] FAO, & INBAR. 2018. Bamboo for land restoration. INBAR Policy Synthesis Report 4. INBAR: Beijing, China.

Table 8.1. Challenges and solutions to the planting of bamboo in Tanzania.

Critical challenges	Applied solutions
Governmental officials and local communities resistance to using bamboo for land restoration due to a lack of experience.	Frequent visits made by team members to coordinate with leading department's key officials to organise training and film showings to demonstrate bamboo's potential for land restoration. The team conducted awareness raising campaigns and distributed materials, including leaflets and posters in the local language.
Unclear land tenure and ownership rights in the region.	The project targeted only community and homestead farm land where clear ownership rights existed
Low motivation of community in establishment of plantation forest as economic value of plantation forest.	The project team set up a bamboo production unit to work with the local community to highlight the potential economic and income generating activities.
Developing good quality and larger quantity planting materials needs time and investment	The project team promoted homestead micro nurseries
Non-cooperation from the side of the mining company to trial and participate in land restoration.	Provide bamboo planting materials and setting-up a demonstration plot. Invite the mining company to different events on bamboo related activities, i.e. training and exposure.
Community expectations – people expected to receive economic benefits quickly.	The project team worked to educate the community about the bamboo cycles. The bamboo crop could be harvested after 3-4 years. The project facilitated several livelihood activities on bamboo, i.e. furniture making, bamboo crafts through using existing resources to help the community gain economic benefits in the interim period

Using bamboo in riparian buffer zones on the Muvumba River under the NAP project

Natural and gallery forests, and other natural vegetation, that used to exist along the Muvumba River have also been cleared for crop production and cattle ranches and cut for use in construction or for firewood. Almost 95% of riverbanks and their catchment areas are used for agriculture. Most of the ranches and farms are, however, poorly managed, as a result of overgrazing and poor farming methods, and ground (grass) cover is almost completely depleted. Soil compaction is common with most soils having developed a hard pan and having lost their water retention capacity resulting in reduced groundwater recharge, excessive surface water run-off and soil erosion. As a result of farming, chemicals (insecticides and herbicides) are also released into the river and during prolonged dry spells and drought periods, flows reduce substantially, causing a water crisis for livestock, plants and humans[490].

To address these issues and in doing so, contribute to improving the climate resilience of local communities, a buffer zone (10 m wide) will be established along a portion of the Muvumba River using a mosaic approach. It will be planted in combination with the assisted natural regeneration (ANR) of existing riparian vegetation, as well as useful tree and fodder grass species (bamboo, agroforestry, elephant grass, etc.) to stabilise riverbanks, reduce erosion, attenuate flooding and prevent / reduce ingress of pollutants to the river system. This approach is aligned with the Muvumba River Catchment Management Plan[491] and Rwanda's National Bamboo Policy's objective of "reducing

[490] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).
[491] Ministry of Environment. 2018. Muvumba Catchment Management Plan (2018–2024).

soil erosion, siltation of rivers and water bodies by growing bamboo on slopes and buzzer zones along river banks and lakeshores"[492].

Remaining areas of riparian vegetation in the 10 m buffer zone will be protected and restored using an ANR approach. Bamboo stands will then be planted in areas that are completely degraded (limited or no riparian vegetation present), with agroforestry trees then planted between the bamboo/riparian vegetation mosaic and nearby croplands to provided additional NTFPs such as fruit. Agroforestry trees will also be planted within the surrounding croplands to improve productivity, reduce erosion and reduce the impacts of high temperatures through shading (Figure XX).

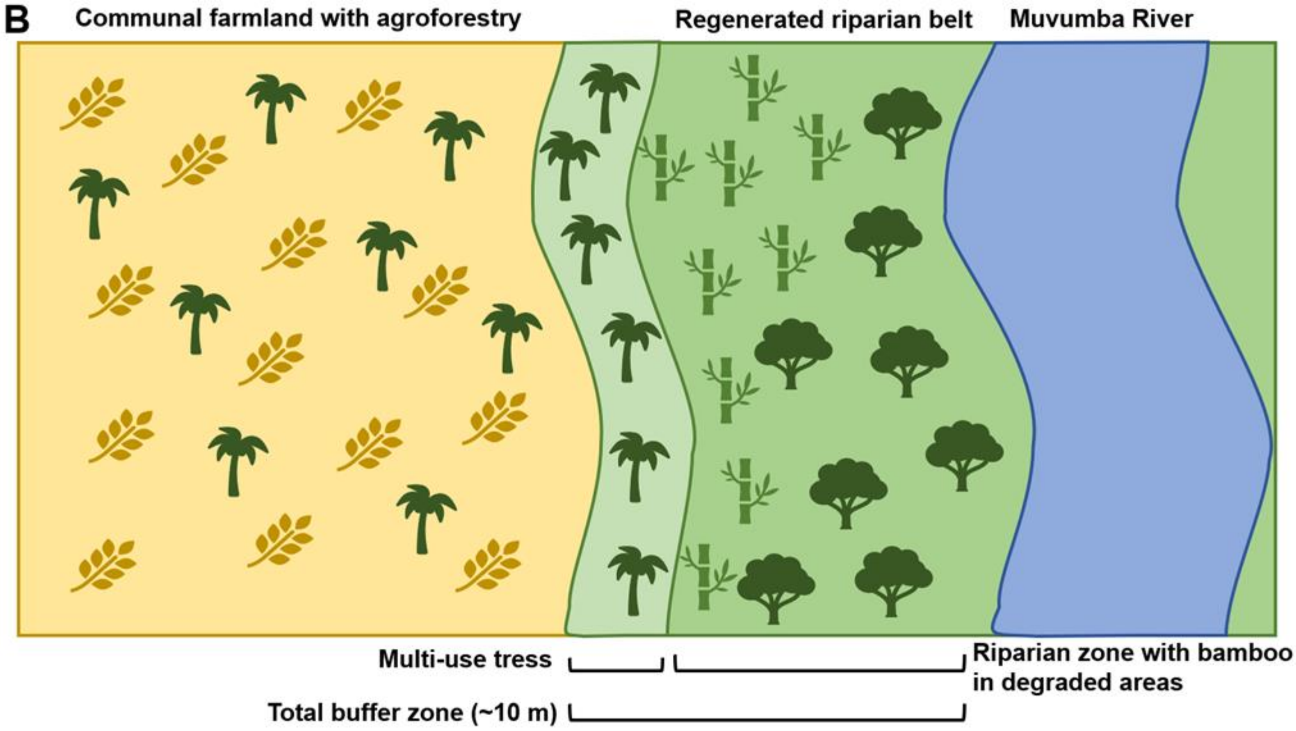

Figure 96. Schematics showing the placement of the buffer zone along the Muvumba River.

ANR accelerates the natural successional process by protecting against disturbances (fire, stray domestic animals and humans) and by reducing competition from invasive species[493]. The use of ANR in forest restoration offers several key advantages over conventional reforestation through planting. Firstly, ANR is significantly cheaper to implement as costs associated with seedling production, site preparation and planting are greatly reduced. Second, ANR takes advantage of natural successional process which ensures that the plant community that is established is well adapted to the site conditions. Lastly, the naturally regenerating plant community in the tropics typically comprises a mixture of species. Therefore, ANR results in more diverse, multilayered vegetative cover than from typical reforestation involving the planting of a limited number of species. This diversity enhances habitat quality for local wildlife and environmental stability. Where necessary ANR will include enrichment planting of indigenous riparian species.

Bamboo will be planted to reduce pressure on natural riparian vegetation (part of a mosaic approach to restoration). By planting bamboo as part of a larger landscape, degraded lands could be restored to productive use, thereby alleviating some of the pressure on riparian areas and forests from

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492 Ministry of Forests and Mines. 2011. National Bamboo Policy.

493 FAO. 2019. Restoring Forest Landscapes Through Assisted Natural Regeneration (ANR). A practical Manual. Available at: http://www.fao.org/3/ca4191en/CA4191EN.pdf

development uses, and providing communities with secure incomes, thereby reducing smaller-scale pressures that drive continued degradation[494]. Planting bamboo is particularly important in locations where a return to pure or mixed forested areas is not realistic. In a landscape mosaic approach, bamboo is planted in areas that combine forests and trees with other land uses. That is not to suggest that bamboo should be utilized to restore all landscapes. Of course, bamboo cannot be a panacea; there are many management, propagation and technology challenges to overcome, as well as concerns that to provide such restoration benefits it is only grown and harvested under a framework of sustainability.

[494] Rebelo, C & Buckingham, K. 2015. Bamboo: The opportunities for forest and landscape restoration. *Unasylva*. 66:91-98.