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Rwanda Environment Management Authority (REMA)

Baseline study on Multi-dimensional Poverty Environment in Musanze and Bugesera Districts and proposed Interventions for poverty reduction, sustainability and climate resilience

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List of Acronyms

AEZs	Agro Ecological Zones
AF	Alkire and Foster
AfSIS	Africa Soil Information Service
CAADP	Comprehensive Africa Agriculture Development Program
CBHI	Community Based Health Insurance
CIBA	Consultancy for Innovation and Business Action Ltd
CIP	Crop Intensification Programme
CROM DSS	Catchment Restoration Opportunity Mapping Decision Support System
EAC	East African Community
EAs	Enumeration Areas
EDPRS	Economic Development and Poverty Reduction Strategy
EI	Exposure Indicator
EICV	*Enquête Intégrale sur les Conditions de Vie des Ménages*
ENR	Environment & Natural Resources
FAO	Food and Agriculture Organization
FGD	Focus Group Discussions
GDP	Gross Domestic Product
HIC	High-Income Country
IGAs	Income-Generating Activities
INDCs	Intended Nationally Determined Contributions
JDAF	Joint District Action Forum
KII	Key Informant Interviews
LTR	Land Tenure regularization
M&E	Monitoring and Evaluation
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government
MINECOFIN	Ministry of Finance and Economic Planning
MININFRA	Ministry of Infrastructure
MMA	Mixed Methods Approach
MOE	Ministry of Environment
MPAT	Multidimensional Poverty Assessment Tool
MPI	Multidimensional Poverty Index
NAMAs	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Plan of Action
NER	National Enrolment Rate
NGOs	Non-Governmental Organizations
NISR	National Institute of Statistics and Research
NST-1	National Strategy for Transformation
OECD-DAC	Organization for Economic Co-operation and Development/ Development Assistance Committee
OPHI	Oxford Poverty & Human Development Initiative
P-E	Poverty–Environment

PEA	Poverty Environment Action for Sustainable Development Goals (SDGs)
PEI	Poverty Environment Initiative
PLWDs	Persons Living With Disabilities
PPP	Public Private Partnership
PRICE	Project for Rural Income through Export
PSTA4	Plan Strategique pour La Transformation Agricole (Phase 4)
PSU	Primary Sampling Unit
RDDP	Rwanda Daily Development Project
REMA	Rwanda Environmental Management Authority
RFP	Request for Proposal
SACCOs	Savings and Credit Cooperatives
SDGs	Sustainable Development Goals
SEAB	Sustainable and Environmentally Friendly Agriculture Business
SI	Sensitivity Indicator
TWG	Technical Working Group
UMIE	Upper-Middle Income Economy
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VNP	Volcanoes National Park

Executive Summary

Tremendous efforts are being deployed by the Government of Rwanda to deal with poverty. Currently, 38.2% and 16% of the population live in poverty and extreme poverty respectively. Statistics indicate that approximately 70% of the total population earns their livelihoods from rain-fed subsistence agriculture (NISR 2015a); whereas 13% of households in Rwanda have experienced cases of environmental problems, most of them (57%) were pertaining to heavy and destructive rains (NISR, 2018a.) This is an indication that the natural resource base and its contribution to economic growth and poverty reduction is under pressure, due to the imbalance between the population and the natural resources especially in rural areas (MINECOFIN, 2020). This situation is aggravated by the high vulnerability caused by the undulating terrain, susceptibility to erosion and climatic hazards.

This baseline study was conducted to comprehensively document poverty-environment levels in Bugesera and Musanze Districts. It had the following three objectives: (1) Multi-dimensional poverty-environment assessment, and proposal for effective Poverty Environment mainstreaming in both Districts; (2) Proposed inclusive and sustainable poverty-environment interventions which address both poverty reduction and environment-natural resource management, and provide opportunities for private sector and other partners to effectively contribute to sustainability and poverty reduction; and (3) Proposed scale-up plan and practical implementation of the same or similar interventions to other Districts in the country.

To achieve the objectives of the present study, mixed methods triangulation design consisting of both qualitative and quantitative approaches. The quantitative data was collected using household (HH) survey questionnaire administered to a total of 224 households for Bugesera District and 231households for Musanze District, and desk review through which secondary data was collected. Primary qualitative data was collected through Focus Group Discussions (FGDs) and interviews for key informants with 92 and 36 participants respectively in Bugesera District; and 96 and 35 participants respectively in Musanze District. Poverty levels were assessed applying the combination of ENR and MPI methodologies to measure the ENR-MPI for both Districts. Thereafter, ENR dimensions (soil, water, forest, fishery, and mining) were linked to poverty dimensions (standard of living, health and education), and χ^2 (Chi-square) and correlation tests were computed to show the contributions of ENRs indicators to poverty dimensions.

The major findings of the baseline study are as following:

a) *ENR-MPI in Bugesera and Musanze Districts;*

The computed ENR-MPI shows Head count ratios (H) where 33.9 % of the total population in Bugesera District are ENR-multidimensional poorer than their counterparts from Musanze District at 20.1%. In terms of average percentage share of weighted deprivations, the intensity of deprivation among the ENR- poor (Adjusted Head Count ratios-Mo) is 50.2 % and 47.6 % in Bugesera and Musanze Districts respectively. The study established that the ENR- Poor population was 146,157 in Bugesera District while in Musanze District, it was 82,827.

The soil related ENR poverty contributes comparatively more than other resources to ENR-MPI, standing at 56.8% in Musanze District and 65.3% in Bugesera District. The forest related ENR poverty contributed 7.5% and 8.07% to ENR-MPI in Musanze and Bugesera Districts respectively. The fishery resource related ENR poverty contributed 7.5% and 11.8% to ENR-MPI in Bugesera and Musanze Districts respectively.

b) ENRs-Poverty linkages in Bugesera and Musanze Districts

The findings indicate that the mismanagement of soil, water, forest, fishery and mining resources have retrospectively contributed to poverty in Bugesera District at 44.9%, 13.1%, 12.5%, 16.3% and 13.1%; while it retrospectively contributed at 47.6%, 11.6%, 17.4%, 10.4% and 13% in Musanze District. It was clear from the findings that environmental problems affected ENRs differently and they highly impacted on agriculture and household livelihoods in general as highlighted below.

Bugesera District (See **Table 30** *and* **Table 34***)*

(a) *Drought events*: These events led to forest destruction, which, in turn contributed to the reduced rainfall amounts. Soil moisture and water levels in the lakes and rivers reduced during such periods. These combined factors led to low agricultural and animal production, and consequently to low household income levels, food and water shortages, health related problems and limited sources of cooking energy. Women and children spend much of their time collecting fire wood and fetching water as a result of deforestation and water shortage. Findings revealed that people from Bugesera District travelled long distances (all other factors being constant) to reach sources of water and fire wood, compared to those from Musanze District. The distance travelled for water and fire wood reduced women's household productivity, increased drop-out rates in schools and reduced class attendance among children.

(b) *Floods*: Frequent flooding events make Akagera and Nyabarongo rivers overflow, farm land flooded and water logged in marshlands (e.g.: Mwogo, Gashora and Juru Sectors) which leads to high crops loss. Consequently, many households faced food shortage and limited access to clean water. The shortage of agricultural production and productivity has led to overfishing in the local lakes and rivers. The Overflow of Akagera River and neighbouring lakes has resulted in increased drop-out rates among in-school children citing shortage of food and poverty related income in the families, and no capacity to pay school fees and buy school materials.

(c) *Change in temperature and windstorms in the lakes:* the increase in variation of temperature and windstorms in the lakes have negative impacts on the procreation of fish as fish eggs (roe) get damaged. Indeed, fish production has reduced in RUMILA, KIDOGO, RWERU, MILAYI and CYOHOHA lakes, influencing the reduction in income and increased malnutrition among under 2-5 years' old children, pregnant and lactating mothers and other category of the population in Bugesera District.

(d) *Destructive rains and strong winds*: Though landslides are not frequent in Bugesera District due to its less hilly topography, destructive rains coupled with strong winds caused landslides and soil erosion destroyed crops and houses, leading to food shortage and loss of human lives, resulting in low-income among the population.

(e) *Soil erosion*: Secondary data showed that the mean soil erosion rate in Bugesera District was (105 $t.ha^{-1}.a^{-1}$). In Bugesera District, soil erosion depleted soil nutrients (with negative effects on agriculture production) and has contributed to pollution of water bodies (groundwater, harvested water and surface water), which may cause health problems to human and fish population.

Musanze District (See **Table 35** *and* **Table 36***)*

(a) *Change in rainfall*: Irregular rainfall patterns in the Birunga National Park destroyed the fertile land, through soil erosion and water runoff in Kinigi, Busogo and Gataraga sectors. This led to crop losses.

(b) *Soil erosion*: Secondary data showed that Musanze has mean soil erosion rate of (244 $t.ha^{-1}.a^{-1}$). This has caused soil infertility and limited agricultural production and productivity; and contributed to pollution of water bodies.

(c) *Destructive rains*: These are the main cause of landslides and soil erosion which damage crops, shrubs, forests, houses and other infrastructure (e.g.: feeder roads, bridges, culverts).

(d) *Floods*: Soil erosion on mountain watersheds makes River Mukungwa to overflow and land area is flooded and water logged in its marshland. This leads to overfishing in the rivers, crop losses and low agricultural production. Thus food for households becomes insufficient as good soils are covered by a lot of infertile sediments.

(e) *Water pollution*: Due to soil erosion and chemicals discharged into rivers and ponds from households and industries (e.g.: Mukungwa and Mugara), water becomes polluted and causes death of fish stocks. Groundwater, harvested water and surface water are polluted to a great extent.

As mentioned above, the main environmental problems that drive poverty in Bugesera District are droughts, floods, increase in temperature and windstorms in the lakes; while soil erosion, destructive rains and landslides drive poverty in Musanze District. The χ^2 (Chi-square) test shows higher degrees of association between livelihoods indicators and ENR related problems in Bugesera District compared to Musanze District at 0% to 5% as level of statistical significance (p-values less than 0.05). This substantiates the findings that, based on Household Food Insecurity Access (HFIA) index, 51.3% of the sampled households in Bugesera District are severely food insecure, compared to 32.2% of their counterparts in Musanze District.

This study, and others (e.g.: UNDP, 2007), revealed that droughts linked to food insecurity in Bugesera District, and effects of rain water from Birunga National Park in Musanze District play a major role in Environmental Natural Resources degradation as well as poverty.

Based on the results of this study, a comprehensive approach to reduce poverty and protect the environment was developed. It included: (1) short and medium term interventions, and (2) long-term common program for Bugesera and Musanze districts need to be implemented in each of the two Districts. Short and medium term specific interventions are expected to rapidly address relatively urgent issues including poverty and environment management highlighted in the findings of this study. The long- term common program initiative is mainly based on a comprehensive approach namely: : Sustainable and environmental friendly agriculture businesses programs which include environmental aspects. The long-term common program shall be executed following five (5) main steps of interventions as chronologically developed in Chapter V. In line with the proposed priorities from the two districts, most crutial projects to deal with poverty and environment problems were selected and highlighted below:

Project 1: Nyabarongo-Akanyaru-Akagera watershed management for a sustainable use of water and floods control downstream in Bugesera District;

Project.2: Development of an updated soil fertility assessment and fertilizer recommendation to increase management accuracy and optimize yield per unit area for Bugesera and Musanze Districts;

Project 3: Integrated agriculture using irrigation technology: especially for vegetable, fruits and other income generating commodities targeting the Bugesera growing cities and related infrastructure like the International Airport.

Project 4: Sustainable and environmentally friendly use of the watershed of Gacaca, Cyuve, Nyange, Kinigi and Shingiro Sectors for agriculture production;

Project 5: Appropriate land husbandry innovations for sustainable land management in both Districts;

Project 6: Management of rain water from volcanoes that cause flood in Musanze city through Construction of concrete dam to retain that water for reuse purpose (irrigation in dry season to increase production of vegetables in that area);

This baseline study also proposed tools for mainstreaming ENRs interventions. These include (i) analytical and decision-making framework and modelling tools (quantitative and transparent approach to making decisions under uncertainty; (ii) case studies and best practices; (iii) social and ENRs assessment tools; (iv) monitoring and evaluation tools (indicators are presented in **Table 49**); and (v) research tools (Components that constitute means of information collection).

The scale up plan shall take into account short and medium term interventions, as well as long-term common program proposed in Bugesera and Musanze Districts. Those interventions shall be adapted to ENR, climate and landscape of each District for before scalling up.. Since Bugesera and Musanze Districts will run the proposed interventions, the lessons from those trials will be used to feed the development of models to be scaled up to the entire rural area of Rwanda. Once the models for the rural area of Rwanda for sustainable development are ready, they will be scaled up to other Districts of Rwanda.

This process may take time but all will depend on how fast different groups of stakeholders including the public sector, private sectors, farmers cooperatives, youth organizations, women associations, people with disabilities associations involved in agriculture and environment activities, NGOs, etc., understand and adopt the proposed model. It is important to mention that, the whole process shall be supported by stakeholders training and adaptive research projects to make sure that all steps made are evidence based. This means that research institutions including RAB, REMA, the University of Rwanda, etc…, be mandated to contribute to the process from the beginning. The focus shall be on a number of research areas including: Land administration, water, soil, crops, animals, agri-business, crop diseases, irrigation, mechanisation of agriculture, food processing, banking/subsidy/insurance, health, law, policy, etc.

Structure of the Baseline Report

This Baseline report is structured into seven (7) key Chapters namely

CHAP I. General introduction
CHAP II. Litterature review
CHAP III. Approch and methodology
CHAP IV. Multidimensional Poverty -Environment
CHAP V. Proposed interventions
CHAP VI. scale up of proposed interventions
CHAP VII. Conclusions

CHAPTER I: GENERAL INTRODUCTION

1.1 Background

It is obvious that Rwanda has deployed significant efforts in the area of poverty reduction. Relevant tools including: regulations, adequate institutions, programs and policies have been put in place and are operating very well. Results from those efforts are evident and a need for strengthening those initiatives comes at the right time. Indeed, there is need to better link "ending poverty" as stated in the current National Strategy for Transformation (NST-1) and the Sustainable Development Goals (SDGs), with the sustainable use of the Environment and Natural Resources (ENRs). This is recognized in a number of existing policies and action plans by the Government of Rwanda. Under this context, mainstreaming ENR into planning and budgeting has been achieved to great extent, with support from Poverty Environment Initiative (PEI) and the Rwanda Environment Management Authority (REMA). In addition, there is need for more efficiency and effective mainstreaming of Poverty–Environment (P-E) linkages mostly at the community level and this study is investigating those synergies in Bugesera and Musanze districts for drawing adequate intentions to support existing efforts.

Globally, 70% of people living below the poverty line depend on natural resources for their subsistence. As a fundamental means of subsistence, natural resources run the risk of overexploitation; and the degradation of the natural environment puts the livelihoods of a large number of people in poverty at risk. Stated differently, the degradation of the environment entails an obstacle to overcome poverty and poverty can aggravate environmental problems through unsustainable practices of use of natural resources (UNDP and UN Environment, 2018).

Studies (e.g.: UNDP, 2007; UNDP and UN Environment, 2018; Thiry et al., 2018) show that poverty is directly or indirectly linked to environment related problems which include: climate change, heavy rainfall, flooding, overflows of rivers, landslides. soil erosion, soil infertility, change in temperatures, e.t.c. These environmental problems affect agriculture productivity that is linked to food security in the households and products for consumption and for markets. Furthermore, industrial (air and water) pollution, deforestation, excessive use of firewood and intensive exploitation of land lead to environment destruction and become the causes of poverty. The natural resources commonly affected by the environmental problems are soil and water.

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In the framework of the United Nations Sustainable Development Goals (SDGs), economic, social, and environmental dimensions are to be advanced together; which calls for explicitly integrating ENRs in poverty alleviation programmes (Thiry et al., 2018). The first objective of the SDGs (SDG 1) is to put an end to poverty, in all its forms, by 2030 (UNDP, undated), that is monetary poverty (NISR, 2018b). However, the eradication of monetary poverty is not the only social challenge that persists. According to UNDP and UN Environment (2018), there are also challenges in terms of malnutrition, employment, social security, access to drinking water and sanitation, education and health. In addition to these challenges, there is the problem of environmental degradation, as well as the exposure to extreme climate events. In the case of Rwanda, environmental protection has been hindered by the imbalance between the population and the natural resources (land, water, flora and fauna and non-renewable resources, which have been degrading for decades). This degradation is observed through massive deforestation, the depletion of bio-diversity, erosion and landslides, pollution of waterways and the degradation of fragile ecosystems, such as swamps and wetlands. Furthermore, massive land degradation and low agricultural productivity were the results of intense exploitation of the land (MINECOFIN, 2020). Land in Rwanda is used for farming and/or livestock development.

On one hand, the majority of Rwandan households are directly reliant on agriculture as their main or only source of income, especially in rural areas (94%), where rural households are more susceptible to consequences from natural hazards (NISR, 2018a). On the other hand, poverty remains a challenge where 38.2% and 16% of the population live in poverty and extreme poverty respectively (NISR, 2015a). According to the EICV5 approximately 70 % of the total Rwandan population earns their livelihoods from rain-fed subsistence agriculture which contributes 33% to the gross domestic product (GDP). Therefore, this has engaged the country into sustainable management of ENRs to transition towards a green economy.

The environment is one out of the seven cross-cutting areas that are considered for attaining inclusive and sustainable development (Republic of Rwanda, 2017). According to NISR (2018a), poor management of the environment might generate human problems. It is estimated that 13.1% of households in Rwanda were affected by environmental destruction (disasters) with 56.8% resulting from heavy and destructive rains; 22% from mountain slides; 6% from floods

and 15.1% from other disasters. Rural households (14.9%) experienced more cases of disasters compared to urban households (5.6%). The same report pointed out that these figures have to be interpreted with caution as they only gave an indication of the perceptions by the households, while multiple problems were not captured. Moreover, other studies (e.g.: Lewis, Clay, and Dejaeegher, 1988; Clay and Lewis, 1996; Kagabo et al., 2013; Karamage et al., 2016) showed that soil erosion and soil losses are some of the most serious environmental problems in Rwanda. UNEP (2011) highlighted multiple variables influencing soil erosion rates which include soil type, drainage, vegetation cover, slope of land, land use practices; while Nambajimana et al (2019) showed that socio-economic causes are one of the major driving forces of accelerated soil erosion in Rwanda. The fact is that the environment itself can have adverse effects on humans, and effective measures should be taken.

In the last two decades, the Government of Rwanda put in place strategies for protection of the environment and poverty reduction (Vision 2020, EDPRS1-2, and NST1, among others). According to MoE (2019), the GoR has signed protocols and agreements for environmental protection and reducing carbon emissions (e.g.: AU Agenda 63, the Sendai Framework, SDGs, the 2015 Paris Agreement on Climate Change and implementation instruments including NDCs, the Kigali Amendment to the Montreal Protocol, Minamata Convention, Nagoya Protocol etc.). The priorities to protect the environment were decentralized to District level; where in every fiscal year, each District signs the performance contracts (Imihigo) which include environment related protection measures such as expanded areas under irrigation; new forests and management of existing ones; woodlots; agro-forests; area protected against erosion (making progressive and radical terraces); e.t.c.

Given the limited financial resources from the Government, the budget allocated to environment protection is still insufficient; though District targets to protect environment are slowly achieved. In view of the above, there is a need to analyze the linkage between Environment and Natural Resources (ENRs) and poverty for sustainable development of Rwanda. This report focuses on two Districts, namely Bugesera (located in the low lands) and Musanze (located in the high lands), in Eastern and Northern provinces respectively as a pilot area for the UNDP Poverty-Environment Action (PEA) in the country.

1.2 Poverty-Environment Action (PEA) for the SDGs

The new Poverty-Environment Action (PEA) for the SDGs follows a global joint support programme under UNDP and UN Environment, and builds on the previous phases of the UNDP-UNEP Poverty Environment Initiative (PEI) support in 22 countries, including in Rwanda. The programme addresses the relationship between unsustainable management of Environment and Natural Resources (ENR) and multi-dimensional poverty. The natural resource base and its contribution to economic growth and poverty elimination is under pressure in Rwanda, mainly because of very high population densities in rural areas. This situation is aggravated by the high vulnerability caused by the undulating terrain, susceptibility to erosion and climatic hazards.

The expected outcome of the PEA project is: ***"Increased and enhanced investments that deliver concrete and significant results in poverty reduction, environmental and natural resource sustainability and resilience building at national and District levels".*** In order to achieve that outcome, the following outputs will be first achieved: 1. "*Strengthened national planning and budgeting capacity and frameworks to sustainably implement poverty-environment actions";* 2*: "Capacity for programming, budgeting and action that eliminate poverty and deliver sustainable ENR management at District-level"; and* 3*: "Increased investments with enhanced impacts for poverty elimination and ENR sustainability catalyzed."*

In the process of increasing investments for enhanced impacts for poverty elimination and sustainable ENR, PEA project, Rwanda is planning to work closely with Districts (Bugesera and Musanze) to develop viable projects, with the aim of promoting socio-economic activities to reduce poverty, but also protecting ENR for sustainable development.

1.3 Objectives of the study

This Multi-dimensional Poverty Environment Assessment was carried out to document poverty levels and to propose poverty-environment related interventions and/or investments in the Districts of Bugesera and Musanze. More specifically, it entails:

(1) Baseline study on Multi-dimensional poverty assessment, and proposal for effective Poverty Environment mainstreaming in both Districts;
(2) Proposal for inclusive and sustainable project interventions which address both poverty reduction and Environment-Natural Resources management, and provide opportunities for the private sector and other partners to effectively contribute to sustainability and poverty reduction; and
(3) Proposal for scale-up plan and a practical implementation of the same or similar interventions in other Districts in the country.

1.4 Outline of the report

This baseline assessment report of multidimensional poverty environment in Bugesera and Musanze Districts is composed of seven chapters; chapter I General introduction presents background to the assessment; PEA for the SDGs which describes rationale for this assessment and the assessment purpose; chapter II Literature review outlines the information already available on ENR; chapter III approach and methodology presents the updated and current research methods applied; chapter IV contextualizes poverty and environment and natural resources (ENRs) and discusses Multidimensional Poverty- Environment in Bugesera and Musanze Districts, and shows the computation of ENR-MPI, establishes linkages between ENRs and poverty; chapter V focuses on proposing comprehensive interventions; chapter VI shows how interventions proposed in Bugesera and Musanze could be scaled up in other Districts. while chapter VII outlines the major outputs with regards to the three objectives of this study.

CHAPTER II: LITERATURE REVIEW

2.1 Introduction

This chapter presents the review of existing literature related to poverty-environment in Rwanda. It starts with definitions of technical terms in order to better understand the subject matter. Furthermore, it discusses global, regional and national outlook and context, with focus on relevant policy documents on multi-dimensional poverty-environment such as the SDGs document, National Strategy for Transformation (NST1), Vision 2050, Green Growth and Climate Resilience Strategy, ENR policies and strategies for Rwanda, NISR reports, performance contracts (*imihigo*) at District level, among others. It also looks at the District specific poverty issues; existing practices and interventions amongst citizens as well as existing gaps, lessons learned and opportunities towards sustainable poverty reduction and environmental protection.

2.2 Definition of technical terms

One dimensional measure is so often employed to define poverty commonly based on income, with a caveat that no single indicator can capture the multiple dimensions of poverty. Multidimensional measures of poverty, a rapidly growing approach[1], are designed contextually and with purpose of measure to incorporate various indicators and priorities narrowing down to lowest administrative levels of a country with a view to informing policy formulation suited to poverty reduction and deprivation in a given country.

Multidimensional poverty encompasses the various deprivations experienced by poor people in their daily lives, such as poor health, lack of education, inadequate living standards, disempowerment, poor quality of work, the threat of violence, and living in areas that are environmentally hazardous, among others.[2]

Professor Robert Walker defines poverty as "not just the absence of income, money and/or money-like resources required to meet needs, but also the multiple consequences of this absence that are simultaneously experienced by people in poverty. Some of these consequences – the non-monetary dimensions of poverty – serve to prolong poverty and can become causes of its perpetuation." This focuses on specific financial resource features like material deprivation, social isolation, exclusion and powerlessness and physical and psychological ill-being.

The definition confirms that poverty is dynamic, with changes in people's 'scores' on each dimension indexing both the nature of the poverty experience and its trajectory.[3] The global MPI scrutinizes a person's deprivations across 10 indicators in health, education and standard of living and offers a high-resolution lens to identify both who is poor and how they are poor.

[1] Ref: Multidimensional Poverty Measurement and Analysis - a book from OPHI (published in June 2015)

[2] Ref: Oxford Poverty & Human Development Initiative (OPHI

[3] Walker, R. (2014) http://ukcatalogue.oup.com/product/9780199684823.

It complements the international $1.90 a day poverty rate by showing the nature and extent of overlapping deprivations for each person.[4]

2.3 Linkage with sectors

This section discusses the four key areas of Socio-economics, Agriculture, Environment Natural , and Resources aspects with key reference to status, key milestones and plans and gaps identified in Rwanda specifically to the two Districts of Bugesera and Musanze.

2.3.1 Review of Socio – economic aspects

The National Strategy for Transformation (NST1) has been developed as implementation instrument for the remainder of Vision 2020 and for the first four years of the new Vision 2050. It also integrates far sighted, long-range global and regional commitments by embracing the Sustainable Development Goals (SDGs), the Africa Union Agenda 2063 and its First 10-Year Implementation Plan 2014-2023 as well as the East African Community (EAC) Vision 2050. Rwanda's economic growth is projected to grow at 7.8% in 2019 and 8% in 2020 basing on the "Made in Rwanda" policy, enhanced public investments such as the near completion Bugesera airport and the country's strong record of implementing reforms to achieve its long-term development goals, good governance build-up and structural transformation facilitated by broad-based growth including job –creating wealth.

The high-level development targets in this long-term development agenda included among others; a raised per capita income of US Dollars 1,240[5], from US Dollars 220 in 2000; An average GDP growth rate of 11.5%; an increase in life expectancy from an average of 49 years in 2000 to 66 years, and a reduction of poverty levels from 60.4% of the population below poverty line to below 30%. As the country approaches the end of the initial long term development agenda (Vision 2020), the Government has embarked on developing other planning instruments (both long and medium-term) and they include: a Blue print of Vision 2050 and the National Strategy for Transformation (NST 1) and its related sector strategic plans, which have been developed to address the remaining development imperatives in Vision 2020, focusing on the country's long-term development aspirations in the next 30 years and the medium-term development strategy in the next seven (7) years (NST1).

Under the blue print of Vision 2050, the Government of Rwanda envisages: increased income levels, high-quality livelihood, and modern living standards for all Rwanda's citizens. To have the necessary resources for doing so, the country envisages becoming an Upper-Middle Income Economy (UMIE) by 2035 and a High-Income Country (HIC) by 2050. In terms of actual targets of this ambitious development agenda, the government also has it in its plans that by 2035, the GDP per capita will increase to over USD 4,036 and to over USD 12,476 by 2050. Currently the GDP publications of national surveys that were conducted by the National Institute of Statistics of Rwanda (NISR) show that, from 2007 to 2017, the GDP has increased with an annual growth rate of 7.5%.

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[4] Global Multidimensional Poverty Index 2019 Illuminating Inequalities

[5] Revised Vision 2020

The GDP growth rate was 7.9% in 2007/2008 and increased to 8.9% in 2017/2018. The GDP per capita (per head) was $414 in year 2007 and it increased to $774 in the year 2017. The current progress of poverty reduction is observed through the report of Household Integrated living conditions Survey from EIC1 (2000/2001) to EICV5 (2016/2017) years, the results revealed that the headcount poverty was reduced from 58.9% to 38.2%, and the extreme poverty also reduced from 40% to 16%. Bugesera District was ranked 15th out of 30 Districts with headcount poverty of 40.3% and extreme poverty of 17.8% while Musanze District was ranked 16th with headcount poverty of 40.7% and extreme poverty of 18.1%.

There are key challenges which remain to be addressed, for instance poverty is still prevalent and more in the rural areas (38.2%) compared to urban areas (15.8%).[6] The productive base remains with very little choices with very few productive sectors coupled with challenges of high transportation costs.

The assessment of existing literature reviewed revealed various gaps in the economic development of the country. As shown in the list below, the Government is currently engaged in addressing the following key gaps identified in Rwanda's economic development (NST1):

- Sustaining the momentum on accelerated poverty reduction,
- Managing constraints associated with high population density, land degradation and scarcity,
- Reducing reliance on rain-fed and low input agriculture,
- Broadening the productive base,
- Decreasing the reliance on biomass energy and reducing the high cost of electricity,
- Mitigating inequality and ensuring the enjoyment of equal rights by Rwandans of all walks of life in accordance with the existing international human rights obligations to which Rwanda is party,
- Strengthening the private sector,
- Being landlocked with high transportation costs and
- High dependence on foreign aid and vulnerability to external shocks.

In 2018, the agriculture sector grew by 6% following favourable weather conditions and various Government measures to increase food and other agricultural production and in 2019 the agriculture sector grew by 5.6% while the manufacturing sector grew by 10%, much higher than its 5 years' average and accounted for 16% of the total GDP. Growth in manufacturing was boosted particularly by the recovery in the construction sector, which grew by 14% and in 2019, the industry grew by 11.8%. The services sector grew by 9% mainly driven by a recovery in wholesale and retail trade while the continuing expansion of the air transport segment grew by 8.8% in 2019. In 2019, inflation increased on average by 2.0 (end November)

[6] EICV 5

and it is projected to increase to 5% by the end of 2020 and to remain the same over the medium term. The fiscal deficit in 2019 was 2%.[7]

The Agriculture sector in Bugesera District currently has very insignificant number of agro-processing industries. The ministry of commerce (MINICOM) works with agro-processors across varied Small and Medium enterprises (SMEs), dealing with coffee, maize, passion fruit, tomatoes and animal feeds among others. In its District Development Strategy (DDS) for the period of 2018 - 2024 framework, Bugesera District is aiming to promote the Bugesera Private Sector in order to cooperate and build their capacity with a view to valorising these kinds of opportunities in alignment with self-resilience and the *Kora Wigire* program and the "Made in Rwanda."[8] On the other hand, the agriculture sector in Musanze District is benefiting from a recently rehabilitated government-owned warehouse located in Cyuve Sector, which has a capacity of 3,500 Metric Tons (MT). There is also one Irish Potato Collection Centre located in Kinigi Sector.[9] In terms of social development, Rwanda's poverty indices dropped from 56.7% in 2005/06 to 39.1% in 2013/14 and is projected to reduce to 20% by the year 2020, calculated based on the Gini coefficient measure of poverty. The income inequality has decreased from 0.52 to 0.45 and Rwanda has incrementally transformed her strong growth into reduced poverty and improved equality amongst the citizenry.[10]All these are happening partly because of the government commitment to reduce poverty in collaboration with development partners.

Bugesera District population is estimated at 13.9% of the whole of Eastern Province population and forms 3.4% of the total Rwanda population.[11] Out of this 34.3% are poor and 20.1% are extremely poor.[12] The Vision 2020 *Umurenge* Programme (VUP) in Bugesera District benefited 2,430 households with almost 365 graduating from poverty.[13] The Bugesera District labor force participation rate was 57.1% while unemployment rate was 11.2%. The District level of job opportunities was at 58.6%.[14] The Bugesera economy is principally dominated by primary, secondary and tertiary sectors with very low production and productivity faced with various challenges. These ultimately constitute barriers to District's development and consequently contribute to Poverty.[15]

Musanze District population represents 3.5% of the total population of Rwanda and 21.3% of the population of Northern Province. The recent data from *Ubudehe* profiling projected an

[7]Sustaining the Momentum Rwanda's 2019/20 National Budget Bulletin, (Rwanda Budget analysis) June 2019 and http://www.minecofin.gov.rw/fileadmin/user_upload/Key_statistics_on_Rwanda_Dec_2019.pdf (p.16) (MINECOFIN -End June

[8]Bugesera DDS 2018 - 2024

[9]Musanze DDS 2018 - 2024

[10]Source: African Economic Outlook (AEO) 2019

[11]Rwanda Population and housing census 2012

[12] EICV4 Report

[13] Bugesera District Development Strategy (DDS) 2018 - 2024

[14]Labor force survey 2017

[15] Bugesera District Development Strategy (DDS) 2018 - 2024

increase from 368,267 in 2012 to 406,479 in 2018.[16] 53.6% of the Musanze District population is below the poverty line against 44.9% nationally while 24.1% is in extreme poverty line against 26.2% nationally. The District has increased and sustained graduation from core social protection programs for male and female-headed households by connecting them to economic opportunities and financial services.[17]

2.3.1.1 Private Sector Development

The Rwanda Private Sector Development Strategy (PSDS) of 2013 to 2018 aimed to redress the imbalance in private sector development and unleash Rwandan entrepreneurship. The PSDS is at the heart of the new Economic Development and Poverty Reduction Strategy (EDPRS-II), implemented from 2013 to 2018, and escalated to the Vision 2050 to help achieve the goals for growth, jobs, exports and investment. The PSDS provides an overarching framework for reform initiatives, helping to inform priorities and establishing a framework for monitoring progress and sets out the key gaps and weaknesses of ongoing efforts and how they can be addressed by the Government and other institutions. The PSDS aims to develop an entrepreneurial, innovative and competitive sector that delivers broad-based and inclusive economic growth resulting in many more and better-paid jobs for Rwandans.[18] The EDPRS-II's pillar on "Productivity and Youth Employment" on the other hand focuses on skills and attitudes, technology, entrepreneurship, access to finance and business development and labour market interventions. Entrepreneurship promotion can benefit from private sector delivery, which generally leads to better outcomes than delivery by public programmes.[19]

The PSTA4 projects that the private sector can contribute to the strategy in areas where there is a positive expected financial return. Through incentives and partnerships, they are expected to contribute up to 15% of the total PSTA4 investment envelope, increasing their share from 1% in the first year to 28% in the final year.[20]

The Bugesera District has a young population that is economically active, favored by proximity to Burundi border providing potential for improved economic activities. The District authorities allotted plots to investors at Nemba to build a trading center at the border besides the existing seven (7) main trading centers and at least a small trading center in each Sector, each with a modern market. This presents an opportunity for development of SMEs. Currently trade is developing, although the private sector is still very small and hence, its employability is still low.[21]

The private sector in Musanze District faces numerous challenges key among them being insufficient skills and innovation, minimal infrastructure (energy and transport) development, access to finance, market and supply chain gaps. Musanze District therefore needs to lay down

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[16] LODA February 2018
17 Musanze District Development Strategy (DDS) 2018 - 2024
18 Rwanda Private Sector Development Strategy (PSDS) 2013-18
19 EOCD 2013
20 Ministry of Agriculture & Animal Resources, Strategic Plan For Agriculture Transformation, 2018-24
21 Bugesera District Development Strategy (DDS) 2018 - 2024

concrete strategies to address the binding constraints towards private sector development. Even though the District serves as a tourist hub, tourism in the last five years was characterized by lack of diversity, poorly maintained infrastructures and an acute shortage of trained manpower in the hospitality sector.[22]

2.3.1.2 Youth Productivity and Employment

The number of unemployed young people globally is currently estimated at over 70 million.[23] Young people are more likely to work in the informal labour market, in jobs with limited economic security, few training opportunities and poor working conditions.[24] Young people typically face significant barriers to entering the labour market like mismatches between the skills and experience demanded by employers and general under preparedness for work, and minimal access to credit. Young people face additional barriers, such as age limitations on opening an account and low financial literacy in quest to accessing financial services.[25] There exist additional barriers in finding employment to youth population especially women living in fragile or conflict-affected environments, young people moving to urban areas and living in slums and the rural poor.[26]

The workforce to population ratio in Rwanda has remained almost stable between (84% and 86%) in more than 10 years from EICV2 to EICV5. The highest rate (86.6%) was obtained in EICV4 while the lowest rate was obtained in EICV2 (84%). The workforce to population ratio established in EICV5 (86%) has a little change as compared to the one of the previous EICV4 (86.6%). The stability in workforce to population ratio may be related to the population growth which kept pace with the increase in number of workers.

According to the Labor force survey 2017, Bugesera District labor force participation rate was 57.1% while unemployment rate was 11.2%. The District level of job opportunities was at 58.6%. The labour force for Bugesera District was low at 202,263 whereas the working age population that is economically active was 227,915. Labor force participation in the District was 57.1%, while unemployment rate was 11.2% based on their new definition. Bugesera District currently has 167,992 as the total working population (16 years and above) while the unemployed population is 903 and finally the inactive population is 35,528.[27]

In Musanze District, 82.4% of the population was employed, 2.2% was unemployed and 15.8% was inactive. For those with employment, 15% of them were working in wage employment in farms, 25.8% in wage non-farm work and 45.4 % were independent farmers. Unemployment rate in Musanze District was higher in urban areas (3.1%) than in rural areas (2.0%) and unemployment rate among females was higher than males (2.0% vs 1.9%). 64.1% of the youth

[22]Musanze DDP 2012/2013-2017/2018
[23] ILO, 2016
[24] Campbell collection, 2013
[25] UNCDF, 2016
[26] World Bank, 2012
[27] EICV4 – 2013/2014

were employed at the time.[28] Most of the youth aged 14-35 were self-employed (66.1%), and the salaried workers formed 22.4%. Those contributing to family duties were 8%.[29]

2.3.1.3 Urbanization and Rural Settlement

Urbanization is an on-going process in Rwanda. This is an opportunity for growth but also not always easy to implement due to limited resources and the nature of Rwanda landscape. The development of cities in Rwanda is very recent, and the rate of urbanization stands at about 18%. Although this rate is among the lowest in the world, the annual growth rate of the urban population is 4.5%, far exceeding the worldwide average which is 1.8%.

Almost half of the urban dwellers are concentrated in the City of Kigali, with about one million inhabitants. This monocephalic situation highlights the imbalance between urban centres within Rwanda.[30]

Bugesera District's EICV4 data show a clear move from the traditional isolated habitat towards *Imidugudu* or other clustered forms of habitat, which is in line with the policy. The report shows that 77.9% is an increase of the population who live in *Imidugudu* compared to 67.4% from EICV3. In addition, EICV4 shows that 12.9% live in Unplanned clustered rural housing compared to 19.1% from EICV3, 7.0% Isolated rural housing and this shows a decrease of 6.4% from EICV3, 1.8% live in Unplanned Urban Housing from EICV4 compared to 5.2% from EICV3, 0.4% live in Modern planned area.[31]

Musanze District data shows that 52.3% of households are living in settlements (*Imidugudu*) while 3.4% are living in unplanned clustered rural housing, 24.7% are living in isolated rural housing, and 5.6% are living in unplanned urban housing. These are far below the national achievements of 49.2%, 8.7%, 25.6% and 12.8% respectively. 97.7% of households are single house dwelling, 1.5% are multiple households dwelling, 0.6% are group of enclosed dwellings/multiple households and the rest 0.1% are group of enclosed dwellings (single households).[32]

2.3.1.4 Forest Resources

The Rwanda Vision 2020 and now Vision 2050 recognizes the social, economic and environmental deficits that Rwanda faces and as such, emphasizes development options that demonstrate how pro-poor sustainable use of natural resources, including prevention or mitigation of environmental degradation can help achieve development goals. The successive medium-term strategies and recent sector policies and strategies of all the 14 EDPRS sectors have since included environmentally sustainable options among policy priorities.[33]

[28] NISR, Fourth Population and Housing Census (PHC) Rwanda, 2012
[29] EICV4 – 2013/2014
[30] Ministry of Infrastructure Urbanization & Rural Settlement Sector Strategic Plan 2012/13-17/18
[31] Bugesera DDS 2018 - 2024
[32] Musanze District DDS2018 - 2024
[33] EDPRS I & EDPR SII

The Government of Rwanda (GoR) has committed to mainstream environment and climate change into national policies, plans and strategies. In that line, environment and climate change were identified as cross cutting issues in the EDPRS-II[34] towards achievement of the long-term Rwanda Vision 2020 and the SDGs.[35]

In its sector development strategies, the GoR aims at making forestry one pillar of the economic development. The Vision 2020 and the Vision 2050 fixed 30% of the national land area as the target to be attained in terms of national forest and tree cover through afforestation, reforestation (A/R) and improved forest management (IFM). This is to be accompanied by increase in production of wood for fuel and other uses while observing sustainability of forest ecosystems and plantations by adopting Mixed-species approaches to promote ecosystem resilience.[36]

High levels of poverty, population growth and density, land scarcity and competition, environmental degradation and overreliance on biomass/charcoal pose serious risks to the forestry sector in Rwanda. On the other hand, there is relative resilience demonstrated in the context of biophysical exposure and sensitivity by the forest and tree-based systems.[37]

Rwanda has a forested area of approximately 600,000 hectares which is about 22% of the country's land area with 260,000ha of natural forests and 340,000ha public and private plantations (productive forests).[38] The protected natural forests are *Nyungwe* National Park in the southwest and Volcano National Park in the northwest while national reserves include *Gishwati* and *Mukura*, the savannah and gallery forest of the *Akagera* National Park and remnants of gallery forests and savannas of *Bugesera, Gisaka and Umutara*.[39] National Forest Inventory (NFI) data indicates that the country has 2,102,508 hectares of forest resources, mainly domiciled in the Eastern, South and Western provinces with 8.9 million m^3 available for energy wood use.[40]

The Bugesera DDS 2018 – 2024 indicates that 2,800ha of forest cover has been planted, up from the initial 425ha with plans for further 895ha in the strategy period. Agroforestry tree planting is currently at 1,200ha with plans for another 893ha in the strategy period. Bamboo trees have been planted on 80ha in *Ngeruka* with plans for further planting of 13ha in *Mareba* and *Shyara*.[41]

The Musanze District DDS 2018 – 2024 indicates that 94.5% of land in the District will be protected from soil erosion, compared to 78.1% at national level. 29.7% of land surface is

[34] EDPRS 2013-2018
[35] REMA - Sectors Assessment Report for Environment and Climate Change Mainstreaming, 2013-2014 & 2014-2015
[36] Forests and Tree-based Systems Sector Working Paper (Smith School of Enterprise and the Environment) Appendix B, June 2011
[37] Ministry of Infrastructure Energy Sector Strategic Plan 2018/19 - 2023/24 September 2018
[38] Based on FAO's definition of a forest. This excludes agroforestry, a common land use practice in Rwanda
[39] Ministry of Infrastructure Energy Sector Strategic Plan 2018/19 - 2023/24 September 2018
[40] Rwanda Natural Resources Authority (RNRA), 2015
[41] Bugesera DDS 2018 - 2024

covered by forest and 28.6% is protected to maintain biodiversity. Watershed management is undertaken on the rivers *Mukungwa, Mpenge, Mutobo, Rubindi and Mukinga*.[42]
Multiple environmental, social and economic benefits (such as timber, fuel wood, charcoal, sticks for income and household use; soil fertility restoration, soil erosion control, and climate regulation, e.t.c.) afforded by forest and tree-based systems make possible the simultaneous achievement of reductions in vulnerability to climate risk and mitigation of the CO^2 emissions (Mukuralinda et al., 2016, Kiyani et al., 2017). To promote robust, long-term and high-return on investments, immediate and predictable support should be provided to community-based ecotourism, afforestation/reforestation and improved forest management, agroforestry, payments for ecosystem services and improved cook stoves.[43] The unavoidably crosscutting nature of natural resources demands greater levels of coordination, communication and sharing of technical resources.

2.3.1.5 Health and Nutrition

Regarding health and nutritional status in Rwanda, the Demographic Health Survey, DHS2015 revealed that nationally, 38% of children under age five (5) are stunted and 14% are severely stunted. The analysis by age group indicates that stunting is apparent even among children less than six (6) months old. Stunting increases with the age of the child, rising from 18% among children aged 6-8 months to a peak of 49% among children aged 18-23 months, before gradually declining to 37% among children aged 48-59 months. There is a difference in level of stunting by sex with 43% found among boys and 33% among girls. It also indicates that,49% of children born to undernourished mothers (BMI below 18.5 kg/m^2) are stunted compared to 40% of children whose mothers have a normal BMI (18.5-24.9 kg/m^2) and 29% of children whose mothers are overweight/obese.

The disparity in stunting prevalence between rural and urban children is substantial: 41% of rural children are stunted, as compared to 24% of urban children. In Bugesera District stunting was 39%, acute malnutrition one (1)% and underweight nine (9)% while in Musanze District, the stunted children represented 38%, one (1)% for acute malnutrition and seven (7)% for underweight.

2.3.1.6 Educational development

The Government of Rwanda's Vision 2020 and Economic Development and Poverty Reduction Strategy lay out ambitious plans to transform Rwanda into a knowledge-based economy by building a skilled workforce that is able to compete both regionally and internationally. Education is key to this transformation and Rwanda has achieved remarkable success in increasing access to education, with primary school net enrolment standing at 97%. Additionally, the USAID-funded *Akazi Kanoze* Workforce Readiness Curriculum was integrated into the national technical and vocational education and training system under the GoR's Workforce Development Authority.[44]

[42]Musanze DDS 2018 - 2024
[43] Forests & Tree-based Systems Sector Working Paper, Appendix B, June 2011, Smith School of Enterprise & the Environment
[44]https://www.usaid.gov/rwanda/education, 2020

The GoR has partnered with Microsoft in building "smart" classrooms across the country to bring computers, internet connectivity, and basic software packages to all of Rwanda's schools by 2020. This is in an effort to attain the country's priority development strategy of "science and technology education and ICT skills," emphasis on "vocational and technical training in the fields of technology, engineering and management" to develop human capital and turn Rwanda into a "sophisticated knowledge-based economy."[45]

In regards to education status, the percentage of population aged six years or older who have ever attended school is 87%, a common trend observed across all provinces as well as in rural areas and for both men and women. The net attendance ratio (NAR) for primary school children (age 7-12) remains stable 88%.[46] 23% of students in secondary school aged 13-18 attend secondary school at the appropriate age with 25% females and 21% males. The NAR for primary school is slightly higher among girls (88%) compared to boys (87%), while the literacy rate for men is 77.5% and 69% for women.[47]

School attendance and dropouts are key indicators for measuring the link between education status and households of students. Education statistics indicate that in 2017, nationally, dropout rate was 5.9% and attendance rate (NAR) was 98.3%. In Bugesera District, dropout rate was 9.6% for primary schools and 2.5% for secondary schools. In Musanze District, the dropout rate was 6.5% for primary school and 6.3% for secondary school. These indicators of health and education are the ones among many that can be adopted in explaining the level of poverty at household level.

2.3.2 Review of Agricultural aspects

The loss of yields in Rwanda is largely compounded by losses during post-harvest operations, losses caused by yield drying problems, microbial attack, pests and lack of adequate storage facilities. **Table 1** shows that crop losses vary depending on types of crops and causal agents. For example, AFR (2012) reported that, due to lack of drying houses, maize farmers were forced to dry their produce in farms where rains and pests caused post-harvest losses of up to 10%; whereas droughts caused yield losses of up to 30-40% depending on the severity.

Table 1: Crop risks and losses

Risks	Resulting losses					
	Maize	Tea	Coffee	Rice	Beans	Cassava
Lack of drying houses	10%	-	-	-	-	-
Droughts	30-40%	30%	50%	15-50%	50%	40%
Excess rains	-	-	20-50%	-	40%	-
Frost	-	60%	-	-	-	-
Floods	-	12-15%	-	25%	-	-
Pests: Red Mites	-	30%	-	-	-	-
Diseases	-	30%	-	30%	-	-

Source: AFR (2012)

[45] Education in Rwanda, October 15, 2019, Stefan Trines, Research Editor, World Education News Reviews
[46] EICV4 and EICV5
[47] Integrated Household Living Conditions Survey, EICV5 (2016/17), Main Indicators Report

The absence of high yielding varieties and improved breeds of livestock and insufficient access to credit for small crop growers dominated by women, may contribute to the afore-mentioned issues.[48] Despite all those mentioned problems, the Government is putting efforts which have resulted into an increase of 5% in crop production during the agriculture year 2018/2019 compared to the previous agricultural year (2017/2018). In the 2018/2019 agricultural year there was an increase of 5% of annual crop production comparing with the 2017/2018 agricultural year. There was a slight decrease of annual production for maize (-1%) and bean (-0.3%), while there was a great increase in annual production for paddy rice (15.5%) and wheat (16.4%) from 2017/2018 to 2018/2019 agriculture year.[49]

Although the agriculture sector still needs to grow to become a sustainable and environmentally friendly business, it plays a very important role in supporting food production. Indeed, this sector is closely linked with natural resources including: soils, water, plants, animals, e.t.c. The use of those resources in non-adequate ways has already yielded land degradation, yield decline and generally environmental degradation.[50] Indeed, agriculture is the backbone of the socio-economy of Rwanda and any sustainable environmentally friendly initiative for poverty reduction needs accurate information as a basis.

The agricultural sector remains the backbone of Rwanda's economy, and employs nearly 70% of the Rwandan population, mostly in smallholder farming. Because agriculture employs most of Rwanda's population, the performance of the sector has a significant impact on progress in reducing poverty. According to the findings from the EICV5, the reduction in poverty from 39.1%[51] to 38.2% that pushed a million of Rwandans out of poverty between 2005/6 and 2016/17, was driven primarily by agricultural interventions. The poverty reducing effects of agricultural development are particularly significant for women who constitute two-thirds of the total agricultural workforce.

In 2007, the GoR launched the flagship on Crop Intensification Programme (CIP) with the goal of increasing agricultural productivity of priority food crops under the PSTAI. Recognizing that low soil productivity was a major constraint to crop productivity, CIP prioritized improving the availability and access of fertilizers for farmers. To make the fertilizers affordable, subsidies were provided initially for maize, wheat, rice and Irish potato production. Fertilizer use was promoted among farmers through proximity extension services and the use of demonstration centers.

The country is still largely rural (85%) and dependent on agriculture; about one in four rural households live in extreme poverty. Poverty is a rural phenomenon in Rwanda, with 38.2% of rural residents living in poverty compared with 15.8% in urban areas.[52] Vision 2020 and now

[48]UNEP/ UNDP/ GOR Poverty and Environment Initiative Project (PEI), Pilot Integrated Ecosystem Assessment of Bugesera - 2007
[49]*NISR/Seasonal Agricultural Survey 2019, Annual Report*
[50] *Agricultural household survey,* Rwanda, *2018*)
[51] (EICV4)
[52] Integrated Household Living Conditions Survey, EICV5 (2016/17), Main Indicators Report

Vision 2050 seeks to transform Rwanda from a low-income, agriculture-based economy into a service-oriented economy by 2020.[53]

In supporting farmers to increase agricultural productivity, the Strategic Plan for Agriculture Transformation 2018-24 (PSTA4) was elaborated to foster economic growth and to create productive, poverty-reducing jobs for youth, both on and off farm. The PSTA4 Strategic Results Framework has been built to incorporate key indicators reflecting commitments and ambitions of the agriculture sector towards various global, continental and national processes, notably the SDGs, Malabo and the NST. Efforts have also been made to optimize alignment and avoid proliferation of indicators to be reported on in the agriculture sector. In the Strategic Framework, the selected impact areas are aligned to four (4) Comprehensive Africa Agriculture Development Program (CAADP) impact areas: i) increased contribution to wealth creation, ii) economic opportunities and prosperity - jobs and poverty alleviation, iii) improved food security and nutrition, and iv) increased resilience and sustainability. The corresponding impact indicators used are to greatest extent aligned to the various commitments.

Specifically, the agriculture sector is planned to contribute to the achievement of several SDGs, particularly: SDG1 (end extreme poverty), SDG2 (zero hunger, improved nutrition, and sustainable agriculture), SDG8 (decent work and economic growth), SDG13 (climate action) and SDG15 (terrestrial ecosystems, forests, and land); Moreover, the PSTA4 aligns to the EAC Vision 2050 of Increased investment and enhanced agricultural productivity for food security and a transformation of the rural economy.

Through its Intended Nationally Determined Contributions (INDCs) on agriculture, Rwanda is backing its commitment to the 2015 Paris Climate Change Declaration. Planned project interventions in agriculture are closely aligned with the NST1 and follow the EDPRS – II[54] and intended to be implemented up to the last years of Vision 2020 and the first four years of the Vision 2050. Despite impressive growth in agriculture production over the past 10 years, food security and nutrition remain key concerns. PSTA4 adopts a food systems approach for enhanced nutrition and household food security.

The strategy proposes approaches and interventions to ensure that the nutrient quality of commodities is preserved or enhanced throughout the entire Value Chain (VC). In addition, resilience and risk mitigation strategies will continue to be developed, particularly at the household level. PSTA4 postulates that the share of agricultural land under Sustainable Land Management practices will shift from 56% in 2017 to 83% in 2024. These are projected to be achieved through Innovative research on crop improvement and husbandry technologies, Efficient and sustainable use of inputs; Productive alliances, Development of Public Private Partnerships (PPPs) and alternative models where Women and youth access decent employment or substantive income-generating activities in the rural areas. This action requires specific attention and tailored approaches in skills development and training.

[53] https://www.ifad.org/operations/country/Rwanda
[54] EDPRS II, ended in June 2018

It is in this line that farmers' organizations, unions and commodity associations are central to achieving sustainable and inclusive agricultural development. They need to develop into well-organized, well-managed financially independent institutions, able to provide services to their members, to exploit economies of scale for improved bargaining power and to engage in (policy) dialogues with other stakeholders. Substantive Income-Generating Activities (IGAs) in the rural areas require specific attention and tailored approaches in skills development and training.

The PSTA4 promotes developing soil and water conservation as part of integrated watershed management programmes, considering that the most successful approaches are those involving local communities, especially in reconciling the use of crop, livestock, and trees. PSTA4 also encourages the use of a wide range of cost-effective erosion control measures, whereas the focus in previous strategies was mainly on terracing.

Climate Smart Agriculture (CSA) – involves both on-farm measures but also supporting and enabling actions (as described in PSTA4). It has the potential to increase productivity, build resilience to current climate variability and future climate risks and reduce greenhouse gas emissions. These include inter-cropping, cover crops, conservation agriculture (particularly reduced or zero tillage, maintaining crop residues/mulching and crop rotation), crop residue retention, use of improved vegetated fallows and crop rotation. PSTA4 foresees widespread training of farmers in CSA practices to improve adoption rates. The Agricultural Development Fund provides incentives, under the Productivity Window, for private sector investment in climate resilience.

In Bugesera District Agriculture is the main economic activity, the leading sector in the District and provides nearly 79% of employment to the District's population. The key crops cultivated include food crops (*maize, beans, sorghum cassava, bananas, different types of fruits and vegetables*) and cash crops (*coffee, Macadamia, Horticulture and Green beans*). In Musanze District Agriculture is the lifeblood of the District. At least 91% of the population is engaged in agriculture. Musanze is considered to be the granary of Rwanda. Agricultural products for this District include coffee, tea, pyrethrum, wheat, bananas, beans, sorghum, macadamia and potatoes. There are two large factories for pyrethrum and a wheat plant.

In the agriculture sector, very small land sizes (*averaging 0.4 ha*) and challenges of demographic pressures to maximize on returns is predominantly seen. The Land use (national Level) SAS 2019 results estimate agricultural land at 1.4 million hectares (59% of total country land), from which 1.14 million of hectares was arable land. In 2018/2019 agricultural year the physical crop cultivated land was 1.1 (79% of total agricultural land), and increased by 16.8 % comparing to the 2017/2018 agricultural year. Out of the physical cultivated area, one (1) million hectares was used for seasonal crops while 0.5 million hectares of land was under permanent crops. Crop yield (National Level as indicated by SAS 2019 results), the annual average yield for main crops in Rwanda were: 1.46 t/ha for maize, 0.99 t/ha for sorghum, 4 t/ha for paddy rice, 1.19 t/ha for wheat, 14.8t/ha for cassava, 6.78/ha for sweet potato, 9.05t/ha for Irish potato, 6.10

t/ha for yams and taro, 18.04 t/ha for cooking banana, 12.79 t/ha for desert banana, 8.67 t/ha for banana for beer, 11.77 t/ha for banana as whole, 0.83 t/ha for beans, 0.62 t/ha for groundnuts, 0.53 t/ha for pea, 0.53 t/ha for soybean, 10.39 t/ha for vegetables and 6.37 t/ha for fruits.[55]

The Rwandan agriculture sector continues to face the following major challenges:

- Climate change and high dependency on rain fed agriculture,
- Land scarcity, soil erosion and land degradation,
- Domination of production by small farmers with low productivity,
- High level of post-harvest losses,
- Low value addition,
- Limited rural infrastructure with high costs and limited access to markets,
- Low quality, quantity, and high costs of raw materials and inputs,
- Limited access to agricultural services credit and control of resources by women,
- Limited sector innovation and use of new technologies, and
- Limited private sector investment due to perceived high risks in agriculture.

2.3.2.1 Analysis of the agriculture sector

This section outlines existing information with regards to agriculture development indicators as found in a number of reports including EICV4 and 5, District profile for Bugesera and Musanze, (2011) and Agricultural household survey (2018). The excerpts below give an overview of the situation.

- **Percentage of households who engaged in different agricultural activities**

  With regards to the mentioned parameters and referenced studies, the percentage of households involved in agriculture business production, crop production and livestock in the Eastern province were 85.6%, 84.3% and 64.2% in that order. This demonstrates that most of the people are dealing with both crop and livestock production as shown below. Indeed, small percentages of people dealing exclusively with crop production (24.9%) or livestock production (1%) were found. It is however important to mention that involvement in crop production was almost 25 times higher than that of livestock production. Rather, 74.1% of households were busy with both crop and livestock production.

  By comparing these results with those of the national means, it was clear that the values from the Eastern province were lower than national ones for households dealing with livestock alone and both crop and livestock. This was the opposite when considering households dealing with crop production alone. The percentage of 85.6% of people involved in agriculture sector in Eastern province implies that any sustainable development shall be focused on agriculture.

[55]NISR/Seasonal Agricultural Survey 2019 Annual Report

- **Percentage of agricultural households' population by sex and education level in the Eastern Province compared to the whole country**

The EICV5 indicates that the proportion of working age population without any level of secondary education that had jobs was around 90% while the proportion of those with a lower secondary school education level was around 57% and the upper secondary school graduates was 76%. The proportion of university graduates who carried out any economic activity during the last 12 months was 75%; lower than the proportion with low level of education or unskilled population and higher than that of middle skilled people. Between EICV4 and EICV5 there was a visible increase of working level among lower secondary school graduates from 52% in EICV4 to 57% in EICV5.

It was reported that in the Eastern province more females (52.2%) were involved in agriculture production than males (47.8%). Those percentages were close to the means calculated for the entire country (female: 52.8%, males: 47.2%). In the Eastern province, the percentage values for non-educated, primary level, secondary level and tertiary level were 23.9%, 57.2%, 17.4% and 1.5%. In the Northern Province, the percentage values for non-educated, primary level, secondary level and tertiary level were 29.5%, 52.9%, 16.0% and 1.5%. Percentage of non-educated households were higher in the Northern Province than in the Eastern province. The percentages for primary and tertiary levels were higher in the Eastern than the Northern provinces.

The analysis of workforce to population ratio by level of education reveals that ratios were higher among low education level groups as compared to those who are highly educated.

- **Percentage of agricultural households' size (3 persons, 5 and more persons) and laborers aged from 16 and above in the Northern and Eastern provinces**

According to the United nations (UN, 2017), the household, defined as a group of persons who make common provision of food, shelter and other essentials for living, is a fundamental socio-economic unit in human societies. Households are the centres of demographic, social and economic processes. Decisions about childbearing, education, health care, consumption, labor force participation, migration and savings occur primarily at the household level. Understanding the trends and patterns of household size and composition can thus inform efforts towards the achievement of the 2030 Agenda for Sustainable Development.

The presence of children in the household has major implications for a household's priorities, particularly with respect to the demand and allocation of resources for education and health care. In countries of Africa and Asia a substantial majority of households (more than 80%) include at least one child less than 15 years of age.[56]

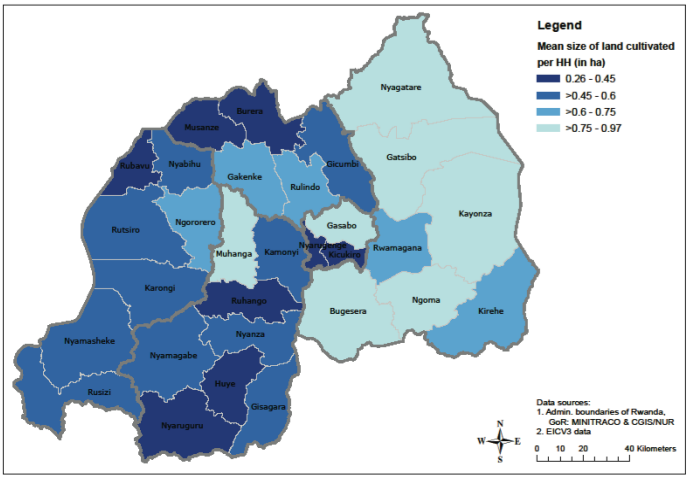
According to the mentioned report, in the Eastern and Northern Provinces, households with three (3) persons were 17.9% and 18.5% respectively. The same report shows that in the

[56] United Nations, Department of Economic and Social Affairs, Population Division (2017). Household Size and Composition Around the World 2017 – Data Booklet (ST/ESA/ SER.A/405) p1, ,p6

Eastern and Northern Provinces households with more than five (5) persons were respectively: 47% and 41.9%. The percentage of male laborers in the Northern and Eastern Provinces were respectively: 41.4% and 37.7%.

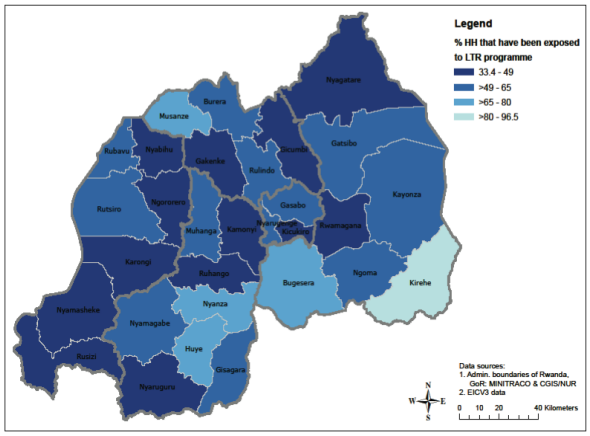
- **Agriculture sector parameters: Comparison of Bugesera and Musanze to other Districts (Mean farm size per household/ Ha)**

Map 1: Mean farm size per household (Ha)



Generally, the size of cultivated land in Rwanda per household is very small. It ranges from 0.26 to 0.9ha. Musanze District comes among those having the lowest household land size due to the high population density while Bugesera is generally listed among Districts having the largest farm land sizes as shown in the ***Map 1***. It is noted that despite the generally relatively large land size cultivated in Bugesera, some crop growers use less than 0.3ha. However, Bugesera has only 30% of growers using 0.3ha while Musanze has 50% of growers using less than 0.3ha of land.

Map 2: Districts that have benefited from LTR



It is important to note that the land reform through Land Tenure regularization (LTR) has generally positively influenced agriculture production as it provides land security ownership and this has enhanced more investment on land. The ***Map 2*** shows that the Districts of Musanze and Bugesera are among those which have benefited from LTR at a relatively high rate.

A study by Melesse and Bulte (2015) in Ethiopia found robust agricultural productivity following the land registration and certification process that was initiated in 1998. They compared the productivity of certified plots with uncertified plots. Using the propensity score matching approach, the productivity of certified plots was found to be 35.4% higher than uncertified plots, with an annual income gain of US$75.40. Other literature also highlights cases where LTR resulted in improved agricultural productivity and income.

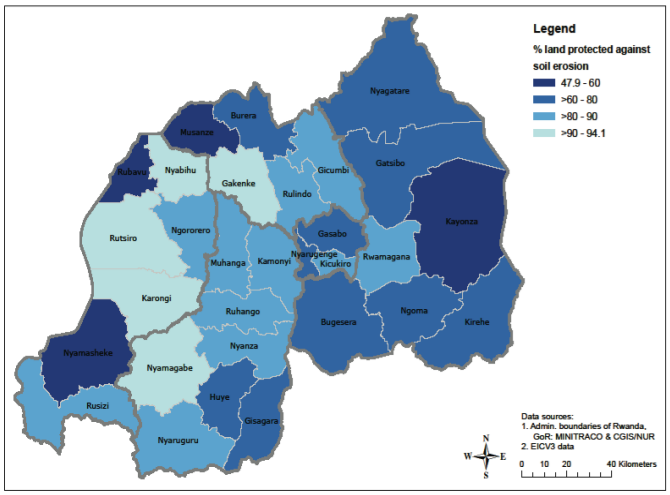
The same report by NISR (2015) shows that crop sharing has increased slightly at the national level from 6% to 7.7%, and cultivable plots affected by land use consolidation programs have increased from 22% to 30% during the same period (2011-2015). It is worth noting that poverty has declined from 56.7% in 2005/6 to 39.1% in 2014/15; access to medical services has improved with a high prevalence of health insurance holders currently estimated at 70% (up from 43.3% in 2005/6) and an average of 56.6 minutes taken to the nearest health centre (NISR, 2015).

The same study by Bizoza revealed that 80% of survey respondents felt they had tenure security even before land titling since the majority inherited the plots from their fathers. The conclusion was that the analysis of the impact of tenure security on farmers' decision to invest in soil and water conservation should be analysed with caution, especially in developing countries similar to Rwanda.[57] Accordingly, the question of whether formal or traditional land rights are conducive to long-term investment should be considered site-specific and open to empirical debate in Rwanda.[58]

Map 3: Percentage of Agricultural households spending on chemical fertilizers

The **Map 3** presents the percentage of agricultural households incurring expenditure on chemical fertilizers by District. In Bugesera 13.2% of households incurred expenditure and also applied chemical fertilizers on their land while 4.0% applied organic fertilizer out of the 89,000 households that practiced agriculture.[59]

In terms of the percentage of agriculture households purchasing input in Musanze District, the utilization of pesticides (51.9%) and chemical fertilizers (46.5%) is much higher than that of improved seeds (13.8%) and organic fertilizers (13%). Furthermore, the purchase of chemical fertilizers and pesticides in Musanze District is significantly higher than the national average (29% for chemical fertilizers and 31.2% for pesticides).[60]



[57] Bizoza A.R. (2015). Soil Erosion Control and Land Tenure Regularization in Rwanda: A historical Perspective. The "2015 World Bank conference on Land and Poverty" The World Bank - Washington DC, March 23-27, 2015.;
[58] Khama S., & Kayitesi E., Land Tenure Regularization in Rwanda: Good practices' in land reform., Africa Development Group, 2016, p.25, 26, 28
[59] Source: EICV4, 2014
[60] Musanze District Development Strategy (DDS) 2018 - 2024

2.4 Assessment of the climate vulnerability in Rwanda

A study conducted by REMA and supported by the Ministry of Environment in 2018 surveyed all the Districts in the entire country to provide data, with a view to help develop plans to deal with climate change mitigation and adaptation. The results of the study in the Districts of Bugesera and Musanze highlighted the following findings:

- The Exposure Indicator (EI) for Musanze District was 0.378. This value was lower than the average of the province 0.389. Musanze District came in the 4th position in having a small EI in the Northern Province. The Sensitivity Indicator (SI) for Musanze District was 0.364 and was lower than the average of the Province, which was 0.394. Musanze District had the lowest SI compared to the other Districts in the Northern Province. The climate change impact in Musanze District was 0.371 and this value was lower than the average impact of the Province, which was 0.392. The Adaptive Capacity of Musanze District was 0.464 and this value was lower than the average of the Province. The vulnerability index of Musanze District was 0.452, slightly lower than the average of the entire Province, which was 0.460.

- The Bugesera District indicated an EI of 0.395, comparatively lower than the average of the entire Eastern Province at 0.368. Bugesera District was 2nd in having a high EI in the Eastern Province, with an SI of 0.356, comparatively lower than the average of the Province at 0.371. Bugesera District was 3rd in having low value for S.I. in the entire Eastern Province with impact indicated at 0.376, a figure comparatively higher than the average impact of the Province, which was 0.370. Bugesera District was in 4th position among the seven (7) Districts in the Eastern Province, indicating impact at 0.376, a value comparatively higher than the average impact of the Province, which was 0.370. In terms of Adaptive Capacity, Bugesera District indicated 0.387, figure almost equal to the average adaptive capacity of the entire Province, which indicated 0.388, placing it in position three (3) among the seven (7) Districts in the Eastern province.[61]

2.5 Environmental protection in Rwanda

The poverty environment linkages are obvious in Rwanda and more specifically in the Bugesera and Musanze Districts. Indeed, report from UNEP in 2011 highlighted that Rwanda was facing extreme gravity of soil erosion problem, with a rate estimated at between 50 and 100 tons per Ha per year. In addition to that, Nabahungu (2013) reported that the relatively high soil erosion rate is linked to the poor conditions of soil and water conservation infrastructures. Therefore, soil protection shall be a priority to ensure sustainable development.

In terms of Environment, PSTA4 recognizes that changes in weather and climate patterns are becoming more acute, and subsequently seeks to build resilience through on-farm measures and enable actions to increase productivity. PSTA4 emphasizes alternative land management to complement terracing with comprehensive climate smart soil and integrated watershed management. PSTA4 also introduces better weather and climate information and early

[61] REMA, 2018: Assessment of climate change vulnerability in Rwanda

warning, and seeks to ensure all investments are climate smart, together with the National priorities for low-emission and climate-resilient development.

The National Adaptation Plan of Action (NAPA) submitted to the UNFCCC in 2007 articulated Rwanda's strategy to reduce vulnerability to climate change particularly from the main climatic hazards. The main NAPA priority addressed by the proposed project is the promotion of "non-agricultural income generating activities" which is considered critical to strengthen resilience of rural communities to climate threats. Moreover, Rwanda's Nationally Appropriate Mitigation Actions (NAMA -2015) established an institutional, legal and policy framework for NAMA.

2.6 Scaling up of ENR and poverty interventions

Scaling up refers to "expanding, adapting and sustaining successful policies, programs and projects in different places and over time to reach a greater number of people." Scaling up entails deepening of a development impact, reaching out to those 'left behind' and ensuring the sustainability and adaptability of results and not just about replicating successes to cover larger groups or populations.[62]

Hartmann and Linn (2008b) conclude that change agents need to systematically review their operational policies and approaches to scaling up.

This chapter has highlighted existing information of the ENR in the two Districts. Based on this information, identified gaps shall be taken into account in the chapter III where updated methodologies are proposed and explained to add value to the existing information.

[62] Scaling up Local Innovations for Transformational Change, UNDP 2011

CHAPTER III: APPROACH AND METHODOLOGY

This chapter highlights the approach and methods the consultants used for gathering all the important information that was subsequently utilized for data analysis. The consultants applied universally accepted research standards in a quest to establish the linkages of MPI and ENRs indicators in Bugesera and Musanze Districts.

3.1 Proposed approach

The approach adopted by CIBA for this assignment was guided by and anchored on participatory processes and focused to meet the requirements of the Terms of Reference (ToR). The consultants used multiple approaches to collect both qualitative and quantitative data. The planning process was participatory and well documented to ensure accurate and timely execution. The execution of the assignment followed the agreed upon working tools approved by the REMA/UNDP teams. CIBA documented and reported on the implementation of the different work streams as part of our accountability promise. In addition, each of the phases and deliverables were subjected to intense quality review in line with our internal quality review mechnisms. Research VISA and necessary clearances were obtained from NISR with keen support from REMA and partners. NISR further granted the consultants express permission to collect data that was unavailable in the EICV5 data base from primary sources, for instance anthropometric measures, education e.t.c.

3.1.1 Approach for assessing ENR-Poverty linkages

The following table summarizes the stages the consultants deployed to gather all information used to respond to the objectives of the three surveys in this assignment:

Table 2: Steps in assessing the ENR-Poverty linkages

I. Baseline on multi-dimensional poverty assessment in the two Districts	
1.1	In depth review of existing documents
1.2	Consultations with main stakeholders at REMA and at District levels
1.3	Existing multi-dimensional poverty levels and localization
1.4	Data sources, gaps and identification of challenges
1.5	Assessment of ENR sustainability and climate resilience due to existing interventions
1.6	Assessment of key activities in relation to poverty environment interventions
II. Proposed sustainable interventions in Bugesera and Musanze Districts	
2.1	Identification of interventions contributing to poverty reduction and ENR conservation
2.2	Identification of District priority geographical areas to improve pro-poor ENR
2.3	Identification of synergies for collaboration in implementation of ENR projects
III. Needs assessment and Capacity building	
3.1	Identification of available and needed capacity and tools to implement ENR interventions
3.2	Synergies and approaches for capacity building on ENR integration in District plans
IV. Prepare Scale-up and implementation plan to other Districts	
4.1	Preparation of narrative report of key findings relevant to scaling up
4.2	Preparation of a scale-up implementation strategy
4.3	Prioritization of the likely and most cost-effective interventions for reducing poverty
4.4	Identification of toolkits assisting to identify, implement and monitor interventions
4.5	Identify institutional framework for scaling up at District level

3.2 Methodology

In the execution of this assignment, the consulting team was guided by the scope of work highlighted in the ToR. The methodology is a reflection of the common understanding of the objectives and requirements for the assignement in terms of establishing the Environment and Natural Resources and poverty linkages with reference to the requirements of the ToR. The consultancy team applied universally accepted research standards with a view to development of international best practice documents for REMA/UNDP and partners.

The consultants employed triangulation and mixed methods and tools for data collection such as Desk reviews, Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). Assignment delivery and completion strategy included revision of draft reports after consolidating feedback from all key stakeholders.

3.3 Research design

The consultants adopted a **Mixed Methods Approach**, using both **quantitative and qualitative tools** for data collection from the farmers and households in the two Districts of Bugesera and Musanze to facilitate analysis and triangulation. The key methodologies utilized for the assessment of the Multi-dimensional Poverty Environment in this baseline study included:

a. **MPI Methodology**
b. **ENR Methodology**
c. **Combined ENR - MPI Methodology**

3.3.1 Sampling Design

The survey team initially selected 16 clusters Enumeration Areas (EAs) and designated them independently with probability proportional to the EA's measure of size in the selected two Districts. In the selected EAs, a listing procedure was performed where all households were listed. This procedure was important for correcting errors existing in the sampling frame, and provided a sampling frame for household selection. The second stage involved equal probability systematic sampling of 24 households within each of the selected EAs. Eligibility criteria were: 1) being a Rwandan citizen residing in Rwanda, 2) being household with 18 to 65 years old of Head of household 3) living in the East African (EA) region at least in the last 5 years.

3.3.1.1 Primary data unit

The sample was selected in two stages: at sector (cluster) and household levels. 16 clusters were selected and among them 32 villages (2 villages by cluster) were selected using random sampling. 455 households with 2,109 members with ages between 18 to 65 -years old were reached for the survey. The Primary Sampling Unit (PSU) was the village (*Umudugudu)*. Enumeration areas (EAs) for each District were split into urban and rural EAs and the listing compiled from households of selected EAs. The listings served as sample frame for the simple random sections of households. Clusters were determined based on the geographical location. In every District eight (8) clusters were selected and in every cluster two (2) villages were selected.

3.3.1.2 Analysis Unit

The unit of analysis, meaning how the results were analysed and reported, was the household. This meant that, for instance, the headcount ratio was the percentage of people who were identified as poor, rather than the percentage of households that were identified as poor. In order to determine the sample size, the formula below was applied: $\boldsymbol{n = \frac{p(1-p)}{e^2} * deff^2}$: whereby: CL: z = 1.96 for 95% confidence level: The percentage of all possible samples that can be expected to include the true population parameter. Deff = design effect (1.19): inflates the variance of parameter estimates, the standard errors, which is necessary to allow for correlations among clusters of observations (reduce the effect of livelihood). p= probability of being selected (p) = 0.5, p = Probability of not selected (q) = 0.5. e = Margin of error (5%): statistic expressing the amount of random sampling error in the results of a survey, n= Minimum sample size. By applying the formula below:

$\boldsymbol{n = \frac{0.5(1-0.5)}{0.05^2} * 1.19^2}$

the survey set to cover **450 households**, as populated in the

Table 3:

Table 3: Sample distribution

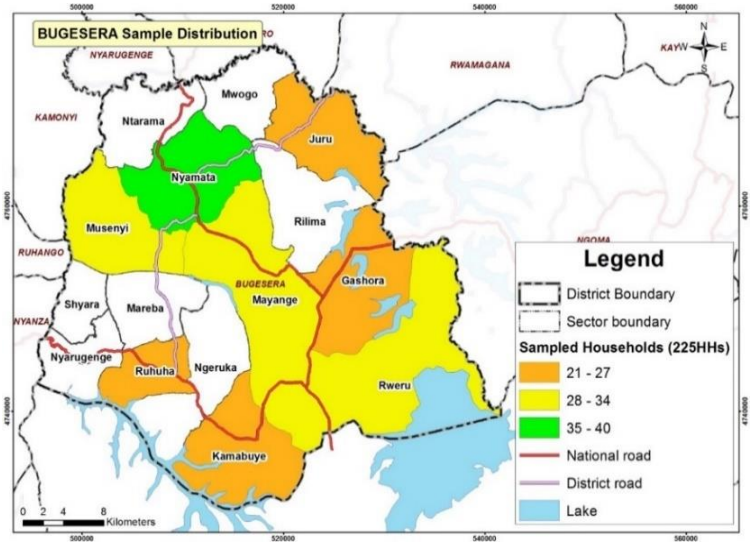
Province	District	Population[63] (Household)	Sample
Eastern	Bugesera	90,607	225
Northern	Musanze	94,523	225
Total		**185,130**	**450**

Source: PEA baseline study, 2020

With a population size of 185,130 household residents of the two (2) target Districts, confidence level of 95%, margin error of 5% and probabilities of selecting respondent (p=50%, q=50%), the sample size calculator provided a minimum sample size of 450 households in the case.

[63] District Development strategies (DDS 2018-2024), District Profiling, LODA, Report 2019

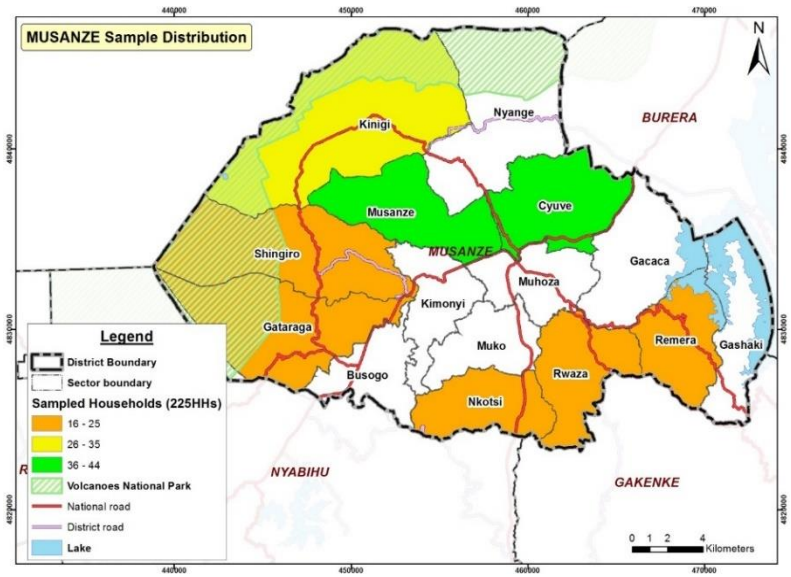
Map 4: Sample distribution Bugesera District



In Bugesera District the survey team selected eight (8) clusters and in every cluster two (2) villages were selected. This sampling frame considered the geographical features and ecological zones within Bugesera District, including Lakes (Gashora, Rweru, Kamabuye, Ruhuha), plain lands, dry-lands, valleys, wetlands, marshlands, hills, tourism zones (Nymata, Gashora), urban (Nyamata, Mayange) and rural settlements (Musenyi, Shyara and Juru).

Source: PEA baseline study, 2020

Map 5: Sample distribution Musanze District



In Musanze District the survey team selected eight (8) clusters and in every cluster two (2) villages were selected. This sampling frame considered the geographical features and ecological zones within Musanze District, including Lakes (Remera sector), plain lands, dry-lands, valleys, wetlands, marshlands, hills, tourism zones and volcanic features (Kinigi, Shingiro, Gataraga), urban (Musanze and Cyuve) and rural settlements (Rwaza and Nkotsi).

Source: PEA baseline study, 2020

3.4 Data collection techniques

A mixed methods triangulation design was applied consisting of one phase where both qualitative and quantitative methods were concurrently used. The execution of this baseline study followed a collaborative and participatory approach and ensured close engagement with all key stakeholders at different levels. Data was collected through quantitative survey (a combination of household surveys, vulnerability assessment and geographical co-ordinates tools), qualitative survey Focus Group Discussions (FGDs), Key Informant Interviews (KIIs), desk review including Methodology for soil investigation sources and observation. ArcGIS version 10.7 was also used to produce various maps in this study.

Quantitative Survey: The consultants developed a structured questionnaire based on the ToRs and objectives comprising of vulnerability assessment and combination of household tools (ENR – MPI). The tools were translated into Kinyarwanda (local language). Both paper-based and electronic questionnaires were reviewed by the technical team and further translated to check quality and accuracy. A back-check questionnaire was additionally developed for quality control and submitted for review. The following are the detailed discussions on the tools used to gather data from respective sources: The questionnaire focused on four key sectors (1) Socio-economic information; (2) Environment; (3) Natural Resources and (4) Agriculture.

Qualitative Survey:
Focus Group Discussions: The consultants conducted 16 FGDs in total with targeted beneficiary farmers and groups to explore in-depth key issues relevant to understanding of the baseline scenario. The targeted groups included Women, Youth (boys and girls), Men and local leaders. For each targeted group sampled, an FGD session was conducted with discussants numbering between 8 and 12, lasting between 45 to 60 minutes. The information was captured on sustainable agricultural practices, gender dynamics, natural resource use, adaptive capacities and understanding and practices on climate change and disasters. The team used semi-structured interview guide to direct the FGDs.

Key Informant Interviews (KIIs): At the inception phase, the team conducted stakeholder mapping to identify suitable individuals and institutions from which to extract expert views and data on indicators identified from the literature gaps and the baseline framework. The team interviewed existing community structures (various committees), project staff, other CSOs, Gender officers, Local Authorities and government officials and Cooperative/MFI leaders/officials as key informants in the study. The team used semi-structured interview schedule to drive the KIIs in documenting success stories on management and policy issues, impediments and lessons learned from the poverty alleviation actions, agriculture and trade sectors at local and National levels (drawn from Government departments, service providers and Private sector).

Observation*:* the team prepared an Observation Record Sheet specifically for institutions, in form of a notebook with a check-list of items that were observed without the need to ask questions. Probe questions followed observations made and duly noted.

3.5 Data analysis

Quantitative data from the field was exported into Statistical Package for Social Science (SPSS) and STATA software which were used for data cleaning and analysis. The report comprises of pictures, graphs, diagrams, narrative analysis, and other inferential statements that sufficiently extrapolated the prevailing performance of selected indicators against the baseline survey.

3.6 Quality assurance and ethical consideration

The recruitment process for data collection teams was conducted taking into account the following four different categories of expert personnel CIBA normally deploys for quantitative/ qualitative data collection/supervision, and quality check. These are (i) supervisor and (ii) enumerators. Field staff were trained and best performers during the training were retained after a series of assessments, while others were used as backups just in case there was an issue with the staff in the core team.

Training of data collectors was conducted based on the training manual, paper version questionnaire and electronic version. The key steps or activities were theoretical and practical sessions, mock interviews, piloting or pre-testing the questionnaire, and evaluation. The first **two** days concentrated on understanding the training manual and the protocol used for complete survey cycles (theoretical class teaching). The theoretical class teaching included in-depth review where we went through the paper-based questionnaire and finally use of tablets. Electronic trainings were followed by mock interviews (between two field teams) which helped them understand the context of the research followed by appropriate changes/suggestions.

The digital data collection approach was based on the *Kobocollect* platform. In addition, this system helped monitor the GPS locations and progress of the interviews as well as assisting in building multimedia-rich nature mapping tools.

The relevant clearances and permission from the relevant authorities in the two Districts of study were granted and presented to the local leaders. REMA and partners helped the consultants to secure necessary clearances including research VISA from the NISR.

3.7 Detailed methodologies

This sub section discusses the details of the three methodologies applied in this study:

3.7.1 MPI Methodology

The MPI is designed to measure poverty level. It follows the Alkire and Foster (2007, 2011) methodology. The consultants designed Multidimensional Poverty Assessment Tool (MPAT) to measure poverty level in the households.

Multidimensional Poverty Assessment Tool (MPAT) presented data that informed all levels of decision-making by providing a clearer understanding of rural poverty at the household and village levels. The study used purpose-built surveys to gather data on people's perceptions regarding fundamental and interconnected aspects of (1) food and nutrition, (2) domestic water supply, (3) health and health care, (4) sanitation and hygiene, (5), housing, clothing and energy, (6) education, (7) farm assets, (8) non-farm assets, (9) exposure and resilience to shocks, (10) gender and social equality. The data was then combined, distilled and presented in an accessible format through standardized indicators, developed through a comprehensive participatory process.

The tool collected a variety of data through the MPAT Household survey and then organized it using the ten (10) MPAT dimensions listed above. For the MPI, all the information for each component must come from the household's perceptions[64].

3.7.2 ENR Methodology

The ENR methodology is designed to identify both who is poor and how they are poor. The consultants combined five different sources and processes for ENR data collection and analysis that included a) Desk review; b) household surveys; c) Methodology for soil investigation; d) qualitative survey and; e) vulnerability assessment as detailed below:

a) ***Desk Review***:

Secondary data from experimental, quantitative and qualitative researches with the results of a combined household survey (MPI – ENR) helped the consultants to compute the ENR – MPI deprivation weights.

The consultants analyzed relevant project documents, theory of change (ToC), project Log-frame, quarterly reports and other baseline survey reports and studies on Multi-dimensional Poverty Environment in Musanze and Bugesera Districts, EICV sources, NSTAs, Rwanda Vision 2020 and 2050, RAB experimental studies, REMA reports, Environmental Mainstreaming Strategy, Green Growth and Climate Resilience report, Rwanda Poverty Assessment 2015, Fourth Population and Housing Census (PHC), Rwanda, 2012, Demographic Health Survey (DHS) 2015, District Development Plans (DDPs), District Development Strategies, Unpublished reports from Districts, UNDP publications and other such studies conducted at Global, Regional and National levels. Data collected included gender, disability and youth considerations, agricultural production and productivity and other relevant project indicators, key data obtained from assessment reports, other baseline and evaluation studies and poverty reports conducted in Rwanda.

b) **Household survey:** This was conducted to measure the household members' perceptions on environmental natural resources specific observations on Soil (soil fertility and soil erosion), water (ground water quality, quality of harvested water, water quality in lakes and rivers), Forest, Minerals and stones.

c) **Methodology for soil investigation**: Before computing the values of different soil parameters, the Food and Agriculture Organization (FAO) soil reference groups of Bugesera and Musanze Districts were extracted from soil database of Rwanda using updated information from Batjel (2007) and Verdoo & Van Ranst (2006). The soil reference groups were used for the developement of soil data using updated techniques of data extraction. The following soil properties (pH, Bulk density, CEC, Total Organic carbon, Total Nitrogen, Total phosphorus, Available phosphorus, Extractable Potassium, Exchangeable Potassium and Exchangeable aluminium) were extracted and computed

[64] Oxford Poverty & Human Development Initiative (OPHI), Oxford Department of International Development Queen Elizabeth House (QEH), University of Oxford

from Africa soil information system AfSIS-ISRIC as described by Heng et al. (2015). ArcMap version 10.5, a spatial analytical tool that uses a technique called zonal statistics was used to combine the information of Rwanda database and AfSIS to produce the soil dataset for Bugesera District and Musanze (Heng 2015).

The dataset was used to compute the fertilizer recommendation for Maize, Coffee and Cabbage in the two Districts as shown on Appendices (Fleischel *et al*., 2014). Using this technique , the consultant established the soil status of Musanze and Bugesera Districts for 2020 (see **Appendix 6).** The three crops were selected on the basis of the following factors: Coffee is an environmentally friendly crop in Eastern Savana and in highland. Coffee is a cash crop of priority in the country. Maize is a priority crop in the two districts and can cope with some poor soil. Cabbage was selected in the two districts because it is a very important food crop but also income generating crop. Farmers are used to crop cabbage and it would be important to provide adequate fertilizer recommendation to increase the yield level.

d) **Qualitative survey:** FGDs, KIIs and observation data collection processes were used to triangulate and validate the data on perceptions from the household members on environmental natural resources specific perceptions on Soil (soil fertility and soil erosion), water (ground water quality, quality of harvested water, water quality in lakes and rivers), Forest, Minerals and stones.

e) **Vulnerability Assessment:** It was essential for the study to shape climate change adaptation decisions. This helped define the nature and extent of the threat that harmed population or ecological system, providing a basis for devising measures that minimized or evaded this harm. It provided a means to understand how different groups, including women who were impacted by climate change and to identify adaptation measures based on needs and priorities. For local vulnerability assessment, it was important to involve local communities in a participatory manner, especially the poor as they were deemed to provide access to a broader knowledge base, which in turn improved problem definition and strengthening the analysis of the results of the study. The results shall be compared to those from the study: "Climate change vulnerability in RWANDA" (REMA, 2018).

3.7.3 Combined ENR- MPI Methodology

This methodology was the combination of the two planned surveys comprising MPI and ENR. The consultants merged the survey tools, (**Appendix 8 – Questionnaire)** and triangulated the collected data for MPI and for the ENR) for the two household surveys to efficiently measure the ENR-MPI.

The MPI is designed to measure poverty levels. It follows the Alkire and Foster (AF) (2007, 2011) methodology. The AF method is a measurement framework that each user must fill in with their own specifications. This framework requires that each user defines the purpose and the space of the measure and selects the unit of identification, dimensions, indicators,

deprivation cut-offs (to determine when a person is deprived in an indicator) weights (to indicate the relative importance of the different deprivations) and poverty cut-off (to determine when a person has enough deprivations to be considered poor).[65]

The development of a national MPI using the AF method implies making the following six (6) calculations and resulting decisions around (i) the unit of identification and analysis; (ii) dimensions and linked indicators; (iii) deprivation cut-offs for each indicator; (iv) weights for each dimension / indicator; (v) poverty cut-off; and lastly (vi) Counting the ENR Poor.

1. Unit of identification and analysis

The "unit of identification" refers to the level at which deprivations are measured, while the "unit of analysis" refers to how the results are reported and analysed. The unit of identification and analysis for this baseline study was a household. The household members' information was considered together and all household members received the same deprivation score at specific indicator. For example, if the main activity generating income for household members is farming and due to ENR problems like erosion, soil infertility or drought has caused decline in agriculture productivity and resultant food insecurity, lack of school fee for education for children, malnutrition in children under 5 years and lactating or pregnant women then, this household is ENR-Multidimensional poor.

Before finalizing indicators into the MPI, the preliminary analysis and test of association was used to examine the relationship between indicators. This informed or led to dropping of some indicators that were not statistically significant at confidence level between 0.05(95%) and 0.1(90%), not significant to combining some indicators into a sub-index or to adjusting the categorization of indicators into dimensions. For example if a household experienced crop diseases, and the respondent (questionnaire administered) chose any of the three (3) levels of that effect and highlighted (1) High negative impacts (2) Moderate impacts or (3) No impact: when it came to analysis, responses (1) and (2) were combined and that household was considered deprived on crop diseases while for (3), the household was non-deprived. Subsequently, the 22 indicators identified in the methodology section were combined into 5 dimensions and further selected to be inserted in MPI calculation largely using "Chi Square" for establishing the relationship between ENR indicators and household livelihood indicators. See summary **Table 4.**

[65] https://www.undp.org/content/undp/en/home/librarypage/poverty-reduction/how-to-build-a-national-multidimensional-poverty-index.html

Table 4: Relationship between ENR indicators and household livelihood indicators

ENR-indicators	*Bugesera at (p<0.1)*	*Musanze at (p<0.1)*
Drought	✓ *Low agricultural Production* ✓ *Food shortage (food insecurity)* ✓ *Health related problems (Can't afford health insurance [Mituelle de santé], lack of quality water, poor sanitation)* ✓ *Limited sources of cooking energy (depleted forests/deforestation)*	✓ *Shortage of water*
Flood events	✓ *Low agricultural production* ✓ *Food shortage (food insecurity)* ✓ *Health related problems (Can't afford health insurance [Mituelle de santé], lack of quality water, poor sanitation)*	*No variable is significant*
Soil erosion	✓ *Low agricultural Production* ✓ *Food shortage* ✓ *Contaminated water*	✓ *Food shortage (food insecurity)* ✓ *Limited sources of cooking energy*
Soil infertility	✓ *Low agricultural Production* ✓ *Food shortage (food insecurity)*	✓ *Food shortage (food insecurity)* ✓ *Health related problems (Can't afford health insurance [Mutuelle de santé], lack of quality water, poor sanitation)*
Windstorms	✓ *Low agricultural Production* ✓ *Food shortage (food insecurity)* ✓ *Health related problems (Can't afford health insurance [Mituelle de santé], lack of quality water, poor sanitation)* ✓ *Contaminated water* ✓ *Shortage of water*	✓ *Unclean water* ✓ *Shortage of water*
Destructive Rains	✓ *Low agricultural Production* ✓ *Food shortage (food insecurity)*	✓ *Low agricultural Production* ✓ *Contaminated water*
Landslides	✓ *Low agricultural Production*	*No variable is significant*
Reduced rainfall	✓ *Low agricultural Production* ✓ *Food shortage (food insecurity)*	*No variable is significant*

	✓ *Shortage of water* ✓ *Limited sources of cooking energy*	
Reduction of forest/ woodlots	✓ *Low agricultural Production* ✓ *Health related problems (Can't afford health insurance [Mituelle de santé], lack of quality water, poor sanitation)* ✓ *Contaminated water* ✓ *Shortage of water*	*No variable is significant*

Source: PEA baseline study, 2020

The **Table 4** shows that the households faced by ENR problems are likely to have a decline in agriculture productivity. From the results of this study, 87.6% and 84.9% of the population in Bugesera and Musanze Districts are farmers. Their main source of income is agriculture and their livelihoods are largely drawn from farming activities. The test statistics show that drought or soil erosion or soil infertility or destructive rains or *flood events, are statistically significant and that they present a strong relationship with the decline in agricultural production, resulting in food insecurity, lack of money for health insurance, dropout of the farmers' children from school due to lack of basic learning materials, lack of quality or improved water sources, e.t.c..*

2. Dimensions and linked indicators

The key step in the development of MPI is to decide the structure of the measure; that is the dimensions and indicators that together measure poverty in a specific zone of intervention.in Musanze and Bugesera Districts. This study has considered five (5) dimensions for environmental and natural resources (ENRs) which are: soil, water, forest, fishery, mining and poverty dimensions (standard of living, health and education)- **(See section 4.7).**

The ENR indicators to be inserted in the MPI were drawn from agriculture and environment aspects in accordance to their roles in the population's wellbeing, welfare and livelihood and their statistical significance tested using statistical tests like test of association (Chi square). The linkages were established between **soil resource and food security**, **water resources and health**, etc. The indicator choice reflects the use or dependence on environment resources by the population. In the context of the Districts, political priorities were considered as well as the published national statistics, as reflected specifically in the District profiles, DDS (2028-2024), Imihigo datasheets, unpublished reports from the Districts (status of the use and exploitation of natural resources, high risk zones, incidence and prevalence of population that have been affected by environmental disasters and hazards, data from NISR (2020), Ministry of Environment (2019) and other relevant sources of data that described Musanze and Bugesera Districts. From these documents, the study concluded to take 22 indicators considered throughout the study, based on the importance and sensitivity to the livelihood of household members **(See Table 5**).

3. Deprivation cut-offs for each indicator

Deprivation cut-offs refer to the minimum level of achievement that a household or individual must have to be considered non-deprived in each indicator. In this study **Deprivation cut-offs** were applied to create a deprivation profile for each household for each of the indicators included in our calculated MPI, the achievement of the households were then compared to the respective deprivation cut-offs and the household classified as deprived or non-deprived. Setting deprivation cut-offs is a normative exercise and our decisions were guided by both international and national standards and by the results of participatory data collection coupled with consultative processes. The consultants also made reference to targets included in District Development Plans of Bugesera and Musanze Districts.

In this study, the consultants used thresholds to decide whether the population in the households were ENR- poor for instance where an individual in a household was considered deprived in each indicator if their achievement fell above the cut-off; and (b) a cross-indicator cut-off (or poverty cut-off) - where a person was considered to be poor if the weighted sum of their deprivations met equal or greater ENR-poverty cut-off. For the District's ENR-MPI, the poverty cut-off was chosen to be at *x*/*n* (where x is indicator while n is number of total indicators) of indicators; that is, a person in a household who was deprived in *k*<x% of the weighted indicators was considered ENR- poor.

4. Weights for each dimension / indicator

Weights (which must add up to one, or 100 percent) was applied to each of the deprivations, which were then summed up so that each person was assigned a deprivation score that gave the weighted percentage of deprivations they experienced. Each household's deprivation score was then constructed based on a weighted average of the deprivations they experienced using a nested weight structure, assigning equal weights across dimensions, and equal weights for each indicator within dimensions. This study did not use a nested (equal) weight structure among dimensions due to the importance of every dimension but applied equal weight for each indicator within the dimensions. Given that almost all of their ENR indicators affected soil, this was attributed to a high weight of 40% for soil and the remaining 60% apportioned 40% to water and forest resources and the other 20% to fishery, minerals and natural stones resources as these impacted the least on the llivelihoods of the household members. Finally, in this study poverty cut-off identified as multidimensional poor all those people whose deprivation score met or exceeded the 100% threshold.

Table 5: The dimensions, indicators, deprivation cut-offs and weights

Dimensions	*Indicators*	**A Household (HH) is Deprived if…….**	*Indicator Weights*	*Dimension weights*
SOIL RESOURCE	**Soil infertility**	- ….soil infertility has highly or moderately affected the livelihoods of the members, and confirmed from soil nutrients calculation in this study showing that a HH is located in a zone that has low soil nutrients, and has not used any manure or chemical fertilizer. This has discussed on the on depletion of soil fertility/ soil infertility or poor soil fertility	4.4%	**40%**
	Drought events	- …the HH highly or moderately experienced drought and has been affected by droughts in their agriculture, livestock and forest activities.	4.4%	
	Soil erosion	- ……a HH experienced soil erosion and has been further affected by soil erosion in their plots and if are in the following soil erosion classes: Moderate, High, Very high, Extremely high	4.6%	
	Destructive rain	- ….a HH highly or moderately experienced destructive rainfall and affected livelihood of its members	4.4%	
	Landslide	- … a HH experienced landslides and has been affected further by landslides in their plots and if are in the following land Slope categories: Moderate, High, Very high, Extremely high	4.4%	
	Food insecurity	- …a HH experienced this and has been affected by food insecurity either Moderately or Severely food Insecure;	4.4%	
	Health	- ….a HH experienced ill health and has been affected by health problems (has no health insurance, affected by one or more illnesses);	4.4%	
	Soil degradation	- …a HH has not used any method of soil fertility conservation, terracing, irrigation methods.	4.4%	
	Agro-foresting	- ….the population experienced and has been affected by not planting agroforestry trees in their farming plots.	4.4%	
WATER RESOURCE	**Water access**	- ……a HH experienced this and has been affected by difficulties in accessing any of the water sources used (Long distance to water sources either clean or not clean);	6.6%	**20%**

Dimensions	*Indicators*	**A Household (HH) is Deprived if…….**	*Indicator Weights*	*Dimension weights*
	Improved water access	- …..the HH does not have access to improved drinking water or safe drinking water is at least a 30-minute walk from home, roundtrip.	6.8%	
	Water management	- …a HH experienced and has been affected by poor management of rain water using any of these methods (tanks of dams).	6.6%	
FOREST RESOURCE	**Natural forest**	- ……a HH experienced and has been affected by animals from the park that damage crops and kill livestock, and prohibition to exploit forest resources.	6.6%	**20%**
	Forest and woodlots plantation	- ….a HH experienced and was affected by not having forest and woodlots plantation	6.6%	
	Deforestation	- …..a HH using firewood or charcoal as source of cooking energy	6.8%	
FISHERY RESOURCE	**Overfishing**	- …a HH experienced and has been affected by overfishing in lakes and rivers;	2%	**10%**
	Nutrition	- ….a HH experienced and has been affected by reduced production of fish.	2%	
	Education	- …..no HH member aged ten years or older has completed six years of schooling.	2%	
	Change of water level of Lake and river water	- ….a HH experienced and was affected by the changes of water level of rivers/ lakes during rainfall and rainstorms) or diminishing of levels due to droughts disturb fishery and affected household's livelihoods	2%	
	Temperature and windstorms in lake and rivers	- …..a HH experienced and was affected by the effects of the change in temperature; windstorms and changing of water levels for fishing activities;	2%	
MINERALS AND NATURAL STONES RESOURCE	**Quarries activities**	- …..a HH experienced and has been affected by the extraction of minerals, natural stones (explosion; air pollution by stone crushing and soil degradation by quarrying)	5%	**10%**
	Dropout school	- ….a HH with a school-aged child is not attending school up to the age at which he/she would complete 6 years of primary school	5%	

Source: PEA baseline study, 2020

5. Poverty cut-off

To determine the poverty cut-off, all 22 indicators selected from above dimensions were tested using chi-square and Pearson Correlation test to test how strongly correlated the indicators were. The study selected eight (8) indicators to be used as cut-off based on their strongly negative impact on the livelihoods of the interviewed households (households faced with those 8 environmental problems led them to be ENR-poor). Based on the results of this study, the eight (8) indicators which were statistically significant at 95% confidence level (p<=0.05) included Soil infertility, soil erosion, Landslides, Drought events, Destructive rain, Flood events, Windstorm and Forest use.

The results also show that environmental problems strongly affected the livelihoods conditions of households in the targeted group where they have contributed to a decline in agriculture productivity, food insecurity, clean water and sanitation. Soil infertility contributed at a rate of 13.7% (r= -.137, p= 0.004) on agriculture productivity, 9.4% *(r=-0.94, p=0.044)* on food security, soil erosion at 9.3% (r=-0.93, p=0.047) on agriculture productivity, 15.4% (r=-0.154, p=0.001) on sanitation, Landslides at 12.0% (r=-0.120, p=0.01) on agriculture productivity, 23.0% (r=-.230, p=0.000), clean water and 9.7% (r=-0.097, p=0.038) on sanitation, Drought events at 12.7% (r=-0.127, p=0.007) on agriculture productivity, 29.4% (r=-0.294, p=0.000) on Clean water, 22.6% (r=-0.226, p=0.000) on sanitation, Destructive rain at 21.7% (r=-0.217, p=0.000) on agriculture productivity, 10.9% (r=-0.109, p=0.020) on Clean water, 18.0% (r=-0.180, p=0.000) on Food security, Flood events at 9.8% (r=-0.98, p=0.037) agriculture productivity, 21.0% (r=-0.210, p=0.000) on Clean water, 15.7% (r=-0.157, p=0.001) on Food security, 32.2% (0.-322, p=0.000) on sanitation, windstorms at 25.9% (r=-0.259, p=0.000) on Clean water, 20.2 %(r=-0.202, p=0.000) on Food security, 12.2%(r=-0.122, p=0.009) on sanitation, (the effects of these environmental problems also played a significant role in food security. Deforestation at 10.0% (r=-0.99, p=0.035) on Food security, 13.3% (r=-0.133, p=0.004).

The households were then identified as multidimensional poor if the weighted sum of their deprivations appeared greater than or equal to the poverty cut-off. After identifying each person as poor or non-poor, the information was aggregated into two informative indices with cut-off (k= 8 out of the initial 22 indicators: that is k=36.3%). Precisely expressed, at least eight (8) out of the twenty-two indicators were strongly significant to warrant classification of a household as ENR -Poor. This baseline study therefore adopted the eight (8) indicators because they were statistically significant, and dropped the remaining 14 because they did not display strong statistical significance. The Correlation of ENRs between Livelihood Indicators and Degree of association of ENRs and poverty indicators were basis of computing the cut-off (**See Table 39 and Appendix table 14).**

The steps described in a) and b) were involved in the computation:

a. Dimension-specific cut-off (deprivation cut-off) – where people in the household were considered deprived in each indicator if their achievement fell equal or greater than the cut- off of 36.3%).

b. A cross-indicator cut-off (or poverty cut-off) - where a person was considered to be poor if the weighted sum of their deprivations met or exceeded the deprivation cut-off.

For the ENR-MPI in Musanze and Bugesera Districts, the poverty cut-off was chosen to be at 8/22 of indicators; that is, a person in a household who is deprived in k≥36.3% of the weighted indicators is considered ENR- multidimensional poor.

6. Counting the ENR Poor

This process involved analysis of ENR–MPI using results of the household surveys: The ENR – MPI was drawn from the two different surveys mentioned earlier, in order to identify the number of MPI – ENR poor in any given District of our research, it was necessary to multiply the ENR – MPI incidence or headcount ratio (H) calculated from the combination of the two household surveys (survey on MPI and ENR) by the population sampled from each District (Bugesera and Musanze Districts). The adopted formula for computation of the ENR poor was as follows:

Number of ENR - poor = H * Total Population.

The methodologies described in this chapter III have been applied and data were collected, computed and analized to produce coherent data sets proposed in the chapter IV.

CHAPTER IV: MULTIDIMENSIONAL POVERTY-ENVIRONMENT

4.1 Introduction

This section contains the core of the study and discusses the details of levels of Multidimensional Poverty-Environment in the two Districts highlighting the demographic features, poverty and ENRs (*fisheries, forestry, minerals and stones*), poverty status in relation to soils, water availability and quality and climate dynamics as the premiers. The subsequent discussions focus on challenges on poverty reduction, lessons from DDS and Imihigo, MPI in the Districts, results of the ENR-MPI, linkage of ENRs to poverty levels and key messages.

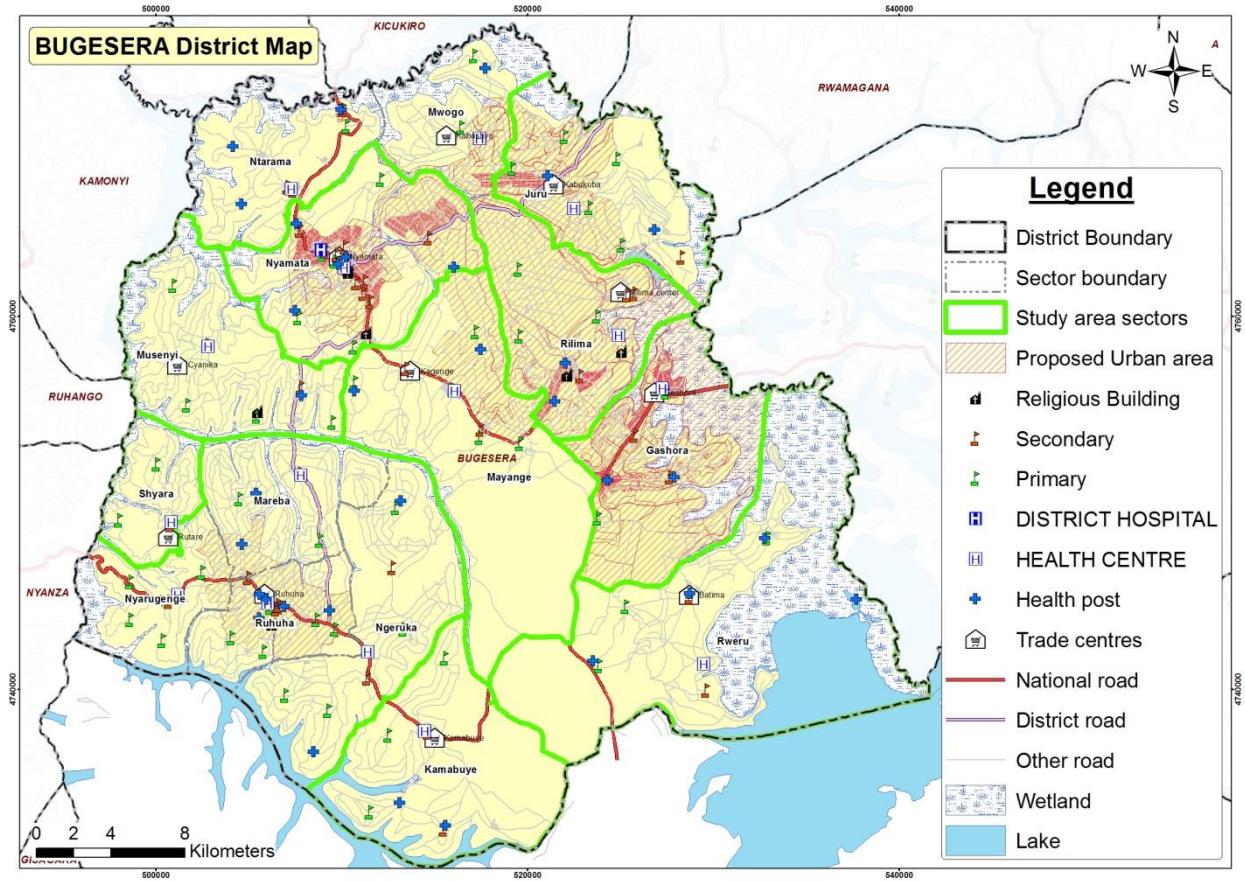
4.1.1 Demographic features of Bugesera District

Bugesera is one of the seven Districts of the Eastern Province in Rwanda. It covers a total surface area of 1,337 Km². The District is composed of 15 Sectors, 72 Cells and 581 Villages with a total Population of 363,339 people, where 177,404 are males and 185,935 are females (General Population census: 2012). Its Population Average Annual Growth Rate is 3.1%, with a population density of 282 people per km.[2] Bugesera District population is estimated at 13.9% of the whole of Eastern Province population and forms 3.4% of the total Rwanda population.[66] The Bugesera District labor force participation rate was 57.1% while unemployment rate was 11.2%. The District level of job opportunities was at 58.6%.[67] The Bugesera economy is principally dominated by primary, secondary and tertiary sectors with very low production and productivity faced with various challenges. These ultimately constitute barriers to District's development and consequently contribute to Poverty.[68] The District currently has 167,992 as the total working population (16 years and above) while the unemployed population is 903 and finally the inactive population is 35,528.[69]

According to the EICV4, Bugesera District shows a clear move from the traditional isolated habitat towards *Imidugudu* or other clustered forms of habitat, which is in line with the policy for addressing poverty. The report shows that there is an increase of the population who live in *Imidugudu* at 77.9% compared to 67.4% from EICV3. In addition, EICV4 shows that 12.9% live in Unplanned clustered rural housing compared to 19.1% from EICV3, 7% Isolated rural housing and this shows a decrease of 6.4% from EICV3, 1.8% live in Unplanned Urban Housing from EICV4 compared to 5.2% from EICV3, 0.4% live in Modern planned area.[70]

[66] Rwanda Population and housing census 2012
[67] Labor force survey 2017
[68] Bugesera District Development Strategy (DDS) 2018 - 2024
[69] EICV4 – 2013/2014
[70] Bugesera DDS 2018 - 2024

Map 6: Baseline Study Locations in Bugesera District & Sectors



Source: Survey Results, PEA Baseline Study, 2020

4.1.2 Demographic features of Musanze District

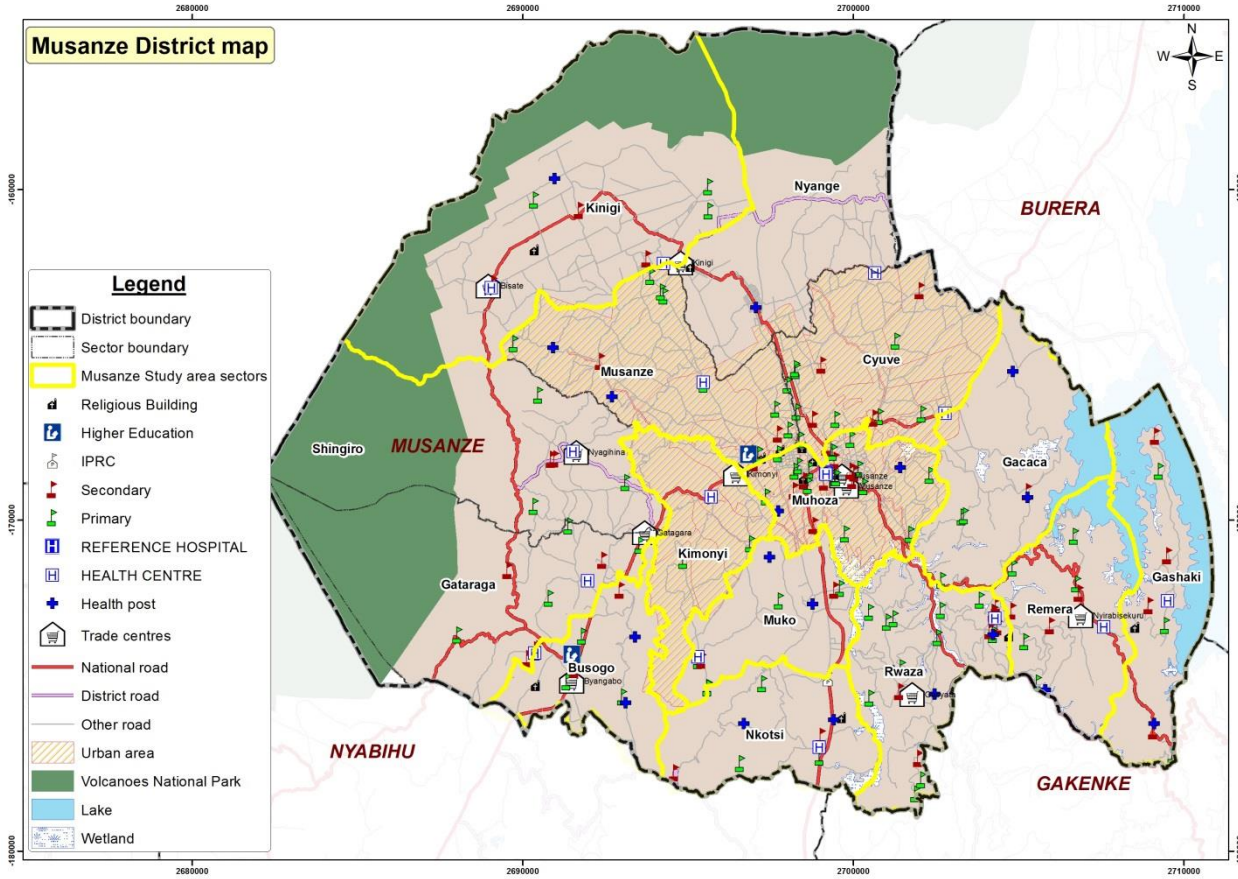
Musanze District is one of the five Districts of Northern Province. It covers total area of 530.4 km^2, of which 60km^2 form Virunga National Park and 28 km^2 hosts Lake Ruhondo. Musanze is divided into 15 sectors, 68 cells and 432 villages with a total population of 368,563 and a gross density of 695 habitants per km^2. It has an average annual growth rate of 1.8% with male population standing at 174,760 and female population at 193,803 (NISR, Census 2012). Musanze District population represents 3.5% of the total population of Rwanda and 21.3 % of the Northern Province population. Employment rate is 82.4%, 2.2% unemployed and 15.8% is inactive.

Musanze District data shows that 52.3% of households are living in settlements (*Imidugudu*) while 3.4% are living in unplanned clustered rural housing, 24.7% are living in isolated rural housing and 5.6% are living in unplanned urban housing. These are far below the national achievements of 49.2%, 8.7%, 25.6%, and 12.8% respectively. About 97.7% of households are single house dwelling, 1.5% of them are multiple households dwelling, while 0.6% are groups of enclosed dwellings/multiple households and the rest 0.1% are group of enclosed dwellings (single households).[71]

[71] Musanze District DDS 2018 - 2024

The agriculture sector in Musanze District has a rehabilitated government-owned warehouse located in the Sector of Cyuve, which has a capacity of 3,500 Metric Tons (MT). There is also one Irish Potato Collection Centre located in Kinigi Sector.[72]

Map 7: Baseline Study Locations in Musanze District & Sectors



Source: Survey Results, PEA Baseline Study, 2020

4.1.3 Poverty and ENRs in Bugesera and Musanze Districts

In their work, Thiry et al. (2018) suggested extending the MPI, which encompasses social and economic dimensions, to include environmental deprivations that simultaneously strike the poor. This is because while ENR constitutes an important source of subsistence and of insurance during times of need, a household's socio-economic status tends to affect its level of vulnerability to ENR degradation. To this end, the following sections present ENRs indicators in the context of Bugesera and Musanze Districts and the current status of ENRs with focus on the five (5) dimensions of ENRs which are soil, water, forest, fishery and minerals and Natural Stones. Different sources were reviewed in order to get data. These include Bugesera District's 2018/19 Imihigo, Bugesera and Musanze DDS (Musanze District, 2018; Bugesera District, 2019), EICV4-5 (NISR, 2015b; 2018), among others.

[72] Musanze DDS 2018 - 2024

4.1.4 Poverty status in Bugesera and Musanze Districts

In the past two decades, Rwanda has experienced a gradual reduction in poverty with a poverty reduction of 20.7% between 2000 and 2017, while the extreme poverty reduced by 24% in the same period (see **Table 6)**. On one hand, poverty and extreme poverty registered a reduction of 14.1% in Bugesera and 14.8% in Musanze Districts between 2010 and 2014, and then respectively increased by 6% and 4.4% between 2014 and 2017. On the other hand, poverty has doubled and extreme poverty tripled since 2010 in Musanze District. Information from KIIs substantiate that poverty increase in Musanze District is due to many factors that include rapid population growth induced by inadequate family planning and polygamy, overexploitation of land, soil erosion and landslides, selling crops before harvesting period, etc. However, these factors are not adequate to sufficiently explain poverty and extreme poverty rates in Musanze District. Factors such as droughts, flooding, poor-quality planting materials, crop perishability, price volatility, limited inputs, diseases and poor post-harvest management may well contribute to low agricultural production and low income levels among the population (AFR, 2012; Okonya et al., 2019). The **Table 6** illustrates the poverty rate in Musanze and Bugesera Districts.

Table 6: Trends of Poverty Rates (%) in Bugesera and Musanze Districts

EICV Rounds	Poverty			Extreme poverty		
	Bugesera	Musanze	Rwanda	Bugesera	Musanze	Rwanda
EICV1 (2000/01)	-	-	58.9	-	-	40.0
EICV2 (2005/06)	-	-	56.7	-	-	35.8
EICV3 (2010/11)	48.4	20.1	44.9	28.3	5.9	24.1
EICV4 (2013/14)	34.3	34.9	39.1	13.4	16.8	16.3
EICV5 (2016/17)	40.3	40.7	38.2	17.8	18.1	16.0

Source: EICV1-5 (NISR, 2002; 2006; 2011; 2015b; 2018a)

Table 7 indicates that, the Headcount Ratio (H): % Population in multidimensional poverty in Bugesera District is greater than cut-off (k=40%) and the Headcount Ratio (H): in Musanze District is below cut-off. These results indicate that, the population of Bugesera District is multi-dimensional poor compared to the population of Musanze District.

Table 7: MPI for Bugesera and Musanze Districts

Districts	Headcount Ratio (H): % Population in multi-dimensional poverty (k=40%)	Intensity of deprivation among the poor (A): Average % of weighted deprivations	Adjusted Headcount Ratio (M0 = H*A)
Musanze	24.7%	50.6%	0.12516
Bugesera	44.1%	52.5%	0.23163
Total	35.2%	51.9%	0.18273

Source: Adopted and computed using EICV5 data (NISR, 2018c)

4.2 Environmental Natural Resources

Under the environmental natural resources, we will discuss on Land husbandry (soil dimension, erosion, and irrigation); water and fishery dimension; forest dimension; minerals and natural stones dimension. The ENR Sector contribution to the environment increased by five (5) percent and contributed 1.2 percentage points to the overall GDP growth rate. NISR, (2019)[73]. ENR has contributed to 28% of the overall GDP.

The **Figure 1** shows the extent of the mismanagement of the ENR Sector in the period 2018 -2019 and how it negatively contributed to the decrease in GDP. The coefficient value in our equation in the **Figure 1** is negative, this implies that the negative contribution of ENR Sectors to the GDP is increasing, therefore there needs to be strategic actions geared towards sustaining our ENR Sectors, and contribute more positively to the GDP.

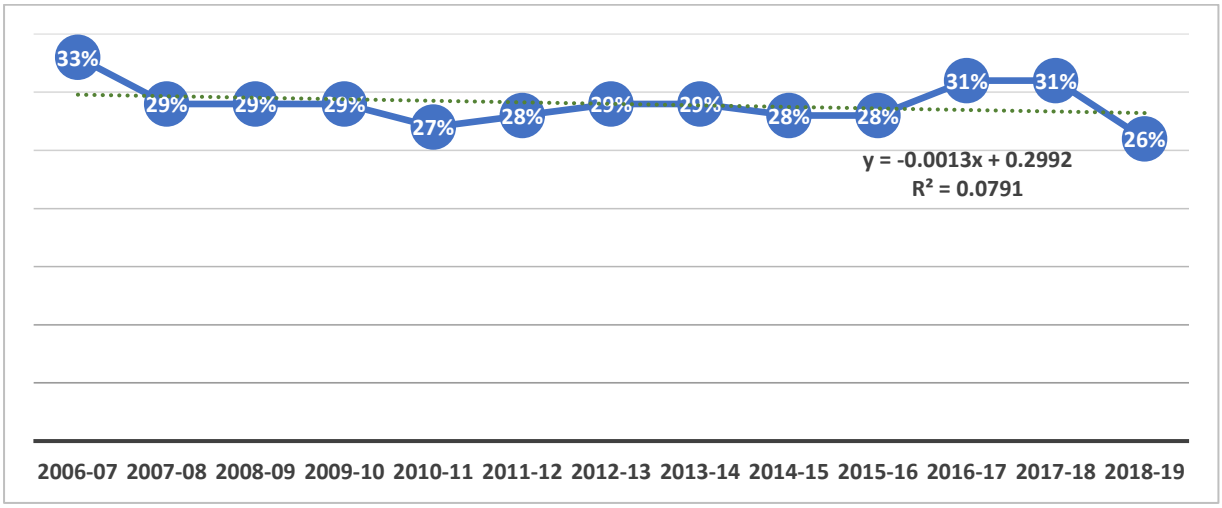


Figure 1: Trend of environmental sector's contribution to the GDP by year
Source: Calculated from Gross Domestic Product (GDP) – 2018 – 19, NISR, (2019)

The **Table 8** shows the components of ENRs and their precise contribution to the GDP in Rwanda. They are ranked as follows: agriculture contributes 65.4%, forestry 23.1%, mining and quarrying 7.7 %, and finally, water and waste management 3.8%.

Table 8: The Components of ENRs

ENR Sectors	% contribution to GDP
Agriculture	65.4%
Forestry	23.1%
Fishing	0.0%
Mining & quarrying	7.7%
Water & waste management	3.8%

Source: PEA baseline study, 2020

[73] NISR, Gross Domestic Product (GDP) – 2018 – 19,

4.2.1 Land husbandry

Due to the nature of terrain in most parts of Rwanda, it is apparent that more appropriate land husbandry technologies need to be introduced. To ensure easy uptake and adoption of these technologies at farm level, policies and strategies have been developed at national and District levels involving both public and private organizations to intervene in erosion control systems and soil fertility management. The recently developed tools are being exploited to find out the appropriate interventions that best respond to underlying land degradation problems, especially prioritizing high risk zones in the highland's region. CROM DSS (Catchment Restoration Opportunity Mapping Decision Support System) tool in combination with available spatial data and existing studies were used to identify areas that need to be protected from soil erosion. The factors comprise soil depth, soil properties and slope gradient but also taking into consideration socio-economic factors. Before proceeding to the step of planning the interventions, all existing areas that are embracing forest cover, erosion control measures, rangeland and settlement were removed.

The combination of these factors resulted into the different land unit categories for land-husbandry interventions such as good agricultural practices, radical terraces with agroforestry (AF)/grasses, progressive terraces with agroforestry/grasses (hedgerows, grass strips, ditches), forest plantation, rangelands and gully protection.

4.2.2 Soil Dimension

In Bugesera District, 77.8% of the population depends on subsistence agriculture. Land is fragmented with an average land size cultivated per household of 0.59ha. Soils are generaly loamy and clay in marshlands, with an approximate area of 6,100ha of arable land and exploited at an average of 46.3%. The exploited land is generally sandy with a low quantity of humus, which makes them more or less fertile but very permeable and fragile (Bugesera District, 2019).

In the past the District experienced drought which resulted in hunger emigration. Estimates from Bugesera DDS show that floods were reported in 1% of households, 9.3% for destructive rains and 0.2% for mountain slides. This is because climate is dry with temperature varying between 20 and 30°C, the average annual rainfall ranges between 800mm and 1,600mm, and the landscape is flat with some ondulating plateaux. The altitude varies between 1,100m and 1,780m. As mentioned, the Bugesera District's landscape endowed with plateaux, favours Manufacturing Sector which comprises of light and heavy industries that consume large quantities of energy. Currently, there are six (6) industries namely Kigali Leather Ltd, IMANA Steel Ltd, Trust Industry, PEAL Ltd, Malebu Ltd, and Bugesera Industrial Park.

In Musanze District, 91% of the population depends on subsistence agriculture and the major economic endowments include availability of lakes and rivers, rich mineral deposits and potential tourism activities. The land is largely fragmented with an average land size of 0.45ha cultivated per household. The District has two (2) distinct zones and consequently related types of soils, one being volcanic area with moderate to high slopes and volcanic ash soils with

predominantly lava stones. The other part comprises steep hills where erosion is active. Soil erosion and soil nutrient loss are major problems, with only about less than half of the land protected against soil erosion (47.3%), while irrigated land is only 1.7% (Musanze District, 2018).

A number of research projects have been done in connection to soil fertility management in Africa and Rwanda (Athanase R. Cyamweshi. et al. 2019, Nsharwatsi N. L. et al. 2016, Charles S. Wortmann and Keith Sones. 2016) and have provided important information which has added value to the previously existing information. In those works, specific fertilizer management have been taken into account as well as specific lands including low lands. Charles S Wortmann et al,(2019) have focussed on secondary and micro-nutrients deficiency in Africa and has concluded that some part of the continent are experiencing serious secondary and micro-nutrients deficiencies.

The same scientist (Chales S Wortmann et al, 2018) and his team detected a deficiency of nutrients in maize crops in Eastern and Southern Africa and recommended the way forward. In 2018, a team of researchers (Athanase R. Cyamweshi et al., 2018) focussed on the East Africa farm lands to investigate nutrients management for Wheat production. They proposed the best way to deal with wheat fertilization in the highlands. Recognizing the value of the work already done by a number of researchers to improve soil fertility in Africa and Rwanda, the optimum yield and proper environment protection have not yet been achieved as demonstrated in this baseline study. There is a need to upgrade the methods so far used to assess specific crops needs for specific soil type. This study has adopted a higher scale soil fertility assessment and fertilizer recommendations as highlighted in the Chapter III of this study.

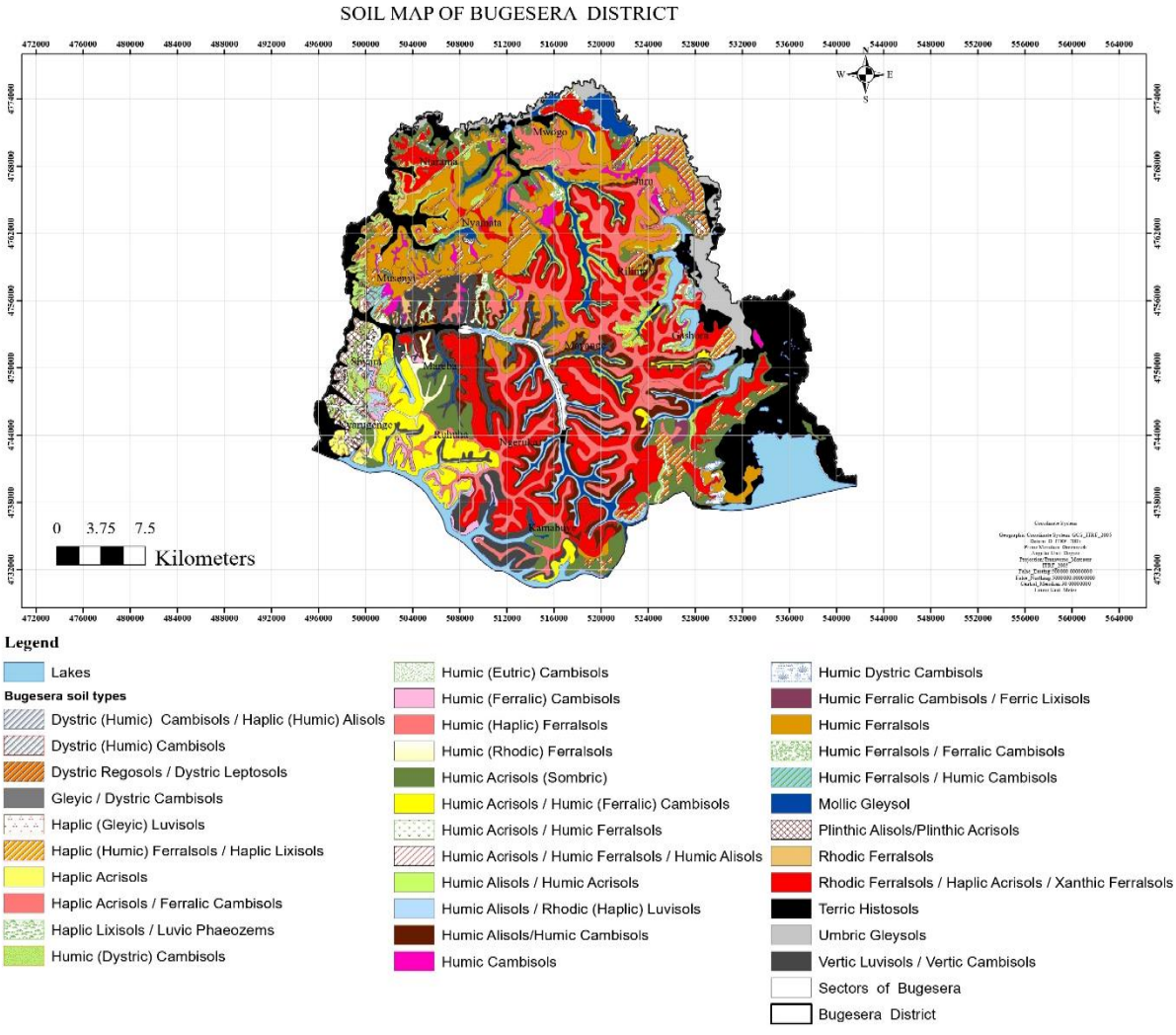
The climate is tropical with average temperature of 20°C, while the average annual rainfall ranges between 1,000mm and 1,200mm per month, and the landscape is mountainous with average altitude of 1,850m. Moreover, April and May bring about the heaviest rains, whereas October and November have a much more moderate rainy period (Musanze District, 2018). Using ArcMap version 10.5, the spatial analyst tool used a technique called zonal statistics to perform tables of values of the soil parameters listed in the following sections.

4.2.2.1 Bugesera and Musanze Districts soils

This study outlines the different soil types found in the two Districts. *The FAO soil classification was used to display the different soil types of the 2 Districts. Following the methodology described, the following parameters were produced and used to perform the fertilizer recommendation of selected three crops (Maize, Coffee and Cabbage). The parameters considered include:* pH, Bulk density, CEC, Total Organic carbon, Total Nitrogen, Total phosphorus, Available phosphorus, Extractable Potassium, Exchangeable Potassium and Exchangeable aluminium. Naturaly poor soils and soils with medium fertility are dominating the Bugesera District.

The poor soils include; Ferralsol, Lixisol, Cambisol, and Leptosol. These soils can be improved by adding Organic matter, use of lime and fertilizer. Soils with medium fertility in Bugesera include: Luvisol, Histosol, Gleysol and Alisols. Idealy, the fertility management of these soils shall be addressed following fertilizer recommendations based on soil test results. For Musanze District, poor soils (Leptptosol, Cambisol, Ferralsol), soils with medium fertility (Histosol, Gleysol, Alisol) and fertile soils (Andosol, Luvisol) are represented. As shown in the fertilizer recommendation, different soils shall be amended with specific fertilizer to correct the deficient element for specific crop. The development of the fertilizer recommendation followed updated methods as outlined in Chapter III. The results are presented in the **Appendix 6.**

Map 8: Soil Map Bugesera District



Source: Survey Results, PEA Baseline Study, 2020

The **Map 8** indicates the soil types of Bugesera District as detailed on the legend and the digitized information**.** The

Table 9 details the important soil parameters in Bugesera District. It follows the FAO soil classification and includes the pH and bulk density besides other parameters

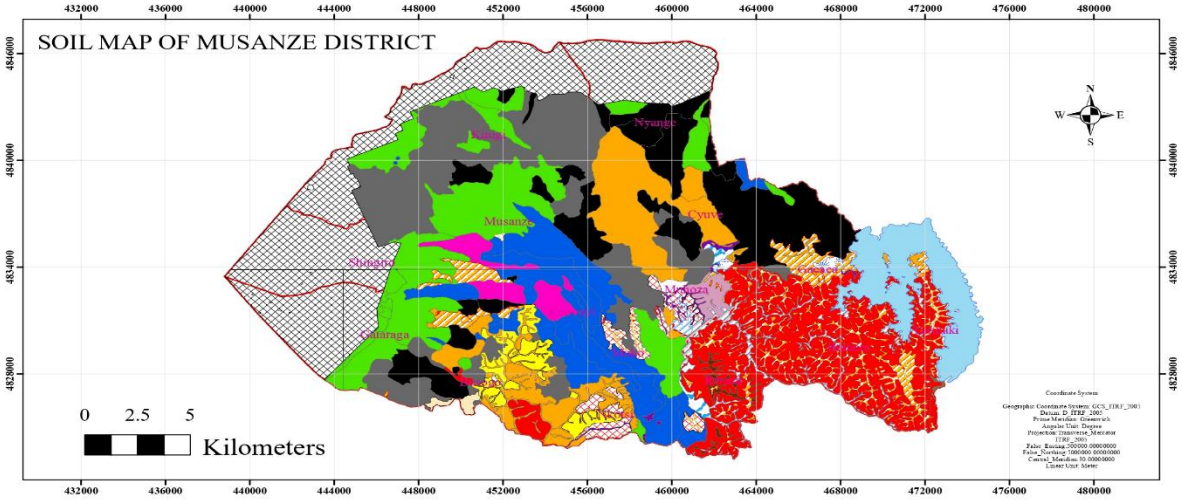
Table 9: Important soil parameters of Bugesera District

FAO_CLASSIFICATION	pH_	Bulk density	CEC	Clay	Sand	Silt	Tot C	Tot N	Tot P	Avail P	Exch K+
	H2O	g/cm3	(cmol/kg)	(%)	(%)	(%)	(%)	(%)	(ppm)	ppm	(cmol/kg)
Terric Histosols	5.50	1.24	19.68	35.34	41.19	22.51	3.17	0.17	278.37	2.82	0.80
Humic (Dystric) Cambisols	5.71	1.29	14.11	35.06	47.05	16.92	1.52	0.17	410.50	4.05	0.55
Humic Acrisols (Sombric)	5.72	1.27	14.79	37.19	44.76	17.07	1.70	0.17	360.61	3.60	0.55
Dystric Regosols / Dystric Leptosols	5.61	1.27	14.90	37.19	44.41	17.35	1.88	0.17	362.68	3.61	0.49
Humic Ferralsols	5.66	1.28	15.16	37.41	45.43	16.15	1.62	0.17	368.57	3.64	0.55
Humic Cambisols	5.62	1.28	15.22	37.22	44.62	17.15	1.75	0.17	361.96	3.64	0.52
Humic Ferralsols / Humic Cambisols	5.63	1.31	14.48	36.63	43.63	18.98	2.15	0.18	343.93	3.43	0.44
Humic Acrisols / Humic Ferralsols / Humic Alisols	5.56	1.33	14.22	37.81	42.03	19.16	2.07	0.18	295.16	2.87	0.50
Humic Acrisols / Humic Ferralsols	5.53	1.29	15.17	38.69	42.18	18.23	2.23	0.18	282.15	2.86	0.49
Plinthic Alisols/Plinthic Acrisols	5.56	1.32	14.75	37.73	42.17	19.25	2.15	0.18	309.00	3.06	0.50
Haplic Acrisols / Ferralic Cambisols	5.87	1.25	14.53	34.90	46.81	17.16	1.19	0.14	549.61	5.41	0.64
Umbric Gleysols	5.56	1.24	17.36	33.56	44.15	21.28	2.57	0.16	295.14	3.02	0.59
Gleyic / Dystric Cambisols	5.50	1.21	17.33	28.33	52.33	18.17	2.47	0.23	234.30	2.32	0.41
Mollic Gleysol	5.70	1.27	14.02	33.92	48.85	16.23	1.43	0.17	387.41	3.90	0.54
Rhodic Ferralsols / Haplic Acrisols / Xanthic Ferralsols	5.83	1.26	13.72	34.98	47.41	16.62	1.28	0.16	384.59	3.86	0.63
Humic (Haplic) Ferralsols	5.87	1.27	13.66	34.04	48.42	16.53	1.18	0.15	393.07	3.91	0.66
Haplic Lixisols / Luvic Phaeozems	5.56	1.29	14.20	37.48	44.14	17.57	1.91	0.17	317.24	3.15	0.59
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	5.62	1.31	15.06	37.65	44.33	17.15	1.93	0.18	318.15	3.25	0.52
Humic Ferralsols / Ferralic Cambisols	5.82	1.26	14.84	37.06	45.50	16.49	1.38	0.15	419.40	4.33	0.58
Haplic (Gleyic) Luvisols	5.90	1.29	14.00	34.00	52.00	13.00	0.80	0.12	626.00	6.13	0.58
Humic Alisols / Humic Acrisols	5.77	1.25	13.69	36.08	45.15	17.54	1.43	0.16	298.00	2.91	0.60
Vertic Luvisols / Vertic Cambisols	5.67	1.28	15.46	37.13	44.21	17.68	1.69	0.17	389.98	3.86	0.64
Dystric (Humic) Cambisols	5.63	1.33	14.50	35.00	46.20	18.10	1.80	0.17	287.56	2.82	0.50
Humic Alisols/Humic Cambisols	5.75	1.28	13.29	33.91	48.85	16.26	1.27	0.16	396.22	3.94	0.60
Rhodic Ferralsols	5.60	1.29	15.32	38.04	42.10	18.92	2.21	0.18	308.63	3.05	0.50
Humic Acrisols / Humic (Ferralic) Cambisols	5.50	1.30	15.43	37.52	43.90	17.61	1.78	0.18	407.76	4.07	0.57
Humic (Rhodic) Ferralsols	5.47	1.33	14.56	38.43	43.80	16.79	1.73	0.17	342.08	3.47	0.44
Humic (Ferralic) Cambisols	5.50	1.28	15.87	38.40	42.77	17.93	1.94	0.18	381.54	3.82	0.75
Humic Alisols / Rhodic (Haplic) Luvisols	5.67	1.28	13.38	35.35	47.34	16.40	1.36	0.17	397.48	3.93	0.54
Haplic (Humic) Ferralsols / Haplic Lixisols	5.73	1.26	15.50	37.46	43.67	17.67	2.03	0.16	269.24	2.71	0.63

Humic (Eutric) Cambisols	5.43	1.32	15.14	38.14	43.00	17.79	2.06	0.18	323.54	3.23	0.52
Haplic Acrisols	5.54	1.31	15.88	40.54	39.68	18.71	2.43	0.18	262.49	2.62	0.54
Humic Ferralic Cambisols / Ferric Lixisols	6.10	1.28	13.29	33.82	49.32	15.82	1.00	0.15	420.15	4.18	0.69
Humic Dystric Cambisols	6.19	1.25	15.92	33.50	47.58	17.92	1.19	0.13	348.73	3.56	0.72

Source: Survey Results, PEA Baseline Study, 2020

Map 9: Soil map of Musanze District



Legend

- Ruhondo Lake
- Birunga National Park

Musanze soils

- Andic Gelysols / Gleyic Andosols
- Dystric (Humic) Cambisols / Haplic (Humic) Alisols
- Dystric Regosols / Dystric Leptosols
- Haplic Acrisols / Ferralic Cambisols
- Haplic Alisols / Dystric Cambisols / Eutric Cambisols
- Humic (Dystric) Cambisols
- Humic Acrisols / Humic (Ferralic) Cambisols
- Humic Acrisols / Humic Ferralsols
- Humic Alisols / Rhodic (Haplic) Luvisols
- Humic Cambisols
- Humic Ferralsols / Humic Cambisols
- Luvic Phaeozems
- Mollic (Haplic) Andosols
- Mollic / Haplic Andosols
- Mollic Andosols
- Terric / Fibric Histosols
- Umbric Andosols
- Umbric Andosols / Umbric Leptosols
- Umbric Gleysols
- Vertic Luvisols / Luvic Phaeozems
- Vertic Luvisols / Vertic Cambisols
- Vitric Andosols
- SECTORS OF MUSANZE DISTRICT
- MUSANZE DISTRICT

Source: Survey Results, PEA Baseline Study, 2020

The **Map 9** indicates the soil types in Musanze District detailed on the legend and the digitized information**.** The **Table 10** details the important soil parameters in Musanze District.

Table 10: Important soil parameters of Musanze District

FAO_CLASSIFICATION	pH_	B.D.	CEC	Clay	Sand	Silt	Tot C	Tot N	Tot	Exch K+	Total P	Avail P
	H2O	g/cm3	Cmolc/kg	%	%	%	%	ppm	%	Cmol/kg	ppm	ppm
Mollic / Haplic Andosols	5.65	0.93	35.89	27.46	35.85	35.67	5.37	4412.97	0.44	0.56	1291.95	12.88
Mollic Andosols	5.60	0.96	35.82	30.05	31.79	37.17	5.49	3574.36	0.36	0.42	898.22	8.89
Umbric Andosols / Umbric Leptosols	5.62	0.95	36.14	27.86	35.13	36.08	5.39	4117.47	0.41	0.35	1421.82	14.08
Humic Cambisols	5.57	0.98	34.52	31.60	33.31	34.17	5.26	3619.42	0.36	0.35	949.50	9.60
Mollic (Haplic) Andosols	5.62	0.99	33.71	31.85	31.95	35.08	4.51	3321.21	0.33	0.41	1054.29	10.40
Vitric Andosols	5.67	0.93	32.57	28.86	34.75	35.31	4.37	4047.63	0.40	0.77	1161.84	11.55
Dystric Regosols / Dystric Leptosols	5.38	1.15	24.70	36.27	35.97	27.00	4.16	3214.40	0.32	0.24	784.72	6.45
Humic (Dystric) Cambisols	5.38	1.13	24.69	34.62	36.74	27.73	4.13	3119.72	0.31	0.22	467.05	4.67
Humic Acrisols / Humic Ferralsols	5.59	1.02	31.12	33.19	32.85	32.73	4.97	2812.22	0.28	0.51	496.09	5.15
Vertic Luvisols / Luvic Phaeozems	5.56	1.05	29.34	33.07	34.72	31.14	4.39	2572.81	0.26	0.37	314.68	3.36
Terric / Fibric Histosols	5.45	1.11	25.15	37.08	33.92	27.92	4.61	2693.31	0.27	0.42	316.78	3.32
Humic Acrisols / Humic (Ferralic) Cambisols	5.28	1.18	21.74	35.77	37.63	25.67	3.76	2835.61	0.28	0.21	416.87	4.25
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	5.37	1.15	21.45	35.01	36.94	27.15	3.84	2656.09	0.27	0.26	385.23	3.77
Haplic Alisols / Dystric Cambisols / Eutric Cambisols	5.62	1.01	28.46	31.65	34.96	32.44	4.66	2597.01	0.26	0.46	313.24	3.11
Humic Alisols / Rhodic (Haplic) Luvisols	5.56	1.03	30.30	34.34	33.99	30.87	4.70	2957.54	0.30	0.39	763.96	7.91
Luvic Phaeozems	5.62	1.00	29.26	30.16	34.84	34.42	4.23	2470.80	0.25	0.47	359.50	3.56
Vertic Luvisols / Vertic Cambisols	5.64	0.99	34.31	30.61	37.71	30.76	4.26	3902.64	0.39	0.61	949.85	9.18
Humic Ferralsols / Humic Cambisols	5.23	1.21	20.76	35.52	39.33	24.10	3.36	2669.32	0.27	0.23	352.50	3.45
Andic Gelysols / Gleyic Andosols	5.63	1.02	34.40	27.35	38.50	33.20	3.77	4160.68	0.42	1.03	733.14	7.03
Umbric Gleysols	5.50	1.16	21.00	37.25	37.00	25.00	3.63	3287.05	0.33	1.13	477.67	4.11
Umbric Andosols	5.57	0.98	38.40	27.20	39.00	32.80	5.94	4639.45	0.46	1.08	1863.50	18.72

Source: Survey Results, PEA Baseline Study, 2020

Data in **Table 11** show that Musanze District has higher mean soil erosion rate (244 $t.ha^{-1}.a^{1}$) compared to Bugesera (105 $t.ha^{-1}.a^{-1}$); with estimated soil loss of 13 and 12 million tons per year in Bugesera and Musanze Districts respectively. Both Districts equally contribute to national soil erosion at 2.1%. The mean soil erosion rate over cropland, which occupies 65% of the total land area in Bugesera District was estimated at 158 $t.ha^{-1}.a^{-1}$; and it was 403 $t.ha^{-1}.a^{-1}$ in Musanze District where cropland occupies 59% of the total land area. This is an indication that land conversion to cropland is one of the major causes of severe soil erosion in both Districts.

According to Karamage et al. (2016), an area is potentially unsuitable for cropland if the erosion rate under cultivation is higher than 300 $t.ha^{-1}.a^{-1}$, which is a threshold of extreme soil erosion. Thus, 3.3% and 1.6% of the croplands in Bugesera and Musanze District are respectively located in unsuitable areas, experiencing extreme soil erosion.

Table 11: Soil erosion rates

Variables	Bugesera	Musanze	Rwanda
Area (10^3 ha)	121	51	2,380
Soil erosion rate ($t.ha^{-1}.a^{-1}$)	105	244	250
Cropland erosion rate ($t.ha^{-1}.a^{-1}$)	158	403	421
Annual soil loss (Million t)	13	12	595
Contribution to national soil erosion (%)	2.1	2.1	-
Cropland coverage (%)	65	59	56
Fraction of unsuitable cropland (%)	3.3	1.6	24.4

Source: Karamage et al. (2016)

4.2.2.2 Physical features in Bugesera and Musanze Districts

Bugesera is characterized by relatively low altitude varying approximately between 1,100m and 1,780m in which its topography is a mixture of plateaus with hills and dry valleys (marshlands). The Bugesera region has chiefly deep soils. Its physical conditions have shown low rates of erosion compared to highland areas but it can't be ignored at farm plot scale because rills and sheet erosions induce loss of topsoil nutrients within a period of time, leaving the surface with outcrop rocks and degraded lands (not fertile). Contrary to other mountainous regions, slope gradient is dominantly gentle resulting in minimum soil erosion and rarity of landslide. Only 3 and 7% of the total area has slope categories above 40 and 16%, respectively. Therefore, farmers perceive that the low production results from the unceasing land degradation emanates mainly interrelated soil fertility and soil erosion (**Table 11).** The land with slope gradients of 0-6%, 6-16, 16-40, 40-60 and > 60 % hold 53, 41, 3.4, 3.4 and 0.01 % of the total area in Bugesera District, respectively (**Table 12**).

Musanze District is dominated with the mountainous parts varying from 1,850m towards a highest peak of 4,507m at Karisimbi. This creates a wet and agreeable climate at an average temperature of 20°C. It has the lowest erosion risk compared to other Districts in the region. The analysis using CROM demonstrated that the erosion risk from high to extremely high ranges covers 18% of the total area (52,945 ha) (**Table 13**). This is related to its biophysical characterization with dominance of gentle to moderate slopes and high coverage of steep lands by natural forest which is Birunga volcanic region and its buffer zone. The slope gradients of 0-6%, 6-16, 16-40, 40-60 and >60 % embrace 35, 28.5, 30, 5.9 and 1.2 % of the total area in Musanze District, respectively (**Table 12**). Hence, there is a limited occurrence of landslides and gullies in Musanze District.

Table 12: Slope categories in the studied Districts

District	Slope categories									
	0-6%	6-16%	16-40%	40-60%	>60%	Total area (0-100%)	>16%		>40%	
Area (ha)							Area (ha)	% Land area	Area (ha)	% land area
Musanze	18,473	15,062	15,669	3,128	613	**52, 945**	19, 410	**37**	3, 741	**7**
Bugesera	70,290	54,150	4,555	4,555	16	**133, 566**	9, 126	**7**	4, 571	**3**

Source: MoE, 2020

The land with moderate to extremely high erosion risks are estimated at 38% of the total area of 133,566ha (**Table 13**). Erosion affects poor soil fertility and destruction of developed irrigation schemes dominantly exploited in Bugesera. The latter nowadays is considered as breadbasket of crop production nearby Kigali the capital city and the rapidly growing population of Bugesera District. Erosion problems are caused by surrounding hillsides in combination with upstream sediment transports that flood the cultivated areas and damage the infrastructures as it recently occurred in April-May 2020 in Rurambi Marshland at 800ha with rice and stevia crops **(Photo 1**). In Ngenda, similar issue was observed with flood rice production as well as pollution of freshwater from the lakes and rivers (Nyabarongo, Akanyaru). Intensification of agricultural activities and other land use changes such as settlement, on the hillsides reduced the capacity of the catchment to retain, restore and regulate runoff from rain and increased siltation. Agricultural land has expanded significantly towards decline of other ecosystems such as wetlands, forests and savannah rangelands. It resulted in reduced water quality and quantity, and soil erosion, among others.

Table 13: Erosion risk classes in Bugesera and Musanze Districts

Erosion risk classes	Bugesera District	Musanze District
Low to very low	85007	43857
Moderate	41119	
High	6336	4493
Very high	914	3431
Extremely high	190	1164
Total area (ha)	**133566**	**52945**

Source: MoE, 2020

Photo 1: Aftermath of flood in Rurambi marshland (damaged rice & stevia crops on 800 ha), April-May 2020

According to the 2017 Agricultural Household Survey (NISR, 2017), about 65.7% and 78.8% of the households in Bugesera and Musanze Districts practiced anti-erosion control measures (**Figure 2**). The adoption of different types of erosion control measures varies from one District to another. The adoption of radical terraces, trees (or wind break or shelterbelt) and beds (or ridges) is higher in Musanze District, while the adoption of progressive terraces, trenches and cover plants (or grasses) is higher in Bugesera District.

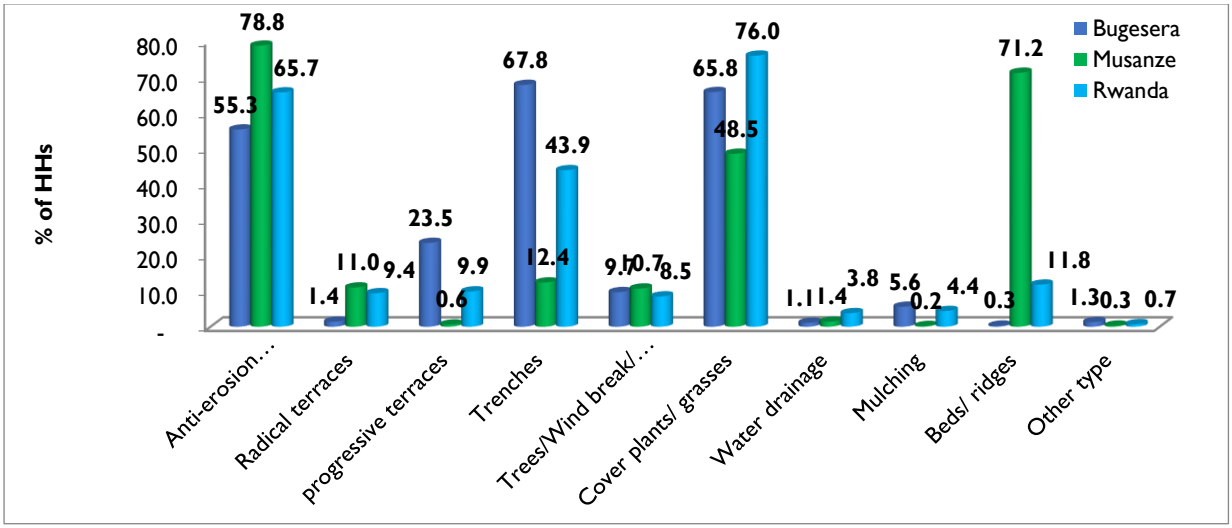


Figure 2: % of HHs practicing erosion control in Bugesera and Musanze Districts
Source: NISR (2017)

Figure 3 shows Percentage of plots by type of anti-erosion activities and District in 2020 Season "A" where Bugesera District commonly mitigates erosion by various practices like ditches, progressive terraces, cover plants and mulching while Musanze District dominantly practices bench terraces beds/ridges.

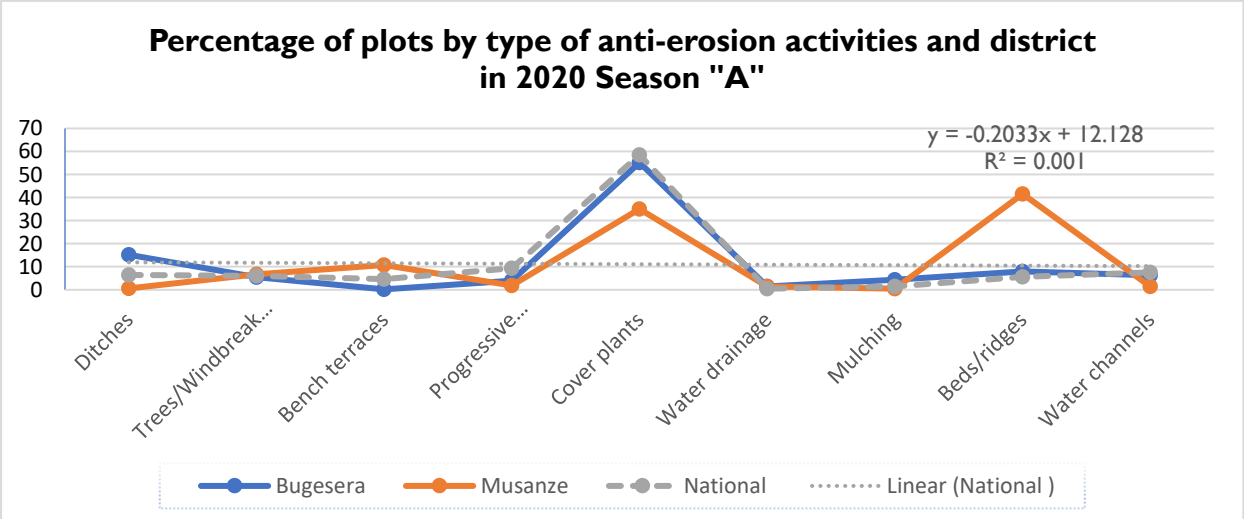


Figure 3:Percentage of plots by type of anti-erosion activities and District in 2020 Season "A"
Source: NISR, 2020[74]

[74] NISR, SEASONAL AGRICULTURAL SURVEY 2020, 2020

Figure 4 shows the percentage of plots by degree of erosion per District in Season "A" of 2020. The findings demonstrate all forms of erosion that Bugesera District experienced compared to Musanze District. In fact, Bugesera District showed very high vulnerability to the different forms of erosion.

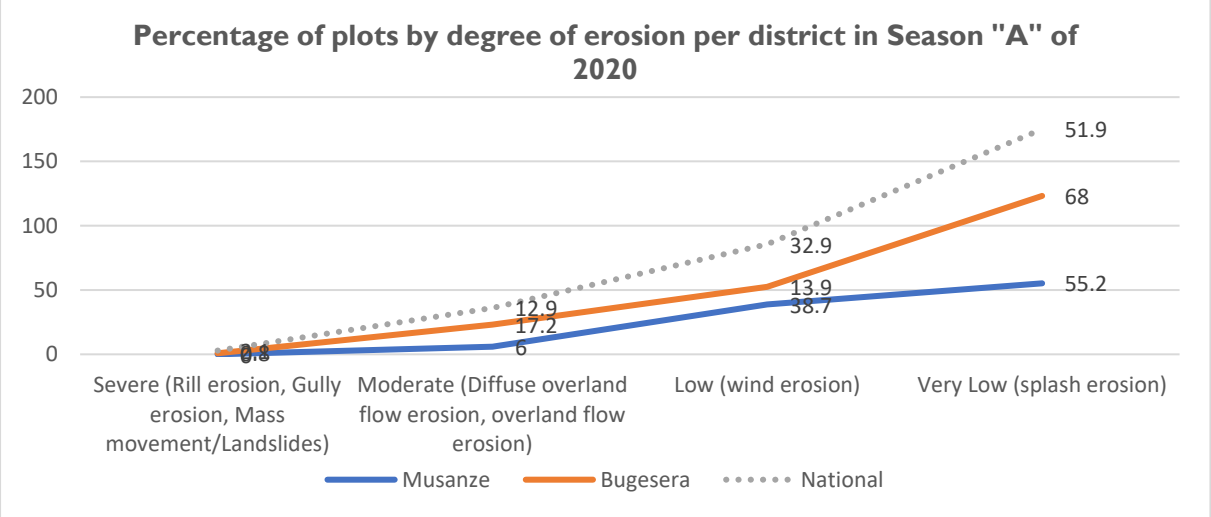


Figure 4:Percentage of plots by degree of erosion per District in Season "A" of 2020 Source: NISR, 2020

4.2.3 Irrigation

Water resource development has been acknowledged to be a primary solution to minimize the dependence of subsistence farming to the unpredictable rainfalls. The country aims at extending new development of irrigation facilities and effective management of existing irrigation schemes. The upcoming milestone indicates that the sector will develop new irrigation infrastructures from 48,508 to 102,284 ha in 2024 (PSTA4, 2018) including small- and large-scale irrigation types or marshland and hillside irrigations.

This target in irrigation will be achieved through various forms of development partnership with NGOs, private sector and International Funding organizations. The agriculture sector needs to promote the capability of individuals and their organizations to develop, manage and use irrigation facilities in a sustainable manner.

Promotion of Public-Private-Partnership (PPP) models involving private sector service providers in the management of irrigation schemes is a prerequisite to achieve the expected successful land and water management and increased sustainable agriculture production. This requires to empower farmers' organizations, and Irrigation Water Users' Associations was well as enforcing partnership with private organizations and public institutions. In the Agriculture Household Survey (AHS) of 2017 demonstrated the low level with 10.1% of agriculture households practicing irrigation and the PSTA4 targets to increase from 48,508 to 102,284ha.

Bugesera District is characterized by a semi-arid climate with high temperature due to relatively low altitude and absence of rains whereby the periods of drought excessively prolong. This prolonged drought induced food insecurity and destruction of the ecosystems.

Despite this climatic condition, the District has a great potential bread basket for staple crops beans, sorghum, cassava, etc.). Bugesera District has deep strongly weathered soils with dominance of gentle slopes but fertile soils are found on the colluvial deposits bordering the marshes and lakes.

Dominant crops grown in Bugesera District are maize, beans, and cassava. Besides, farmers grow a wide range of staple crops (sweet potatoes, sorghum, banana, etc), fruits (yellow banana, pineapple, avocado, etc), vegetables (cabbages, tomatoes, egg plants, zucchini, ect) and coffee. The irrigation is envisaged to increase agricultural productivity and enable graduation from extreme poverty due to considerable water resources (lakes and rivers), as long as erosion is to be protected in the surrounding catchment. The District embraces three (3) rivers namely Akanyaru, Akagera and Nyabarongo and nine (9) lakes. These water bodies can be exploited for agricultural irrigation.

The areas of Musanze District are dominantly subjected to high rainfall amount ranging from 1,200 to 2,500 mm per year with an average temperature of 150°C. Aggressive rainfall accelerates erosion of fragile soils on such steep slopes. They are potentially productive areas for agriculture activities due to their volcanic soil materials. However, some sectors directing away from volcanic chains do not have soils derived from volcanic materials. It is one of the largest producers of Irish Potatoes and pyrethrum in Rwanda. In addition, farmers mostly grow climbing beans and legumes (cabbage, carrot, garlic and onion).

The dominant soil types include *Ultisols*, and *Inceptsols* but also *Andosols, Mollisols,* and *Entisols* are present. They are sandy and clay, laterite and volcanic. The soils are characteristically deep, well developed, with depth from moderate (50-100 cm) to deep soils (>100 cm) but most of them are underlaid on a bed-rock. The bedrock can sometimes be found at a depth of less than one meter. During the dry season the soil is quite friable while in rainy season they filter the water rather than holding it. Hence, the soils are fragile to erosion and need water supply for plant growth.

Figure 5 shows different crop yields Bugesera and Musanze Districts where Bugesera District had higher yield in Cassava, other cereals, paddy rice, yams and taro, fruits, vegetables and fruits in comparison to Musanze District. Musanze District crops yield was higher in sweet potatoes, Irish potatoes, bananas, bush beans and fodder crops compared to Bugesera District.

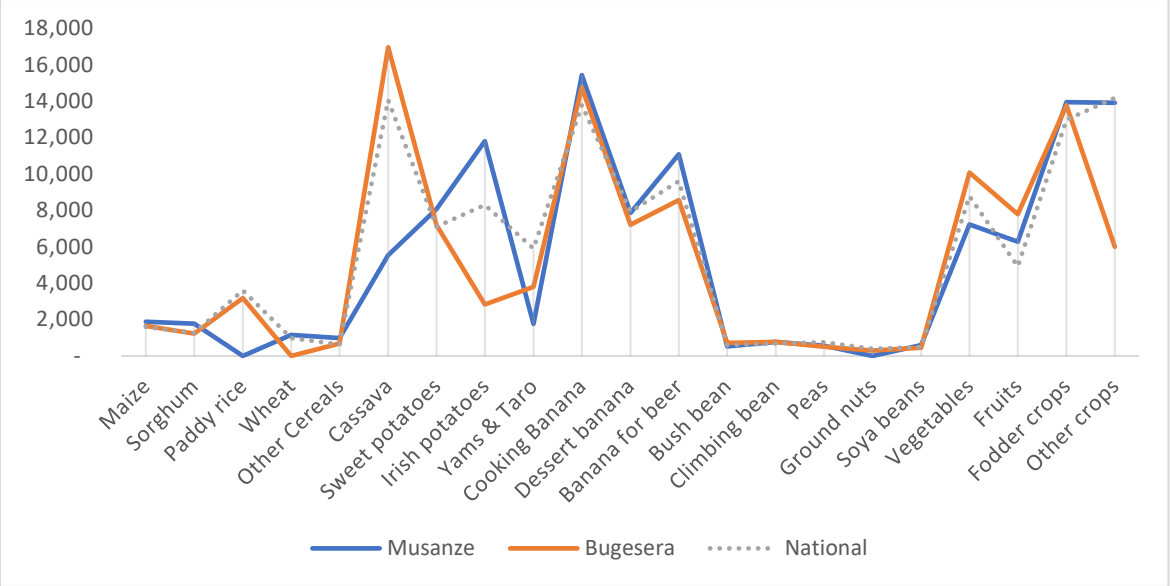


Figure 5:Season "A" 2020 Average yield by crop type and District (Kg/Ha)
Source: NISR, 2020

4.2.3.1 Challenges and Potentialities for irrigation

To address the situation of irrigation in Bugesera, this section will highlight the challenges and the impacts on crop productivity as well as potential targets for increasing irrigation. Potential irrigation areas are found along rivers, lakes, marshlands and water dams domains on a total of 53,595ha. The lake potential irrigation areas are on lakes Cyohoha, Gashanga, Kidogo, Mirayi, Kirimbi and Gaharwa, leaving the marshlands evenly spread within the District. Potential irrigation areas are distributed in the standalone marshlands, lake and river domains with the proportions of 23,845ha (44.5%), 17,115ha (31.9%) and 11,507ha (21.5%), respectively. The rest of the areas is computed to the dam domain at 1,129ha. After prolonged and repeated drought since 1998 in Bugesera, resulting in food insecurity and massive population movements, the Government has put in place irrigation infrastructure starting from development of marshlands in the past 20 years.

The work started by exploiting of eight (8) marshlands (2,004ha) for quick food security restoration equivalent to 3,551ha. The developed marshlands constitute the small scale developed marshlands such as Ruvubu, Rwintare, Gatare, Rwabikwano, Nyabuliba and Kibaza and the large scale developed marshlands in the river basin including Rurambi (850ha) and Gashora (750ha). This contributed to the food security but could not reach the production targets for major staple crops in Bugesera area including rice and market-garden crops. Rurambi area is divided into about 600ha for rice production and the rest for stevia and other vegetables.

Regarding this trend, it is evident that the target has not been reached and there is still a long journey to take. Therefore, irrigated areas need to be rehabilitated or fully developed. In this context of increasing and optimizing irrigated areas, comprehensive studies are on-going to achieve the expected productivity of staple crops. These include 16,000ha under feasibility study and detailed work design in Cyohoha North (2,630ha), Gashora (2,850ha) and Rweru

(4,797ha) which are combining both marshland and hillside irrigations. Further, small scale irrigation has potentially been promoted in Bugesera to support smallholder farms reaching 3,000ha in all sectors of Bugesera within the past four (4) to five (5) years. It is planned to achieve 250ha every year using these small scale irrigation technologies to combat drought and subsequent yield decline in Bugesera.

Some developed irrigation lands have been seriously destroyed owing to the massive flood waters resulting from poor water control in the river basins. In addition, the developed land possess some gaps in terms of catchment protection, inducing siltation and erosion, poor management and maintenance, and inappropriate agriculture practices. Another challenge is limited funding to develop irrigation projects, for instance the cost of developing hillside irrigation is estimated at between $ 10,000 and $ 18,000 per hectare. Similarly, small scale irrigation technologies are quite expensive for rural farmers, estimated at 1,000-3,000 USD per ha depending on instruments used, proximity to water source, e.t.c. even when subsidy is considered. Innovative technology of using solar systems is being promoted in the Eastern part including Bugesera District due to its cost effectiveness related to lower operation cost as well as green technology.

The challenges discussed above hinder the achievement of the expected yields in the Bugesera District. Thus, comprehensive interventions should be undertaken to protect hillsides, increase capacity of farmers, and install continuous monitoring of irrigation infrastructures by local and other responsible entities (RAB, District, RWB). Yield gaps observed in season "A" 2020 for major crops are still low compared to the standard productivity in the research experimentation from RAB. The yields for maize, rice, cassava, bean and banana plantains were 1.7, 3.2, 17.0, 0.7 and 10.5 t ha^{-1} (SAS, 2020), respectively. To continue strengthening food security, yields can be boosted towards the respective ranges of 4.0-5.0, 7.0, 60, 3 and 35 t ha^{-1} with increased investments in agricultural technology such as irrigation, among others. Other options are to establish strategy for operating and maintaining irrigation-drainage infrastructures through enhanced involvement, commitment and ownership by the beneficiary farmers via Water User's Organizations (WUOs) and District Irrigation Steering Committees (DISCs). Development of new models with participatory approach in which youth and other private investors can provide SSIT equipment and services to farmers is encouraged **(See Table 14)**.

Table 14: Comparison of productivity of Bugesera farms versus RAB experiment plots (t ha-1)

Crop	Current production*	Standard productivity at RAB experimental plots**
Maize	1.7	4.0-5.0
Rice	3.2	7.0
Cassava	17	60.0
Beans	0.7	3.0
Banana plantains	10.5	35.0

***Source: SAS (2020)**

Although the ecological conditions do not necessarily need irrigation, the low water retention capacity and several climate change issues caused farmers to adopt irrigation technologies. Currently, climate change issues bring some irregularity in rainfall patterns and to an extent, erratic and aggressive rainfall events can destroy crops in the valleys by flooding and erosion on hillsides with torrential rainfall drops. Irrigation is envisaged to provide resilience while growing seasonal crops. Musanze has limited marshlands which are potential for irrigation, though the only one that can be considered is Mukinga marshland. The latter has been developed by RAB under Quick Win Marshland Development Plan (QWMP) but it needs more improved sustainable management and maintenance. The current youth organization HORECO needs to transmit knowledge to beneficiaries exploiting the lands for increasing ownership and sustainability of agriculture production systems. Otherwise, once the HORECO leaves, it will be a big loss of production on up to 204ha of the marshland bordering both Musanze and Gakenke Districts. This marshland touches the sectors of Cyabingo, Kivuruga, Remera, and Rwaza.

The landscape (topography) and ecological conditions of Musanze District generally favour promotion of small scale irrigation. Thus, the Government promoted its use reaching 30ha in the three year (3) period (2017-2020). Similar challenges on irrigation are experienced in both Bugesera and Musanze Districts, specifically in relation to low capacity building, farmers' low financial capacity and poor maintenance/management. However, irrigation is apparently less relevant compared to the predominant issues of land degradation such as erosion, linked to socio-economic conditions. These water related problems have also contributed to low productivity of major crops in Musanze. In the SAS (2020), the average yields for maize, cassava, climbing beans, bananas , sweet potatoes and Irish potatoes are approximately 1.9, 5.5, 0.7, 12.6, 8.1, and 12.0 t ha^{-1}. These results are far below compared to optimal production as shown in **Table 15**. For potato, the potential can reach 40-60 t ha^{-1}. The limitation of funding further affects the planned irrigation coverage area in the small scale aspects. For instance, the District planned to achieve 70ha under SSIT but it only covered 10ha in the fiscal year 2018-2019.

Table 15: Comparison of productivity of Musanze farms versus RAB experiment plots (t ha-1)

Crop	Current production*	Standard productivity at RAB experimental plots**
Maize	1.9	6-10
Climbing beans	0.7	3
Cassava	5.5	30-40
Sweet potato	8.1	8-23
Irish potato	12.0	42
Banana plantains	12.6	46-56

***Source: SAS (2020)** Sources: 75-82 references[75]**

[75] 75. Musoni, A., Buruchura, R., Kimani, P. M., 2001. Climbing beans in Rwanda: development, impact and challenges, PABRA Millenium Workshop, Arusha, Tanzania.

With respect to agricultural irrigation, **Figure 6** shows that the proportion of households that practiced agricultural irrigation is still low in both Bugesera (11.2%) and Musanze (2.4%) Districts. Furthermore, surface irrigation is predominant in Bugesera (77.3%), whereas traditional techniques are still highly adopted in both Districts (NISR, 2017).

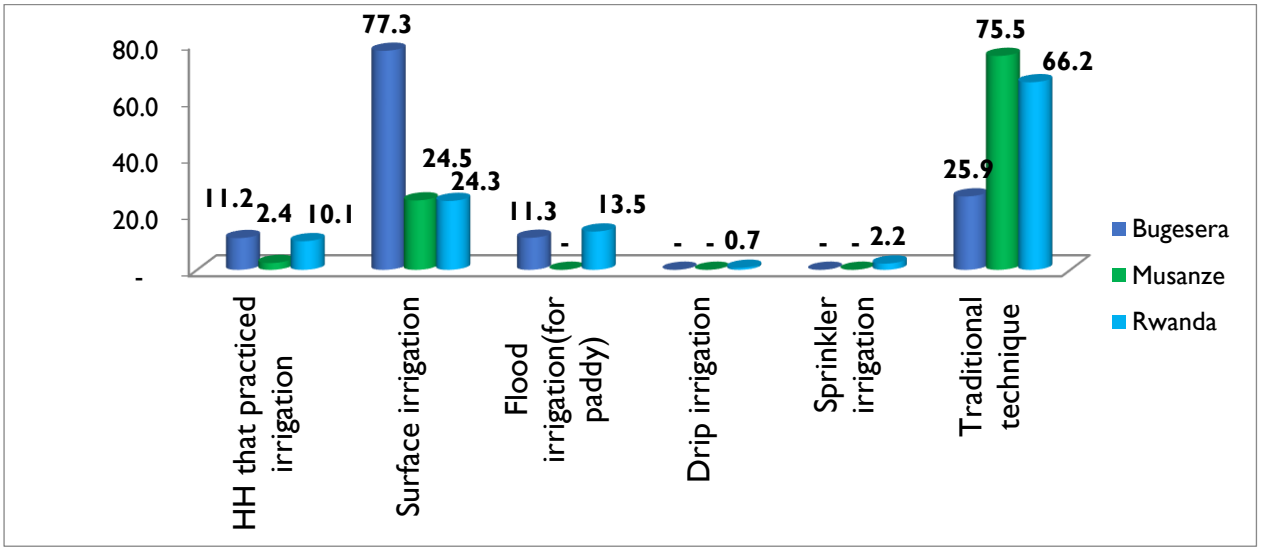


Figure 6: % of HHs practicing irrigation in Bugesera and Musanze Districts
Source: NISR (2017)

Nabahungu (2013) pointed out that very acidic soils (pH<5.0) occupy 50% of the country's area, whereas soil heterogeneity is high. According to Rushemuka, Bock and Mowo (2014), Rwandan soils are categorized into three fertility classes (**Table 16)**. However, given the complex soil scape of Rwanda, the adoption of soil-related technology recommendations is specific to agro-ecological zones (AEZs).

Table 16: Soil fertility classes in Rwanda

Fertility classes	pH	Proportion (%)	Fertilizer requirements to be productive
Fertile soils	>5.5	27.4	They need manure for fertility maintenance
Medium fertile soils	>5.2<5.5	29.5	They require manure + inorganic fertilizers
Infertile soils	<5.2	43.1	They need a combination of lime, manure and inorganic fertilizers

76. RAB, 2012. Bean Varieties Information Guide. Rwanda Agriculture Board.
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Source: Rushemuka, Bock and Mowo (2014)

4.2.4 Water Dimension

According to the District's DDS (Bugesera District, 2019), Bugesera District hydrographical network is mainly characterized by three (3) rivers, namely Akanyaru, Akagera and Nyabarongo. Besides rivers, the District has nine (9) lakes which can be exploited for fishing, tourism, transportation, power generation, agricultural irrigation and farming among others.

4.2.4.1 Groundwater quality

In Rwanda, water pollution is rampant especially when it comes to floods, through downstream pollution in rivers and lakes; hence degrades wildlife habitats and contributes to human health problems (MININFRA, 2018). The **Table 17** presents the quality of groundwater of samples from springs, boreholes, and wells from Bugesera and Musanze Districts as assessed by Nsengimana, Masengesho and Nyirimbibi (2012) from 2004 to 2009. The results indicated different levels of pollution of groundwater in Bugesera and Musanze Districts.

Table 17: Parameters for groundwater samples from Bugesera and Musanze Districts, 2012

Parameters	WHO standards	Musanze District		Bugesera District
		Kigombe	Mpenge	Rwakibirizi
Physical tests				
T^{0}C	20-40	22.36	22.23	22.4
pH	6.5-8.5	7.66	7.16	5.43
Electric Conductivity (µs/cm)	500	1,160.33	855.33	112.4
Turbidity (NTU)	<5	3.33	1.66	1.09
Dissolved oxygen (mg/l)	-	5.33	6.06	-
TDS (mg/l)	500-1,000	812.23	601.06	52.7
Alkalinity (mg/l)	120	462	418	ND
Nutrients and Heavy Metals				
Color (PtCo)	-	23.66	11	-
S.M (mg/l)	-	5.3	2	-
Total hardness (mg/l)	100-300	652.6	466.6	32
Tca (mg/l)	-	383.6	297.6	9.6
TMg (mg/l)	-	269.3	169	2
Cl^- (mg/l)	-	0.23	0.3	1.1
F^-(mg/l)	-	0.47	0.37	0.08
NO_2^- (mg/l)	0.015	0.263	0.017	ND
NO_3^- (mg/l)	30	35.05	17.06	1.3
SO_4^{2-} (mg/l)	-	6	3	4
PO_4^{3-} (mg/l)	-	0.58	0.6	0.31
Cu (mg/l)	0.05	<0.01	<0.01	0.01
Mn (mg/l)	-	0.081	0.059	ND
Cr (mg/l)	0.05	5.4	6.37	2.06
Pb (mg/l)	-	<0.5	<0.5	0.24
Cd (mg/l)	-	<0.1	<0.1	0.01
Zn (mg/l)	-	<0.01	<0.01	0.13
Fe (mg/l)	-	0.18	0.04	0.05

Source: Nsengimana, Masengesho and Nyirimbibi (2012)

By assessing the quality of groundwater wells in Ruhuha Sector in Bugesera District where six (6) samples were collected from three (3) sites in 2015, Nigatu et al. (2015), it was established that groundwater wells may receive pollutants from different anthropogenic activities carried out in its surrounding areas like farming, fishing, and improper disposal of solid waste transported through soil erosion and agriculture runoff. It was also indicated that some of the water wells are chemically and physically polluted and are unfit for human and livestock consumption (**Table 18**) where there is a benchmark of WHO standards and data for 2015.

Table 18: Parameters for groundwater samples from Bugesera District, 2015

Parameters	WHO standards	Test results for all samples
Physical tests		
pH	6.5-8.5	From 5.5 to 6.3
Temperature (^{0}C)	20-40	From 24 to 26.4^{0}C
Electrical conductivity (EC) (µs/cm)	400-1,300	From 128 to 335 µs/cm
Turbidity (NTU)	<5	From 2.05 to 4.05 NTU
Total Dissolved Solid (TDS) (mg/l)	500-1,000	From 70.51 to 195 mg/l
Alkalinity (mg/l)	120	From 153 to 224 mg/l
Nutrients and Heavy Metals		
NO_3^- (mg/l)	1-50	From 1.8 to 4.2 mg/l
PO_4^{2-} (mg/l)	0-5	From 0.16 to 0.64 mg/l
Fe (mg/l)	0.01-3	From 0.02 to 0.3 mg/l
Zn (mg/l)	1-2	From 0.01 to 0.1 mg/l
Mn (mg/l)	0.1-0.8	From 0.122 – 0.420 mg/l

Source: Nigatu et al. (2015)

Similar situation on water pollution was established for 40 samples from springs, boreholes and wells across the country (Nsengimana, Masengesho and Nyirimbibi, 2012); for groundwater wells from 12 sites in Muhanga District (Nigatu et al., 2015); and 55 sites in the Mutara grasslands in Nyagatare District (Dusabe et al., 2019). According to REMA (2019), population growth has increased pressure on land and forests for agriculture and settlements, resulting in land degradation, siltation of water bodies and reduced water quality (**Figure 8**).

Water quality testing results from River Nyabugogo downstream of Lake Muhazi was revealed to be characterized by high loads of e. coli and coliform bacteria (and others not measured) from untreated sewerage effluence; high organic loads and high Biological Oxygen Demands (BOD) and chemical oxygen demands resulting from low concentrations of oxygen; and high sediment loads and turbidity from agriculture and mining activities. Mukanyandwi et al. (2019) revealed that pollutants are easily transported into water bodies during the rainy seasons in urban and rural areas to a greater extent than during the dry seasons. These studies suggested that water protection measures are urgently required, for example, to reduce waste water influx (via sanitation programs) and to maintain soil integrity in upstream areas.

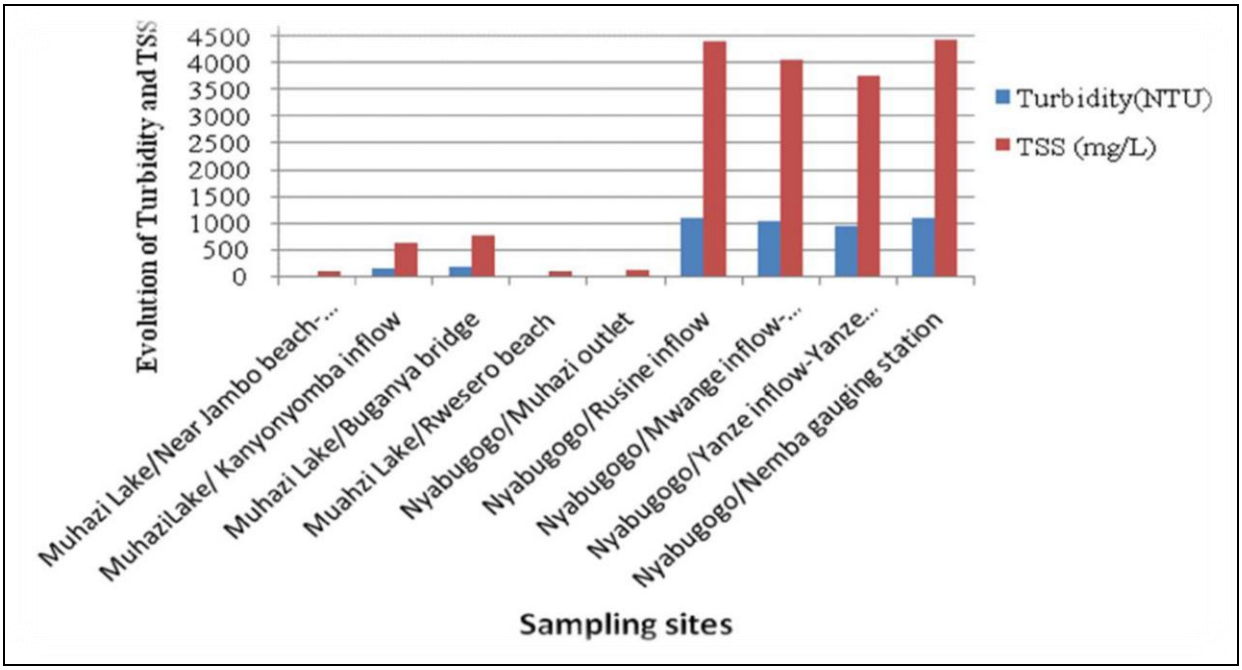


Figure 7: Water quality measurements in Nyabugogo catchment
Source: REMA (2019)

4.2.4.2 Quality of harvested water

According to (MINELA, 2011), the quality of rainwater harvested from rooftop does not usually meet the WHO guidelines for drinking water quality, particularly for bacteriological quality. **Table 19** provides the results of physico-chemical and microbiological analysis of water samples taken from tanks installed by CUEP project in Bugesera District. Water samples were taken from Murama primary school and water tank beneficiaries of Rilima and Rweru Sectors. Results indicated that if the harvested water was consumed without any treatment, it could cause bacterial water borne diseases such as diarrhea and typhoid fever.

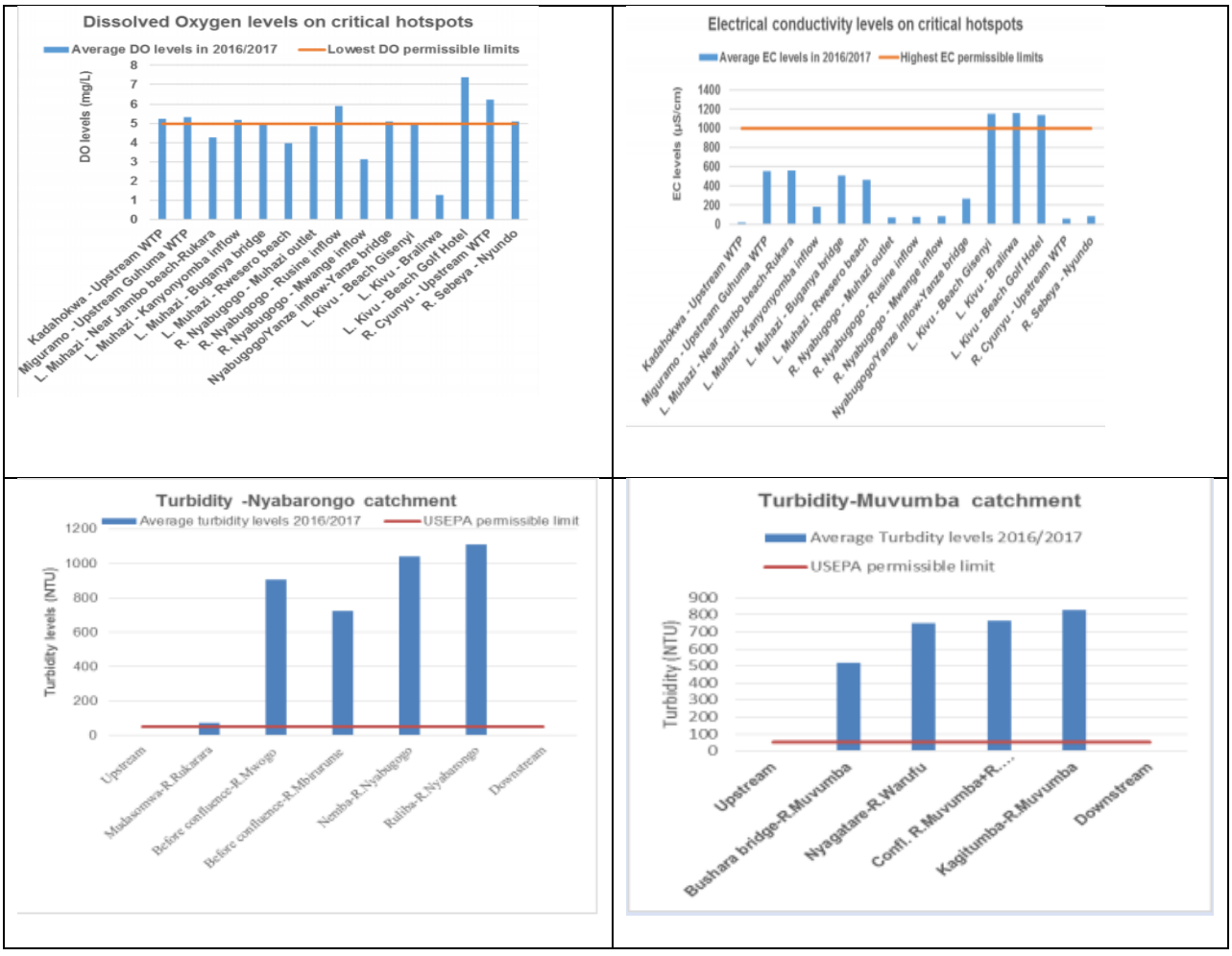
Table 19: Physico-chemical and microbiological results of harvested water tank samples

Parameters	WHO standards	Test results
pH	6.5-8.5	6.41-6.99
Electrical Conductivity (µs/cm)	50-500	10.36- 65.1
Turbidity (NTU)	5	2.75- 4.28
Iron (mg/l)	0.3	0.004- 0.006
Hardness (mg/l)	300-600	8-48
Chloride (mg/l)	250	0.10- 0.40
COD (mg/l)	2	4-7
BOD (mg/l)	5	1.95- 3.21
Total germs (Cfu/100ml)	300	$3x10^{1}$- $6x10^{1}$
Faecal Califorms (Cfu/100ml)	0	$<1x10^{0}$
E. Coli (Cfu/100ml)	0	$<1x10^{0}$

Source: MINELA (2011)

4.2.4.3 Water quality in lakes and rivers

According to RWFA (2017), poor agricultural practices and poor mining on steep slopes as well as discharges of wastewater from domestic and industrial facilities are the principal cause of poor water quality in Rwandan water bodies and this may affect aquatic ecosystems, reservoir and river siltation, excessive nutrient loads and drinking water quality. For example, dissolved oxygen (DO) levels were within the permissible limits in Nyabarongo and Rusizi catchments. However, DO levels crossed the lowest allowable threshold for different sites considered in Muvumba catchments and on key hotspots (Muvumba, Warufu and Kagitumba). **Figure 8** shows (i) high turbidity in all catchment as a result of soil erosion; (ii) Lake Kivu and Lake Muhazi recorded high values of pH and salinity (Electrical Conductivity and Total Dissolved Salts); and (iii) sites such as Lake Muhazi, Lake Kivu (Bralirwa), River Akanyaru downstream, River Rusizi at Kamanyora as well as River Rusine have low DO levels indicating pollution by organic matter.



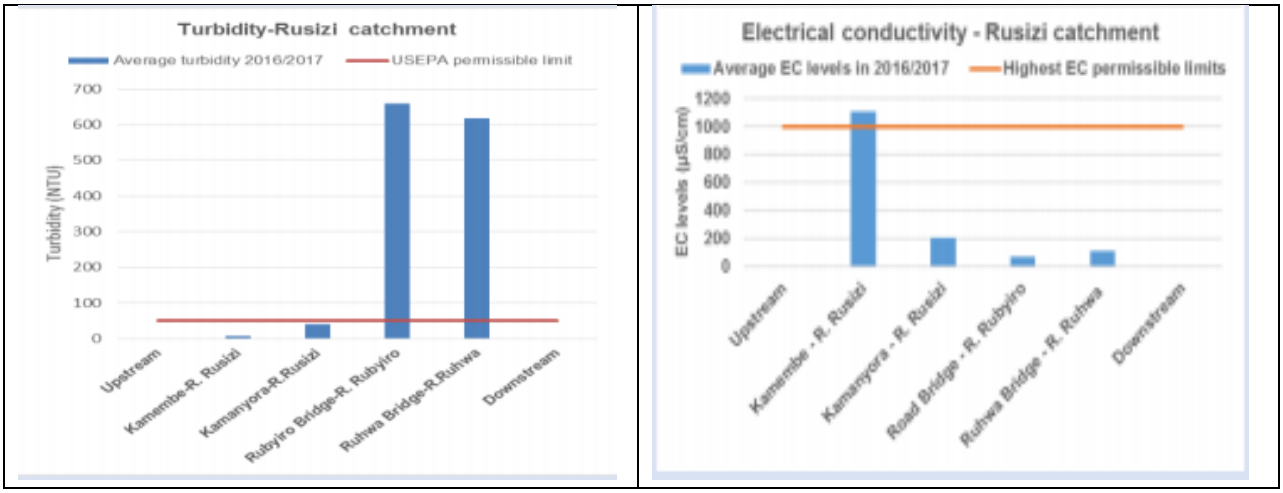


Figure 8: Water quality in some of the catchments in Rwanda.
Source: RWFA (2017)

4.2.5 Fishery Dimension

The lakes in Bugesera District contain fish such as *Tilapia, clarias, soles, silurids*, etc. Hydrological network of Musanze District is made up of Lake Ruhondo and rivers of Mukungwa and Mugara which provide low fish production. Fish farming activities are found in sectors of Gacaca, Gashaki, Remera and Rwaza (Musanze District, 2018).

According to REMA (2015), there has been "increased fishing pressure, heightened illegal, unregulated and unreported fishing, and increased unmonitored fish movements; all driven by increased fish demand and inadequate fisheries and aquaculture management framework." The results have been the depletion of natural fish stocks. In the last years, there has been significant increase in fish production (**Table 20)**. However, an increase in fish harvests is not an indicator of the health of fish stocks. In many cases, it points to over-fishing.

Table 20: Trend in fish harvests in Rwanda's main fishing areas (in thousands of tons), 2008-2013

Zone	2008	2009	2010	2011	2012	2013
Musanze	244	220	482	166	717	-
Rwamagana	3,313	1,377	658	1,058	1,438	-
Kivu	8,121	9,484	10,601	10,438	15,333	-
Other zones	0	0	0	-	1,857	-
Total	**11,682**	**11,445**	**11,741**	**11,662**	**19,344**	24,550

Source: REMA (2015)

Turbidity in surface water can have adverse effects including inhibition of photosynthesis, reducing aquatic plant and algae growth as well as reducing visibility for fish and other aquatic species (RWFA (2017). According to (REMA, 2015), mining activities in Mukura Forest Reserve have led to degradation and decline or extirpation of indigenous fish species in the Nyabarongo-Akagera rivers system. MINAGRI (2011) pointed out that, due to soil erosion, most rivers are heavily silted rendering would be potential aquaculture sites unsuitable.

4.2.6 Forest Dimension

The high demand of forest products led to poor harvesting practices and over exploitation of forest especially in private owned forests which constitute the highest portion of the national forest cover. Consequently, frequent soil erosion was observed, washing the top arable land and resulting in poor soils quality and reduced crop yield on eroded land (MINILAF, 2018). According to (MINILAF, 2017), between 1960 and 2007, natural forests declined considerably by about 64% due to different anthropogenic activities and resettlement of refugees. However, between 1990 and 2000, Rwanda gained an average of 2,600 hectares of forest per year, equivalent to an annual reforestation rate of 0.82%. The rate of habitat conversion was 50% in the period 1990 – 2005. The **Table 21** shows that the cover of natural forest was reduced by 45.3% between 1984 and 2015. Global Alliance for Clean Cookstoves (2012) pointed out that Rwanda lost 37% of its forest cover (around 117,000 ha) just between 1990 and 2010 (20 year period).

Table 21: Change over time of key natural forests in Rwanda, 1984-2015

Name of the natural forest	Area (ha) 1984	Area (ha) 2015	% Loss
Buhanda	1,116	18	98.4
Gishwati	21,213	1,440	93.2
Mashuza	85	6	92.7
Ibanda-Makera	1,425	169	88.1
Karama	3,235	1,061	67.2
Dutake	31	11	65.7
Karehe-Gatuntu	48	19	60.3
Nyagasenyi	45	19	58.2
Akagera National Park	267,741	112,185	58.2
Mukura	4,376	1,988	54.6%
Sanza	49	24	51.0
Mashoza	36	18	51.0
Muvumba	1,286	688	46.5
Ndoha	39	29	26.0
Kibirizi-Muyira	454	352	22.4
Busaga	191	159	16.9
Nyungwe National Park	112,230	101,005	10.0
Volcanoes National Park	16,128	16,004	0.8
Total	**429,728.5**	**235,192.3**	**45.3**

Source: MINILAF (2017)

From the past experience of drought in the Bugesera District, much effort has been made in afforestation. Currently, there are 7,684 ha of forest (woodlots). The share of private forests is 20.6%, 1.16% for District forests, and 78.2% for state forests. However, high demand of trees (for timber and wood) and use of charcoal in the District leads to deforestation. It is estimated that 91.4% of the households use firewood as source of energy for cooking, 7.5% use charcoal (Bugesera District, 2019). About 29.7% of the surface in Musanze District is covered by forest. Currently, there are 11,616ha of forest in the District. These comprise of 2,517ha of bamboo forests, 2,223ha of degraded natural forest, 1,626ha of eucalyptus forest plantation and 5,250ha of mountain humid forest. The share of private forests is 74%, 2% for

District forests, and 24% for state forests. There is a high reliance on forest products. Statistics show that 80.7% of the households use firewood as source of energy for cooking, and 18.7% use charcoal (Musanze District, 2018).

Figure 9 shows that Bugesera and Musanze Districts are some of the Districts with low forest cover. Therefore, more efforts are needed in afforestation within the Districts.

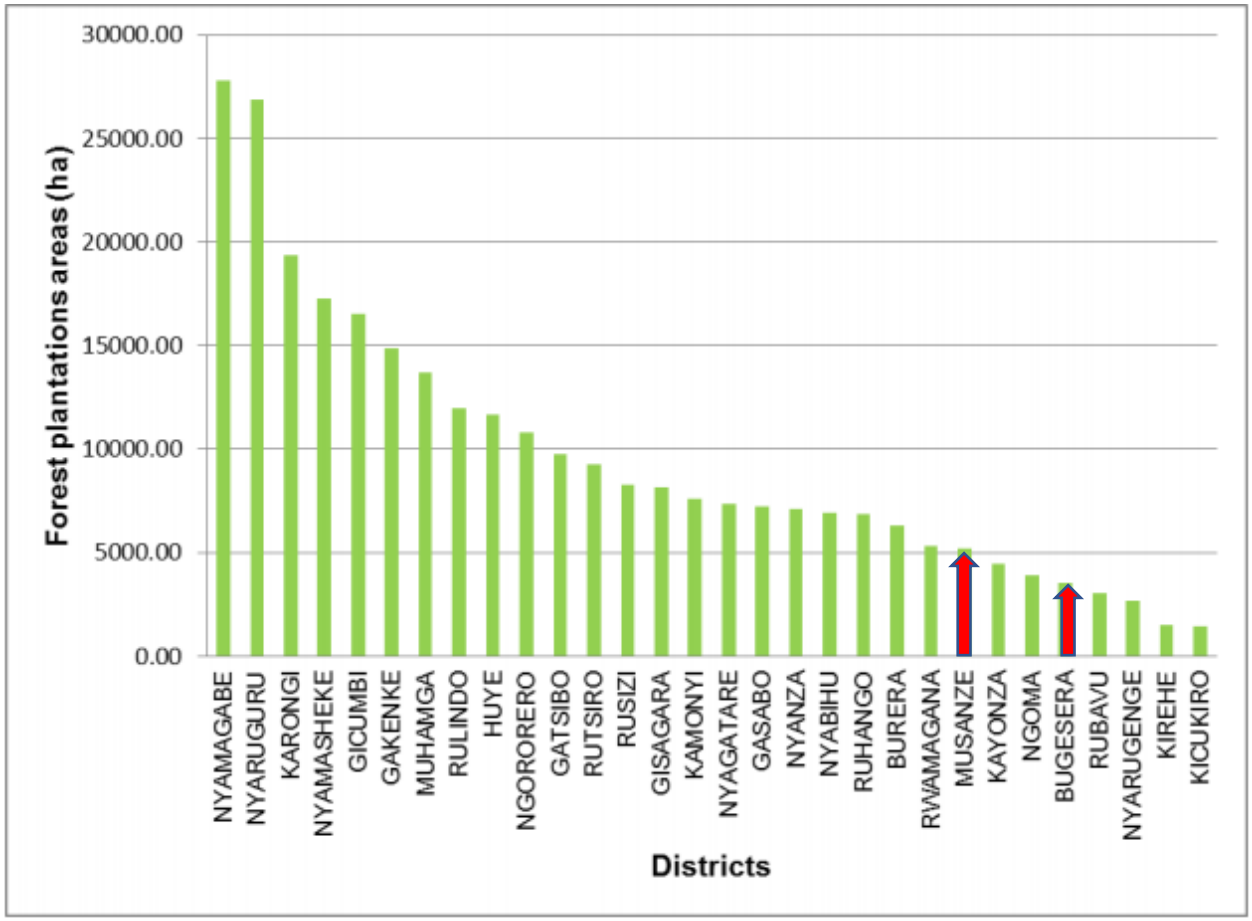


Figure 9: Distribution of forest plantations areas by District (excluding natural forests[76])
Source: Nduwamungu et al. (2013)

The **Table 22** shows that Musanze District has larger forest cover of 36% compared to Bugesera District with 17.5% cover.

Table 22: Summary statistics of forest cover in Bugesera and Musanze Districts

District	Total land without water (Ha)	Total forest cover (Ha)	% Forest cover
Bugesera	122,543	21,479	17.5%
Musanze	50,717	18,091	36.0%

Source: Forest cover Mapping Report, 2019

[76] Forest plantations are included here because most natural forests are protected but also in order to portray the reforestation effort

The **Table 23** shows that Musanze District has more Forest plantation by size compared to Bugesera District.

Table 23: Forest plantation by size in Bugesera and Musanze Districts

District	Forest with area less than 0.25ha	Forest with area between 0.25 & 0.5ha	Forest with area between 0.5 & 1 ha	Forests with area between 1 & 2 ha	Forests with area greater 2ha	Grand Total
Bugesera	738	797	933	911	3,130	6,508
Musanze	1,066	816	927	949	4,340	8,099

Source: Forest cover Mapping Report, 2019

The **Table 24** indicates the Deforestation and afforestation status in Bugesera and Musanze Districts where the Deforestation and Afforestation rates are 21.9 % and 20.9 % for Bugesera and 4.7 % and 17.3 % for Musanze District.

Table 24: Deforestation and afforestation status in Bugesera and Musanze Districts

Districts	FC2019 (ha)	FC2009 (ha)	Deforested area (ha)	Afforested area (ha)	No change (ha)	Deforestation rate (%)	Afforestation rate (%)
Bugesera	20,723	20,922	4,573	4,374	16,349	21.9	20.9
Musanze	17,018	15,113	712	2,618	14,400	4.7	17.3

Source: Forest cover Mapping Report, 2019

4.2.7 Minerals and stones

Bugesera District is characterized by plateaus for which the sides and the tops are made up of rocks and schist which contain gravel, lateritic soil and quartz. They provide quarry stones for construction works. The District has mineral deposits and quarries for mining development (coltan, cassiterite, sand, stones, peat, wolfram, clay soil). However, mining is still traditional (Bugesera District, 2019).

According to the Musanze District's DDS (Musanze District, 2018), mineral deposits are some of the potentialities of the District. They are travertine, cassiterite and volcanic stones which are found in the sectors of Busogo, Gashaki, Muhoza, Nkotsi, and Rwaza; and coltan and wolfram found in Muko Sector. Weak mining, exploration licensing system and insufficient inspection capacity to enforce good practices are the main challenges in this area.

4.3 Challenges/gaps for poverty reduction and ENRs

According to the existing literature, population growth and population density contribute to environmental degradation. Bugesera District has a total Population of 363,339 people, with a population density of 282 people per km^2 and the average annual population growth rate is 3.1% (Bugesera District, 2019). Musanze District has a total population of 368,563 people, a population density of 695 habitants per km^2, and an average population growth rate of 1.8% (Musanze District, 2018). It has also been established that the effects of the population on the environment can be mitigated through education programs focused on improving environmental awareness among the population as well as the use of modern technologies that

are environment friendly (NISR, 2018a). About 13.8% of the households in Bugesera District and 28.3% in Musanze District indicated that they did not receive any information regarding environmental issues (NISR, 2018a).

It is worthy to mention that waste management remains a concern in both Districts. In Bugesera District, 17.5% of the households disposed their domestic wastes in bushes or fields and only 78.0% had composts. Within the towns, the households that used public rubbish was rated 0.0% (NISR, 2015b). In Musanze District, 53.6 % of the households threw their domestic wastes in bushes or field and only 43.3% have composts. In the town, the rate of households that use public rubbish was 3.0% (Musanze District, 2018).

The Districts applied Strengths, Weaknesses, Opportunities and Threats (SWOT analysis in identifying the gaps and challenges which appear in their respective DDS as mentioned in the **Table 25** summarizing some of the challenges/ gaps in poverty reduction and protection of ENRs in the Bugesera and Musanze Districts.

Table 25: Poverty and ENRS related challenges/gaps in Bugesera and Musanze Districts as identified in the DDSs

Areas	Bugesera District (DDS Bugesera District)	Musanze District (DDS Musanze District)
Agriculture and Animal Resources Sector	Soil erosion Availability of unexploited arable land and swamps. Insufficient use of improved seeds and fertilizers. Over-reliance on rain-fed agriculture: Insufficient irrigation and mechanization infrastructures. Limited of agriculture processing industries. Climate change effects due to shortage of rainfall (droughts). Natural calamities destroy basic infrastructures like feeder roads during rainy season, causing loss of people, livestock, trees and crops.	Soil erosion and landslides Climate variability and change High acidic soil Insufficient agriculture inputs (seeds and fertilizers). Floods and landslides caused by rainfall from volcanoes
Energy	Lack of enough budgets to acquire electrical infrastructures to install high and medium voltage lines to connect remote areas with electricity (schools, health facilities, Sectors, etc.). Lack of access to electricity to both on- and off-grid connections to all desired HHs. Limited financial capacity of the HHs to access to both on- and off- grid connections.	Environmental calamities Unaffordable off grid electrification specifically biogas and solar energy Limited resource for poor HHs to have accessibility to electricity
Water & sanitation	High level of vulnerability to climate change. Insufficient clean and safe water in all sectors and other sanitation facilities in cells, sectors,	Climate variability and change Limited access to clean water and improved sanitation

Areas	Bugesera District (DDS Bugesera District)	Musanze District (DDS Musanze District)
	schools, hospitals and other public institutions. Limited innovation and modern technology use to recycle used water. Pressure on land leading to destruction of critical watersheds and water catchments. Inadequate water and waste management systems; Prolonged drought season which limits water availability;	Inexistence of integrated Solid waste management Weak storm water drainage system Inadequate water and waste management systems Water pollution
Urbanization & rural settlement	Inadequate rain water harvest: This has resulted in streams of rain water runoffs emanating from people's houses and the creation gullies especially on steep hill slopes. Lack of landfills and public latrines. Lack of solid waste and sewage treatment Lack of houses for vulnerable people in category one	Limited rainwater harvesting facilities Environmental calamities Insufficient budget to relocate HHs in high risk zone to planned settlement villages Floods and landslides caused by rainfall from volcanoes
Mining	Lack of safety measures for miners who use traditional methods of mining	Poorly developed: Weak Mining and Exploration licensing system and insufficient inspection capacity to enforce good practice
Forestry	Shortage of rains Deforestation due to intensive usage or need of charcoal and trees (timber or wood)	Climate variability and change; Poor and unsustainable forest management Over exploitation of forest resources
Health	Limited specialized medical staff. Limited modern health equipment. High stunting prevalence, malaria and communicable diseases. Some households without improved latrines and waste management. Many people who do not access health care (geographical accessibility)	Limited geographical access to health services Expensive health services Inadequate health services
Employment	Limited programs for youth and women skill development for job creation	Limited resources for youth to start their own business

Source: Bugesera District (2019) and Musanze District (2018)

4.4 Lessons learned from DDS and Imihigo

The study identified a number of lessons learned in terms of development plans. In order to achieve the Strategic Development and Performance Contracts in both Districts, there is need to initiate an effective collaboration with different stakeholders and partners at all levels, including central government ministries and agencies, private sector and civil society.

The study noted that the successful implementation of the DDS and performance contracts has been supported by an effective monitoring and evaluation system in the two Districts. To

facilitate regular monitoring and evaluation, the Districts have established comprehensive management Information System including well-structured and computerized database with quantitative and qualitative indicators, which have supported annual monitoring of the evolution of achievements and changes.

The study observed that it is paramount for the Districts to monitor and evaluate all their planned actions at the Districts, sectors and cells levels to see whether the implementation is being undertaken in line with the plans. Monitoring and evaluation have been ensured by the offices of the Cells, Sectors and Districts Development Committees in collaboration with other development partners.

4.5 Description of multi-dimensional poverty indicators

Currently, Poverty-Environment mainstreaming constitutes a powerful practice to help in eradicating poverty, reducing inequality and weakening environmental degradation. It is obvious and widely accepted that poverty eradication goes hand in hand with sustainable management of natural resources. Thus, economic development and poverty reduction strongly depend on improving management of the environmental natural resources, called the "natural capital" of the poor. Natural capital is determinant to this extent as it includes the major contributions to society and the economy of forests, water bodies, wetlands and agricultural land, etc.

Poor and vulnerable groups are disproportionally dependent on ecosystem services for their livelihoods, and therefore can be most affected by environmental natural resource degradation and ecological shocks (World Bank, 2005). For monitoring the impact of natural resource degradation on the poor households and identifying policy measures to stem the problems faced by the poor people, a set of poverty –natural resources indicators has been proposed.

From a broad definition, a poverty-natural resource indicator is one which changes when "better management of a natural resource leads to decline in poverty". Thus, the proposed indicators, in **Table 26** and **Table 27** are most commonly used and considered as a sample of those with broad utility for monitoring the natural resource related factors that affect the income, food security and vulnerability of poor households in developing countries, including Rwanda. Nevertheless, these indicators also need to be used with caution due to the complex nature of poverty-environment linkages in Rwanda.

Table 26: Multi-dimensional Poverty Indicators for Bugesera & Musanze Districts

Poverty Dimensions	Indicators (%)		Bugesera	Musanze
Education	School attendance		84.8	88.6
	Dropout rate in primary education		9.6	6.5
	Dropout rate in secondary education		2.5	6.3
	Repetition rate		12.1	12.0
Housing	Electricity		18.8	32.3
	Type of habitat	Isolated rural housing	6.8	18.1
		Unplanned clustered	8.9	7.6
	Floor materials	Beaten earth	76.9	74.8

Poverty Dimensions	Indicators (%)		Bugesera	Musanze
		Dung hardened	0.0	0.0
	Material Wall (housing)	Mud bricks	39.4	36.9
		Tree trunks with mud	12.0	29.8
	Source of cooking energy cooking	Firewood	91.4	80.7
		Charcoal	7.5	18.7
	Land ownership		71.0	78.4
Public Services, Social services & Economic Activity	Improved sanitation		87.0	83.2
	Safe drinking water		77.5	92.5
	Garbage disposal	Bush	69.6	53.6
		River or lakes	0.0	0.0
	Health insurance	Mituelle de santé	83.0	79.0
	Access to health care facilities*		See notes below	
	Working only in subsistence agriculture activities		59.0	44.5
Health	Nutrition (for U-5 Children)	Stunting	25.0	37.0
		Underweight	9.0	8.0
		Wasted	1.0	1.0

Source: NISR, MOH & ICF (2015), NISR (2018)

4.6 Results of ENR - MPI in Bugesera and Musanze Districts

In this study, the ENR-MPI Model results were computed, applying the following parameters of ENR-MPI: The Percentage of the population in multidimensional poverty (Headcount Ratio - H), the Average % of weighted deprivations (Intensity of deprivation among the poor - A) and Adjusted Headcount Ratio (M0 = H*A). The Censored Headcount Ratio of an indicator is the proportion of the population that is ENR multidimensional poor and has been simultaneously deprived in each indicator; each dimension and their indicators have a percentage of people who are poor and deprived as shown in the column of deprivation cut-off; where the population in the households experienced and was affected by the ENR problems in the system of livelihoods.

The properties of the Multidimensional Poverty Index were pursued to determine the values of ENR-MPI Model. The **Table 27** presents the distribution of ENR-Multidimensional poverty in both Districts.

Table 27: The Percentage of the population ENR- Multidimensional Poor (H) and (k=36.3%) per ENR-Linked Indicators in Bugesera and Musanze Districts

ENR Dimensions	ENR-Linked indicators	(%) of Population who are ENR-Multidimensional Poor in BUGESERA District	(%) of Population who are ENR-Multidimensional Poor in MUSANZE District
Natural resources of soil	Soil infertility in plot for farming	26.5	15.0
	Drought events	33.4	15.6
	Soil erosion	33.3	20.0
	Destructive rain	9.7	24.6
	Landslide	7.2	19.0
	Nutrition	28.8	19.3
	Health	13.3	10.9
	Land degradation	33.3	20.0
	Agro foresting	16.9	11.2
Natural resources of water	Water access	18.2	3.5
	Improved water access	22.9	5.2
	Water management	30.7	15.9
Natural resources of forest	Natural forest	5.9	4.4
	Forest and woodlots plantation	16.9	11.2
	Deforestation (firewood, construction)	15.4	7.5
Natural resources of fishery	Overfishing	5.1	0.8
	Nutrition	31.6	6.0
	Education (Dropout and irregular class attendance)	2.2	0.2
	Change of water level of Lake and river water	33.4	15.6
	Temperature and windstorms in lake and rivers	28.6	13.8
Mineral and Natural stones	Quarries activities	33.3	20.0
	Education (Dropout and irregular class attendance)	0.1	0.0

Source: PEA baseline study, 2020

Table 27 presents ENR dimensions and associated indicators that are linked to poverty in each District. The following sections discuss each dimension.

4.6.1 Soil Resources

Soil as an environmental resource has great importance for population livelihoods through soil nutrients for cultivation of crops. The crops grown play a major role in food security for the populations and as a source of income. The environmental problems linked to soil cause poverty in the population and some of them were deprived and multi-dimensional poor in socioeconomic, agriculture and environment itself. The following ENR-linked indictors justify the percentage of the population who are ENR-MPI among the populations in Musanze and Bugesera Districts. The following ENR- linked indictors were examined:

- **Land plots for farming and livestock:** The plots and livestock are the main source of food security and income for the population. The ENR-MPI computed indicate that land (plots) and livestock have been affected by environmental problems linked to soil, which led the population to be ENR- multidimensional poor where 26.5% of the population in Bugesera and 15.0% of population in Musanze District are ENR-poor.

- **Drought events:** The drought events affected soil resource and led to dryness of land that negatively impacted on agriculture productivity and pastures for animal livestock. The results of ENR-MPI reveal that these effects brought 33.4% of population in Bugesera and 15.6% of population in Musanze District to be ENR-poor and deprived of soil nutrients, food security and income from agriculture.

- **Destructive rain:** The Destructive rain affected soil resource, led to soil erosion, feeder-roads and bridges were destroyed, houses in high risk zones including unplanned settlements and isolated areas were destroyed and few deaths occurred. The results of ENR-MPI reveal that 24.6 % of the population in Musanze District and 9.7% population in Bugesera District are ENR-poor and deprived of fertile soil, income from agriculture, lost houses, and missing of members who lost their lives.

- **Landslide:** Landslides affected soil resource, led to soil erosion, feeder-roads and bridges were destroyed, houses in high risk zones including unplanned settlements and isolated areas were also destroyed and few deaths occurred. The results of ENR-MPI reveal that 19.0% of the population in Musanze District and 7.2 % population in Bugesera District are ENR-poor and deprived of fertile soil, income from agriculture, lost houses, and missing household members who lost their lives.

- **Nutrition:** Nutrition and food security of the populations in Musanze and Bugesera Districts are more associated to the soil resource. The nutrition status has been affected by soil linked environmental problems where the population plunged in to poverty, which led to household food insecurity. The results of ENR-MPI reveal that 28.8 % of the population in Bugesera District and 19.3 % of the population in Musanze District are ENR-poor and deprived of Nutrition, insufficient crops harvest and other food from livestock resources to feed the family members.

- **Health:** The Health of the population is linked to the soil resources through nutrition from agriculture produce, water sources (boreholes), and earning from agriculture activities that help them to afford medical insurance and other needs related to their well-being. The results of ENR-MPI reveal that 13.3% of the population in Bugesera District and 10.9% of the population in Musanze District are ENR-poor and deprived of healthy living due to soil related problems.

- **Land degradation:** land degradation is caused by environmental problems that are linked to the soil erosion, soil contamination, deforestation, fertility decline, and other factors that

can affect unprotected soil. These can be attributed to the poverty in the population that was affected by those vectors of land degradation. The results of ENR-MPI revealed that 33.3% of the population in Bugesera District and 20.0% of the population in Musanze District were ENR-poor.

- **Agro forestry:** Agro-forestry is one of the measures for mitigating soil erosion by inter-planting trees and food crops The ENR-results indicate that the population that did not practice agroforestry on their land plots were affected by soil erosion and resulted in the ENR-poor at 16.9 % and 11.2 % of the populations in Bugesera and Musanze Districts respectively.

4.6.2 Water Resources

Water is a potential source of population livelihoods in different areas of life such as drinking, household use, soil wetness and irrigation for agriculture. The absent or insufficient of water is very precarious of livelihood of the population. The environmental problems affected water sources and led to poverty at household level. The following indicators were examined and were linked to ENR-MPI:

- **Water access:** Access to water enhances the well-being and living conditions for the populations. Divergent low access to water poses various risks to life through health-related problems, and nutrition conditions of the population. The ENR-MPI results indicate that 18.2% and 3.5% of the population in Bugesera and Musanze Districts respectively are ENR-poor due to insufficient water access. These were caused by the drought and deforestation observed in Bugesera District since 2000.

- **Improved access to water:** The improved access to water is linked to the use of potable, clean and safe water. This brings good health to the population and fighting waterborne diseases such as diarrhea, and other related water worms in human and animal bodies. The findings of the study indicate that the majority of the population in Bugesera District uses water from lakes (45%) and Akagera River (17.0%), while 12% of the citizens in Musanze District use unimproved water from boreholes and mountains. These resulted in poor health among the population emanating from water borne diseases harbored in unimproved water sources. The ENR-MPI results indicate that 5.2% and 22.9% of the population in Bugesera and Musanze Districts are ENR-poor.

- **Water management:** Water management is one of the main factors that help the populations to live safe and healthy. Rain water harvesting, sinking ponds, channeling support in agriculture activities, control of erosion and floods and reduction of other environmental hazards that are linked to poor water management are the key actions. Water management refers to maintenance of catchment areas, water sources and medium of transportation to end users including water pipes, boreholes, etc. The results indicate that the population that does not manage water is multidimensional poor where 30.7% and 15.9% of the population in Bugesera and Musanze Districts are ENR-poor due to poor management of water sources.

4.6.3 Forest Resources

The forest resource is very important in the livelihoods of the populations. The forest covers maintain the moistness of land, forest is the ground and lifesaver of biodiversity, and it is also the source of rainfall. The forests are a source of livelihoods for populations providing cooking energy source, and income from wood, charcoal and firewood. Deforestation is one of the key environmental problems that depletes or diminishes forest cover resulting in impoverishment for forest resources dependent populations. The following indicators were examined and were linked to ENR-MPI:

- **Natural forest:** The drought events in Bugesera District depleted the size of forest cover and greatly reduced hunting activities. The wanton destruction of Birunga National forest reduced dependence on forest resources. The ENR-MPI results indicate that 5.9% and 4.4 % of the population in Bugesera and Musanze Districts respectively are ENR-poor. This ENR poverty rate is linked to drought events that reduced the size of grown forests and natural forests of Gako in Bugesera District. The depleted land in Bugesera lacks moisture and makes it unsuitable for growing trees. In Musanze District, land size for planting new forest is limited compared to the need for agriculture. On the other hand Birunga National Park has banned hunting of game animals, fetching of firewood and burning of charcoal depriving the forest dependent communities of the income they would otherwise generate from the forestry based resources.

- **Artificial forest and woodlots plantation:** Both private and government owned forests play great importance to regulate climate conditions, mitigate erosion, provide source of energy for cooking, wood and timber for construction and form source of income, etc. The population who live in the deforested habitats, and continually failing to establish new forests and rehabilitate the existing ones, run the risk of encountering various challenges subsequently leading to ENR-poverty. This result is similar to the natural forest linked poverty as stated in the previous paragraphs; the ENR-MPI results indicate that 16.9% and 11.2% of the population in Bugesera and Musanze Districts respectively are ENR-poor. This is attributed to the small size of woodlots planted and owned by the populations resulting in unmet demands for firewood and timber for construction compared to the requirements of forest resources for their livelihoods.

- **Deforestation (firewood, construction):** The ENR-MPI results also indicate that 15.4% of the households in Bugesera District and 7.5% of the population in Musanze District are ENR-poor due to forest degradation that is linked to the demands for firewood, charcoal, timber and wood for construction.

4.6.4 Fisheries Resources

Fish, based on their high content in vitamins and proteins plays a major role in nutrition especially for children under two (2) to five (5) years, lactating mothers and pregnant women. Fishery activities are a source of income for citizens. Bugesera District experienced drought events and agriculture activities were largely affected by loss of labour force from citizens

residing near the lakes in Gashora and Rweru sectors near Cyohoha South shifted from agriculture to fishing activities. The ENR-indicators with fishery resource are as follows:

- **Overfishing:** Overfishing refers to over-exploitation of fishery resources including capture of below table size fish, young and old fishes and sometimes destruction of fish eggs and breeding grounds by use of inappropriate fishing gear and materials (Mosquitoes-net) and non-observance of fishing cycles. The overfishing was prohibited by the local authorities and the lakes were subsequently banned followed by fixed and officially published fishing calendar. These impacts of overfishing that led to the banning of fishing affected the population whose livelihoods are fisheries based as some of them lost their occupations resulting in reduced income from fishing. The ENR-MPI results indicated that 5.1% and (0.8%) of the population in Bugesera and Musanze Districts were ENR-poor due to lose of livelihoods.

The ENR-MPI results indicate that the population in both Bugesera District and Musanze Districts are ENR-poor due to overfishing. Lack of fish nutrients in the diet and the disrupted income from fishing negatively impacted the citizens.

- **Nutrition:** Fish is rich in vitamins, proteins and other nutrients for children (under 2-5 years), for lactating mothers and pregnant women. The drought events and ensuing overfishing in the water bodies led to the reduction in the quantity of fish consumed in the households contributing to poverty. The ENR-MPI results indicate that 31.6% and 6.0% of the population in Bugesera and Musanze Districts are ENR-poor resulting from reduced quantity of fish in the lakes due to the effects of droughts, fluctuations in temperature, and occurrence of windstorms in the lakes and rivers. These factors lead to malnutrition and food insecurity.

- **Education (Dropout and irregular class attendance):** Due to lack of school materials and low capacity to pay school fees by households, children were discouraged from attending school and school drop-out incidences was observed. Some of the children from households residing near the lakes and Akagera River opted to indulge in fishing activities instead of attending school. The ENR-MPI results indicate that 2.2 % and 0.2% of the population in Bugesera District and Musanze Districts respectively are ENR-poor due to drop-out and irregular class attendance for children who opted to undertake fishing in the lakes (commonly in Gashora, Juru, Rweru and near Lake Cyohoha).

- **Change in water level in Lake and river waters:** this refers to soil erosion, overflows and increase in flooding and water levels in lakes and rivers. This may in one way, or another, disturb the fishing activities, where the quantity of fish follows overflow and flooding. Similarly, when the quantity, volume and water levels are reduced the fish are also disturbed resulting in fish mortality. This affects the fish yields and nutrition of the population due to death of fish. There is also reduced amount of fish in the lake, insufficient fish nutrients available to the population, and reduced income from fishing activities. The ENR-MPI results

indicate that 33.4% of the population in Bugesera District and 15.6% of the population in Musanze District are ENR-poor due to Change of water level in the Lake and river waters.

- **Temperature and windstorms in lake and rivers:** temperature and wind are very important for fish productivity. The change in temperature and windstorms in lakes and rivers disrupt the ecosystem and lives of fish. Excess temperature and increased wind reduced fish brooding and caused destruction of fish-eggs. These occurrences reduced the quantity of fish and affected nutrition status and income generation from fishing activities resulting in poverty. The ENR-MPI results indicate that 28.6% and 13.8% of the population in Bugesera and Musanze Districts are ENR-poor because of the reduced fish population in the lakes and in rivers leading to insufficient fish nutrients and dietary requirements, and loss of income from fishing activities, etc.

4.6.5 Minerals and stones

The extraction of minerals and natural stones result in increased soil erosion, deforestation and compete with farming activities on plots. Using explosives and stone crushers destroys bio-diversity and perpetuate air pollution. Bugesera District has quarries for natural stones and Musanze District has stones used on asphalt tarmacked roads. The following ENR- linked indicators were examined:

- **Mining activities:** The ENR-MPI results indicate that 20.0% and 33.3% of the population in Bugesera and Musanze Districts are respectively ENR-poor due to quarrying activities, soil was degraded and facilitated erosion. Some of the quarries were neither back filled nor reforested by new trees.

4.7 The ENR-Multidimensional Indices in Musanze and Bugesera Districts

In the MPI properties, Sabina Alkire and James Foster created a new method for measuring multidimensional poverty which identifies who is poor by considering the intensity of deprivations they suffer, and includes an aggregation method. The consultants adopted the method to compute the ENR-MPI. **Table 28** illustrates the computed Headcount Ratio (H), intensity of deprivation among the poor (A), and Adjusted Headcount Ratio (M0 = H*A).

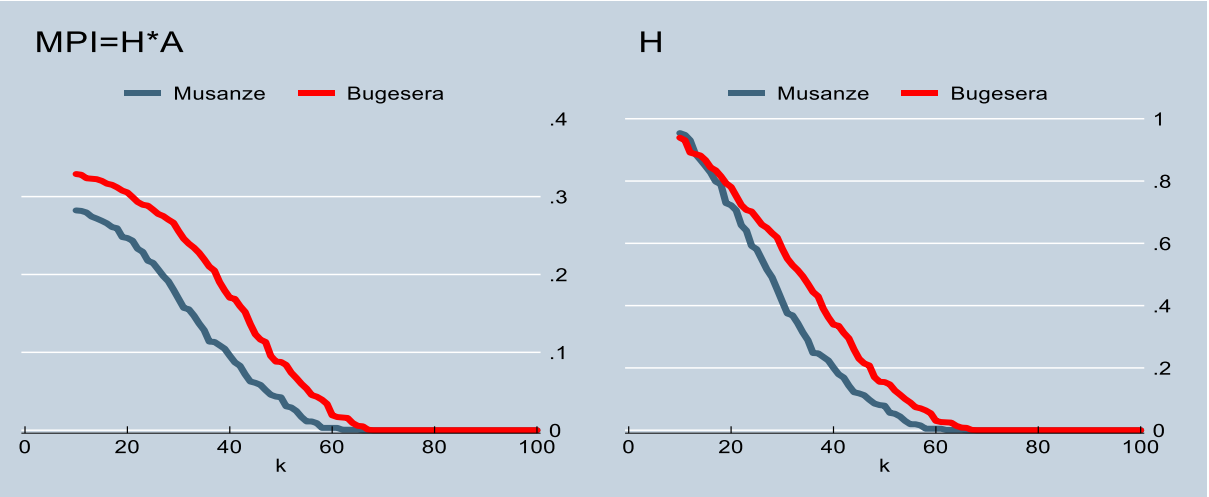
Table 28: Head Count Ratios (H), intensity of deprivation among the ENR-Poor (A) and Adjusted Headcount ration (Mo).

District	Headcount Ratio (H): % of the population in Environmental Natural resources multidimensional poverty (ENR-Poor) with k=36.3%	Intensity of deprivation among the poor (A): Average % of weighted deprivations	Adjusted Headcount Ratio (M0 = H*A)
Musanze	20.1%	47.6%	0.10
Bugesera	33.9%	50.2%	0.17
Total	**27.1%**	**49.3%**	**0.13**

Source: PEA baseline study, 2020

As already explicitly explained in the methodology section, the households that attained scores above eight (8) ENR- linked indicators affected by environmental problem were considered ENR-poor. The results of this study therefore indicate that the Headcount Ratio (H), i.e. percentage population falling in the ENR- multidimensional poverty, was 33.9% in Bugesera

District and 20.1% in Musanze District. The intensity of deprivation among the ENR- poor (A), as an average percentage share of weighted deprivations was 50.2% in Bugesera District and 47.6% in Musanze District. Bugesera District had larger population who were ENR-Multidimensional poor compared to Musanze District. This situation is validated by the trends for ENR-MPI in the Districts as presented in



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10: Trend of ENR-MPI in Bugesera and Musanze Districts
Source: PEA baseline study, 2020

Table 29: Number of ENR-Multidimensional Poor in Musanze & Bugesera Districts

Formula	**Number of ENR - poor = H * Total Population Where H is the incidence or headcount ratio**		
RESULTS			
District	Total Population	Incidence/ headcount ratio (H	Number of ENR - poor
Bugesera	431,141	33.90%	146,157
Musanze	414,113	20.1%	82,823

Source: PEA baseline study, 2020

The study established that 33.9% of the entire population of 431,141 (146,157 Persons) in Bugesera were ENR-Multidimensional Poor and 21.1% of the entire population of 414,113 of Musanze District (87,378) were ENR-Multidimensional Poor.

Table 30: Effects of Natural Resources & linkage of indicators onENR Multidimensional Poverty in Musanze and Bugesera Districts

Natural Resources	**ENR-Linked indicators**	**Contribution of ENR to its**	**ENR-Contribution**	**Contribution of ENR to its**	**ENR-Contributi**

Dimensions		linked indicator in Musanze District	to ENR-MPI in Musanze District	linked indicator in Bugesera District	on to ENR-MPI in Bugesera District
Soil	Soil infertility	6.96	65.35	6.92	56.79
	Drought events	7.23		8.73	
	Soil erosion	9.29		8.71	
	Destructive rain	4.51		6.43	
	Landslide	8.84		1.88	
	Nutrition	8.97		7.53	
	Health	5.04		3.47	
	Soil degradation	9.29		8.71	
	Agro foresting	5.22		4.40	
Water	Water access	1.21	8.54	3.56	14.07
	Improved water access	1.81		4.49	
	Water management	5.52		6.02	
Forest	Natural forest	1.54	8.07	1.16	7.47
	Forest and woodlots plantation	3.92		3.30	
	Deforestaion (firewood, construction)	2.61		3.01	
Fishery	Overfishing	0.16	7.59	0.59	11.85
	Nutrition	1.25		3.71	
	Education (Dropout and irregular class attendance)	0.04		0.26	
	Change of water level of Lake and river water	3.25		3.93	
	Temperature & windstorms in lakes & rivers	2.89		3.36	
Mineral and Natural stones	Quarries activities	10.45	10.45	9.80	9.82
	Education (Dropout and irregular class attendance)	0.00		0.03	

Source: PEA baseline study, 2020

The results in the **Table 30** indicate that in Bugesera District, the Natural Resources dimensions and its linked indicators that were affected by environmental problems contributed to ENR-MPI as follows: Soil (56.8%), water (14.0%), Forestry (7.5%), Fishery (11.8%) and extraction of mineral and natural stones (9.8%). On the other hand, in Musanze District the Natural Resources dimensions and its linked indicators that were affected by environmental problems contributed to ENR-MPI as follows: Soil (65.3%), water (8.54%), Forest (8.07%), Fishery (7.5%) and extraction of mineral and natural stones (10.45%).

In general, Bugesera District had the population who are more ENR-Multidimensional poor in comparison to Musanze District. This situation is validated by the ENR-MPI trends in the two Districts of this Baseline study.

4.8 Linking ENRs to Poverty level in Bugesera and Musanze Districts

This section discusses the linkages between poverty dimensions and indicators presented in the **Table 26** and ENRs indicators discussed in Sub-sections **4.6 and 4.7**. The linkage is primarily based on data from household and qualitative surveys (FGDs). Data collection interviews and discussions were conducted on 224 households, reaching 92 discussants for FGDs and 36 respondents for KIIs from Bugesera District; and on the other hand covered 231 households, reaching 96 discussants for FGDs and 35 respondents for KIIs from Musanze District.

Results from the households indicate that change in temperature was observed in Bugesera District (198 HHs representing 71.0% of the sampled households) compared to Musanze District (39 HHs representing 16.9%). The change in temperature has caused environmental problems which led to various negative impacts on the livelihoods of the households. For those households which observed change in temperature, 96.6% and 71.7% of the households from Bugesera and Musanze Districts, respectively, indicated that the change in temperature resulted in negative impacts for instance droughts and floods.

4.8.1 ENRs- poverty in Bugesera District

4.8.1.1 Environmental problems

Droughts

According to NISR (2018d), the contribution of agriculture and livestock production to household livelihoods was 69% in Bugesera District. However, Bugesera Cassava Zone, one of the twelve livelihood zones of Rwanda, is prone to drought and is the only food-deficit production zone in the country. The data gathered from FGDs and KIIs validates the fact that low agricultural production and limited availability of animal fodder in farms from the Sectors of Mayange, Rweru, Ruhuha, Kamabuye and Ngeruka can be attributed to the drought episodes experienced in the recent past. It was established that households also experienced a considerable decrease in milk production, droughts destroyed crops and ultimately caused starvation. The prolonged drought spells led to food insecurity and aggravated poverty at household levels (See **Table 34**).

NISR (2018d) indicate that 8.9% of the households in Bugesera District were food insecure, poor/borderline food consumption was 12%, stunting among under-5 children was 25%. Furthermore, 23% of the households used crisis/emergencies livelihood coping strategies[77].

[77] The livelihoods-based coping strategies module is used by NISR to better understand the longer-term coping capacity of households. The indicator is derived from a series of questions regarding household behaviours that lead to asset depletion, such as, selling productive assets or decreasing expenditure on productive inputs. ***Crisis***: HHs that Harvested immature crops, Consumed seed stock that were to be saved for the next season, decreased expenditure on productive inputs, (fertilizer, pesticide, fodder, etc.). ***Emergencies***: Sold the last female animals, migrated the entire household, and begged.

Results from the household survey indicate that, due to droughts, 52.7% of the households had difficulties in feeding their families, 42.9% of them experienced soil dryness on their farmlands, and 37.1% faced difficulties in feeding their animals. Through PSTA4 and NST1, the Government of Rwanda has committed to promoting Small Scale Irrigation Technology (SSIT), with a 50% subsidy on irrigation facilities, to increase land under irrigation on both hillsides and marshlands for improved productivity and commercial farming (Republic of Rwanda, 2017; MINAGRI, 2018), farmers in Bugesera District indicated that such investments were not affordable to them and still beyond their economic capabilities.

Other effects of droughts in Bugesera District included:

- ***Water resources*** (rainfall, borehole, river, lakes levels): 63.4%, 30.8% and 29% of the respondents indicated that the quantity of rainfall, quantity of water in boreholes and the level of water in rivers and lakes were drastically reduced.

- ***Water borne diseases*:** There was a problem of insufficient clean and safe water in Bugesera District. Results from the household survey showed that 90 households suffered from various health problems as a result of using unimproved /dirty/contaminated water in their households and for drinking as well. About 63.9% of those households used water from rivers, lakes, ponds or streams. Statistics from EICV5 (NISR, 2018a) show that 19.6% of the households in Bugesera District used unimproved drinking water sources (mainly surface water). The problem of unsafe water is not new as the UNDP (2007) study also showed that the majority of the population from sectors of Gashora, Nyarugenge and Nyamata used water from lakes and rivers; and 90% of the diseases in Bugesera District were water borne. For those who accessed improved drinking water sources, user satisfaction was reportedly low since 65.5% of the users were not satisfied with the main drinking water source (Bugesera District, 2019).

- ***Deforestation*:** 81% and 19% of the households indicated that they intensively use firewood and charcoal respectively as a result of the droughts. These actions cumulatively contributed to wanton deforestation in the Bugesera District. Additionally, the study established that majority of the households did not have their own woodlots and thus depended on the dictates of the market forces for direct supply and purchase of fire wood and charcoal. The exorbitant costs negatively affected the households' incomes by leaving them with little or no income to purchase other items such as food and paying for health care services (UNDP, 2007). Furthermore, studies (e.g.: REMA, 2019; Kabera et al., 2020) showed that the use of biomass fuel for cooking puts pressure on forest resources and creates indoor air pollution that jeopardizes the health of those exposed. According to the New Times (of June 09, 2019[78]), one out of four people is affected by respiratory diseases every year, which are mostly caused by cooking with firewood, charcoal, kerosene, and ambient air pollution. The same report showed that deaths attributable to poor air quality in 2017 reached 12,000 of which 75.3% and 24.7% were due to indoor air pollution and to ambient air pollution respectively.

[78] https://www.newtimes.co.rw/news/over-three-million-suffer-respiratory-diseases-annually-report

- ***Less household productivity for women*:** Due to shortage of water and limited availability of fire wood in Bugesera District, women spent large portion of their productive time fetching water and gathering fire wood, compromising other household chores (and/or economic activities). This may result in health problems and reduced income due to lost productivity (UNDP, 2007). **Figure 11** shows that the population from Bugesera District travel long distance and spend more time (all other factors being constant) to reach the limited sources of water and fire wood compared to Musanze District.

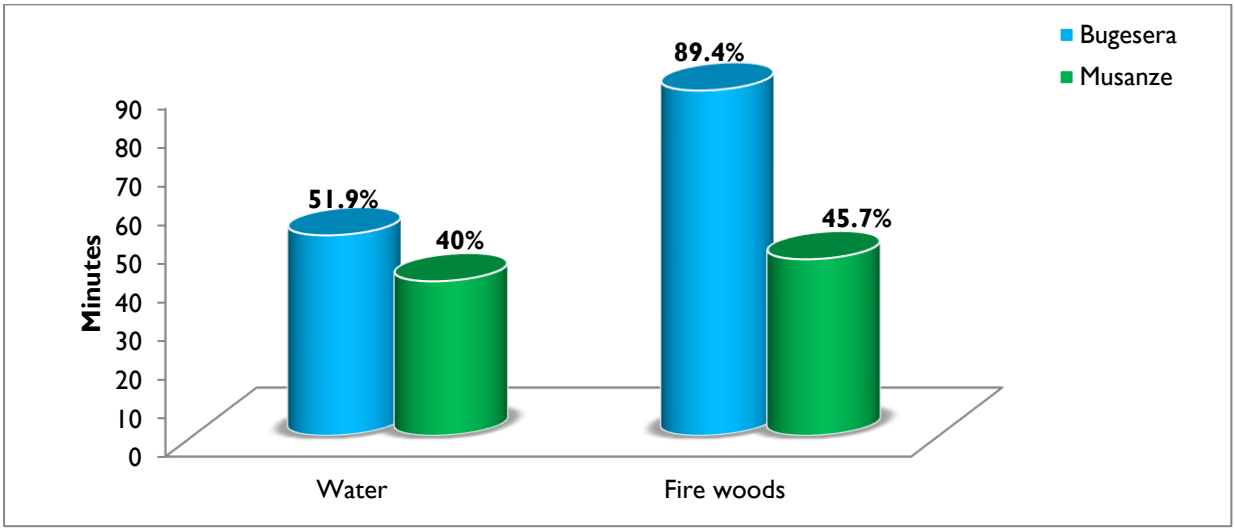


Figure 11: Average time for reaching water and fire wood sources among sample HHs in Bugesera and Musanze Districts
Source: PEA Baseline (2020).

Floods

The topography of Bugesera District exacerbates flooding and overflows in events of excessive rainfall. Floods in the marshlands along Nyabarongo and Akagera rivers affected various crops (such as maize, rice, and vegetables). About 55.8% and 37.1% of the respondents indicated that they experienced crop damaging weeds and big crops losses respectively. Excessive rainfall also caused *soil erosion*. Household survey results indicated that 30.3% of the households experienced soil infertility resulting from soil erosion. About 51.8% of the sampled households in Bugesera District experienced soil erosion with 40.5% and 50.9% of them respectively indicating that soil erosion had high and moderately negative effects on their livelihoods.

Destructive rains

The effects of destructive rains in Bugesera District were not so high. About 26.3% of the households indicated that destructive rains affected houses (mainly constructed with mud and brick walls). The destruction of houses constructed with tree trunks with mud was acknowledged by 5.4% of the sampled households. National statistics show that 39.4% and 12% of the households in the District had walls made of mud bricks and tree trunks with mud respectively.

According to (NISR, 2018c), 9,215 households (representing 9.7%) from Bugesera District were affected by environmental destruction. The **Figure 12** shows that the majority (75.2%) of respondents acknowledged that their dwellings were destroyed by destructive rains.

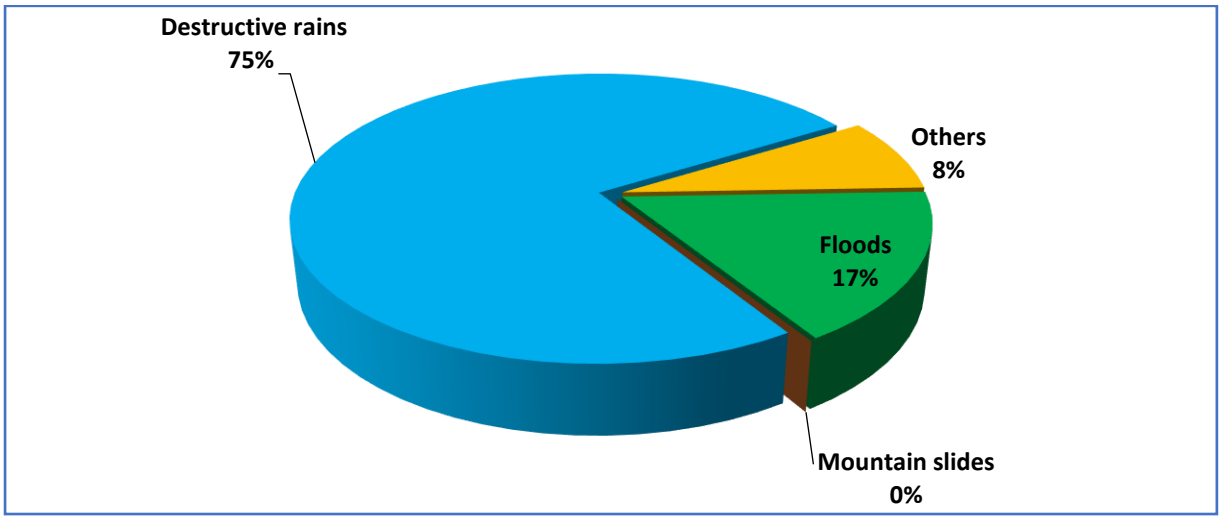


Figure 12: Environmental destruction of HHs in Bugesera District
Source: NISR (2018c)

Landslides

The study established that the effects of landslides in Bugesera District were not so considerable, similar to the findings on destructive rains. About 2.2% of the respondents in isolated rural housing and 4% in unplanned clustered housing indicated that they were affected by landslides. However, 16.5% of the respondents indicated that landslides which resulted from destructive rains reduced the forest cover and woodlots.

Strong winds

Data gathered from FGDs and KIIs confirmed that besides the effects of droughts, floods and destructive rains, there were other environmental problems which constituted root causes of poverty in the District. Very strong winds blew away roofs from houses and damaged sugar cane and banana plantations. For example, in January 2015, at least 75 households in Nyamata Sector lost their roofs during heavy storm (The New Times[79], 14th Feb 2015). Furthermore, environmental conditions favoured crop and fruit tree diseases (e.g.: cassava and mangoes).

Soil infertility

Soil infertility may be caused by environmental events such as water logging, erosion, etc., by naturally lacking essential soil-based nutrients for crops, and by excessive exploitation of land. The latter is considered in this section. About 50.9% (114 households) of the respondents indicated that they observed soil infertility on their farmlands; and this affected their agricultural production and productivity.

[79] https://www.newtimes.co.rw/section/read/185975

Drawing from the FGD sessions in Musanze District, the discussants recommended that in-depth and periodic Methodology for soil investigation on the soils, seeds, chemical fertilizers and pesticides in use should be conducted. This baseline study further noted that the units of measurement were applied blanket throughout the country yet the soils were different. In addition to this, the discussants observed that the country should subsidize the cost of chemical fertilizers and pesticides since the retail prices for the farmers were prohibitive.

The **Table 31** shows that Musanze District practices chemical fertilizers application at the rate of 55% while Bugesera District does at 33%, with Musanze District dominating on application of chemical fertilizers with a margin of 22% between the Districts. Musanze District practices organic fertilizers use at the rate of 91.8% while Bugesera District does at 67.4%. Finally, Musanze District again uses more organic fertilizers compared to Bugesera, a margin of 24.4% between the two Districts.

Table 31: Use of fertilizer in Musanze and Bugesera Districts

	Bugesera District		Musanze District		Total	
	Count	%	Count	%	Count	%
Use of chemical fertilizers						
Yes	74	33.0	127	55.0	201	44.2
No	150	67.0	104	45.0	254	55.8
Type of chemical fertilizers used						
NPK	30	40.5	67	52.8	97	48.3
DAP	60	81.1	92	72.4	152	75.6
Urea	57	77.0	72	56.7	129	64.2
Lime	0	0.0	1	0.8	1	0.5
Use of organic fertilizers						
Yes	151	67.4	212	91.8	363	79.8
No			19	8.2	73	92
Type of organic fertilizers						
Fresh animal dung			20	9.4	12	32
Composted animal dung			160	75.5	117	277
Composted plant residues and animal dung/			103	48.6	36	139
Plant residues			76	35.8	12	88

Source: PEA baseline study, 2020

The **Table 32** shows summary of the quantities of chemical fertilizers applied on different crops. Maize utilized the highest amount of fertilizers followed by beans and Irish potatoes in both Musanze and Bugesera Districts.

Table 32: Use of chemical fertilizers on various crops

	Musanze District			Bugesera District		
	Type of Fertilizer applied			Type of Fertilizer applied		
Type of crop	NPK	DAP	Urea	NPK	DAP	Urea
Maize	74.6%	77.2%	86.1%	80.0%	78.3%	80.7%
Beans	73.1%	82.6%	93.1%	86.7%	83.3%	84.2%
Irish Potatoes	46.3%	31.5%	18.1%	3.3%	3.3%	0.0%

Wheat	19.4%	14.1%	12.5%	0.0%	0.0%	0.0%
Banana	17.9%	17.4%	29.2%	10.0%	6.7%	5.3%
Cassava	11.9%	14.1%	18.1%	20.0%	18.3%	12.3%
Tomatoes	7.5%	10.9%	15.3%	3.3%	1.7%	0.0%
Sorghum	3.0%	3.3%	8.3%	6.7%	10.0%	14.0%
Soya	1.5%	1.1%	1.4%	0.0%	0.0%	1.8%

Source: PEA baseline study, 2020

Application of fertilizers is thought to improve soil fertility. However, the proportions of households that apply fertilizers remain low. Results from the household survey indicated that 33% of the sampled households applied chemical fertilizers, and 67.4% of them applied organic fertilizers on their plots. According to NISR (2018c), the rate of use of inorganic fertilizers was 28% of the households from Bugesera District, and 5.8% for the use organic fertilizers. In addition to this, the majority of households still use traditional seeds. According to the 2017 Agricultural Household Survey (NISR, 2017), 22.9% and 35.1% of the households used improved seeds in cropping seasons 2017 "A" and "B" respectively.

4.8.1.2 Fertilizers Recommendation Computation in Musanze and Bugesera Districts

Steps for Fertilizer Recommendation

In case one would want to practice intensive production, it is important to invest into specific recommendation for each crop and even for each variety of crops to complement other considerable investments deployed for crop production. Each crop has a range of nutrient need. The calculation of fertilizer needed to be applied is calculated by taking into account the available soil nutrients and the crop nutrients requirements. Depending on the type of crop, a depth is considered and the mass of soil is calculated on One (1)Ha using the bulk density of the soil, the soil area (Ha). The concentration of the nutrient in the given mass of soil is also calculated based on the value of nutrient content/Kg of soil. At the end, a comparison is made between the soil available nutrient in Kg/Ha and the total nutrient requirement in Kg/Ha. The difference between the two (2) is the fertilizer recommended to be added to soil (more details on fertilizer recommendations on **Appendix 6.**

4.8.1.3 Losses caused by environmental events, 2016-2019

Assessments conducted by the Ministry in Charge of Emergency Management (MINEMA) reported damages caused by different events including building collapse, fire, floods, hail storms, landslides, lightning, mine disasters, rain with strong winds and wind storms. The

Table 33 shows that six (6) people lost their lives while ten (10) people were injured between 2016 and 2019 in Bugesera District. In the same period, 1,464 houses and 2,758.8ha of crops were damaged, 11 types of livestock were killed, and 12 infrastructures were affected (including 7 classrooms, 2 churches, 1 administration building and 2 transmission lines).

Other information sources indicate that, in April 2018, the road connecting Nyabagendwa to Rilima Prison in Rilima Sector of Bugesera District was blocked by floods and interrupted all

movements.[80] This was caused by overflows in Akagera River which lasted for a long time in the same area. On 28 April 2020, the road connecting Ngoma District and Bugesera District was inaccessible after Kanyonyomba River flooded and completely washed away a bridge in Gashora valley affecting human transportation and vehicles and hampering trade, mainly on agricultural products, between the two Districts.[81]

Table 33: Disaster effects in Bugesera District (2016-2019)

Damages	2016	2017	2018	2019	Total
Death	2	0	3	1	6
Injured	0	3	5	2	10
Damaged Houses	29	528	757	150	1,464
Crops (Ha)	0	168.5	2,589.4	1.00	2,758.9
Livestock	1	0	9	1	11
Classrooms	0	0	6	1	7
Roads	0	0	0	0	0
Churches	0	1	1	0	2
Bridges	0	0	0	0	0
Admin. Buildings	0	1	0	0	1
Transmission lines	0	1	1	0	2

Sources: MIREMA Assessment (2016, 2017, 2018, 2019)

[80] https://mobile.igihe.com/amakuru/u-rwanda/article/abantu-18-bahitanywe-n-ibiza-byatewe-n-imvura-idasanzwe
[81] https://www.newtimes.co.rw/news/ngoma-bugesera-road-inaccessible-flood-washes-away-bridge

Box 1: Testimonies regarding the ENRs-poverty linkages in Bugesera District

Droughts

"Sometimes there is shortage of rainfall, and it ends before flowering of cultivated crops. This reduces agricultural productivity and production. In such circumstances, we face shortage of food and people get poor".

"The drought episodes reduced water levels in rivers and lakes. For example, fish in Rumira; Kidogo and Mirayi lakes in Gashora; and Rweru and Cyohoha lakes were reduced. Also, the quantity of milk supplied to milk collection centers of Kibugabuga, Ngeruka and Ruhuha was reduced".

'Here, irrigation is practised by cooperatives and big companies. Agricultural projects in the marshland of Akagera (Gashora – Rukumberi) are those with high capital. First of all, the individual households were not directly involved in those irrigation systems; secondly; even with subsidies, buying irrigation equipment is still very expensive compared to the purchasing power of individual households".

Floods

"I experienced hunger in my family after my crops were destroyed by floods in the Akagera marshland. I could not afford other non-agricultural products such as oil, salt and other household items. It is not only me; other people have migrated to Ndego and Rukara Sectors of Kayonza District and Nasho in Kirehe District to look for land to cultivate and agricultural employment".

Destructive rains

"Windstorms destroyed banana plantations in Gashora Sector, and also destroyed the rooftops of houses and schools in different areas of this District".

Soil infertility

"Change in soil fertility resulted from the over cultivation of land, season after season, year after year, because people have small plots to cultivate while they have to feed many people at household level (5-8 persons). This has led to perennial poverty among our people".

4.8.2 ENRs- poverty linkages in Musanze District

4.8.2.1 Fertilizer Recommendation for Maize, Coffee and Cabbage in Bugesera & Musanze Districts

The soils study presents the following recommendations:

- No need for K fertilizer for the 2 Dstricts
- Deficiency of N was higher in Bugesera than Musanze
- P is deficient in both Districts with lower value in Bugesera than Musanze
- Lower soil pH in Bugesera than Musanze. Slightly acidic in Bugesera
- High diversity of soil types in Bugesera than Musanze
- In Musanze soils are dominated by Andosol
- Relatively lower yield of the 3 crops in Bugesera than Musanze
- Andosols are getting degraded and need to be protected
- Perennial crops shall replace seasonal crops on steep lands

In such a case, adequate and specific fertilizers which do not contain Potassium are proposed: Those may include: Di-ammonium Phosphate, Urea and other types available to the market.

Water pollution

Water pollution has direct and indirect negative effects on human beings. In Bugesera District, water pollution is caused by different agents such industries, soil and metal sedimentation from the surrounding hills.[82] A case in point was Kigali Leather Limited which was closed in May 2018 because of discharging waste into Akagera River.[83] According to UNDP (2007), agricultural run-off from upstream caused by unsustainable farming practices and overgrazing, which also caused susceptibility to soil erosion, was the major source of water pollution. It further pointed out that the waters of Lake Cyohoha north and Rumira changed colour in the last 10 years before this study was conducted, indicating eutrophication or other physical or chemical change in water.

The **Table 34** summarizes the linkages between poverty and ENR and the precise impacts on agriculture and livelihoods in Bugesera District. The observed major environmental problems include droughts (as result of reduced rainfalls), and floods (as a result of excessive rainfalls).

Table 34: Linkages between poverty and ENRs in Bugesera District

Environmental Problems	Affected ENRs	Impact on Agriculture	Impact on HH Livelihood
Drought	Soil: Change in moisture content Water: reduced water level in river or lakes	Reduced agricultural and animal production, Change in the number of agricultural products, Limited availability of animal fodder.	Low income level Food shortages Shortage of drinking waters (Bore-holes) Health related problems
	Forest: deforestation	Reduced rainfall Increased soil erosion	Food shortages Limited sources of cooking energy
Floods	Water: Overflow in Akagera River, Soil: Soils were flooded and water logged in marshlands (e.g: Gashora & Juru Sectors) which let to soul infertility	Crop losses Crop diseases	Food shortages Unclean water
Destructive Rains	Soils: landslides	Crop and animal losses Crop diseases	Food shortages Losses of human lives Destruction of houses Unclean water
	Forest: reduction in forest cover or woodlots	Reduced agricultural production	Limited sources of cooking energy
Landslides	Forest: reduction in forest cover or woodlots	Crop losses	Limited sources of cooking energy

[82] http://www.fonerwa.org/backend/content/ecosystem-protection-using-bamboo-belts-around-lakes-bugesera-district
[83] https://www.newtimes.co.rw/news/leather-factory-suspended-polluting-akagera-river

Environmental Problems	Affected ENRs	Impact on Agriculture	Impact on HH Livelihood
Soil erosion and over cultivation	Soils: Soil infertility	Crop loss Low agricultural production	Food insecurity Lower incomes
Strong winds	-	Crop losses	Food shortages Destruction of houses Lower incomes
Water pollution	Water: Akagera River	-	Low income Possibility of health-related problems Water shortage for livestock

Source: PEA baseline study, 2020

4.8.2.2 Environmental problems

According to NISR (2018d), the contribution of agriculture and livestock to household livelihoods is 45% in Musanze District. Like Bugesera District, agricultural activities in Musanze District depend heavily on rain. Information collected from qualitative interviews indicates that temperature in this District has slightly increased. It used to be between 12^0C and 21^0C, but currently varies between15^0C to 24^0C. It is also observed that rain is more irregular compared to the previous years. About 36.4% of the sampled households indicated that they observed reduction in the quantity of rainfall.

The change in temperature has affected the climate in the District, which has also affected agricultural seasons – though the latter depends on location. For example, the agriculture season in Kinigi Sector is different from the agricultural season in the Sectors of Rwaza and Muko. Sometimes, floods and erosion from high volcanic mountains destroy the cultivated crops in the valleys of Gataraga and Cyuve Sectors.

Floods

The mountainous topography of Musanze District allows occurrence of erosion incidences on the mountain watersheds, flooding in their lower parts, and overflow in Mukungwa River in events of excessive rainfall. For example, 70ha in Mugogo valley (Busogo Sector) were flooded and the crops were damaged.

About 52.8% of the sampled households in Musanze District experienced soil erosion, while 55% experienced big crop losses due to excessive rains and rainstorms, and 26.8% experienced soil infertility on their farmlands. For those households which experienced soil erosion, 23% and 63.9% of them respectively indicated experiencing highly and moderately negative effects on their livelihoods.

About 44.6% of the sample households acknowledged that they suffered from various health problems. However, this may be attributed to other underlying issues since the majority of the population used improved water sources (43.6% for protected well, and 25.6% for public

tap/stand pipe). National statistics from EICV5 (NISR, 2018c) show that the proportion of households which still use unimproved drinking water sources (mainly surface water) is small (5%).

Destructive rains

There were high effects of destructive rains in Musanze District. According to the results of this baseline survey, 50.6% of the households indicated that destructive rains affected their houses (mainly houses constructed with mud bricks wall). The destruction of houses constructed with tree trunks with mud was acknowledged by 22.9% of the sampled households. National statistics on the other hand show that 36.9% and 29.8% of the households in Musanze District have walls made of mud bricks and tree trunks with mud respectively.

Landslides

Similarly, to destructive rains, there have been considerable effects of landslides in Musanze District. About 39% of the respondent's experiences landslides on their farmlands. Regarding housing, 34.4% of the respondents in isolated rural housing indicated that they were affected by landslides, and this was 18.2% in unplanned clustered housing. However, 18.2% of them indicated that landslides which resulted from destructive rains reduced the cover of forests and woodlots; which limited their access to firewood as main source of cooking energy used by 93.3% of the sample respondents.

According to (NISR, 2018c), 7,644 households (representing 8.4%) from Musanze Districts were affected by environmental destruction. **Figure 13** shows that the majority (56.1%) of the respondents acknowledged destruction by mountain slides.

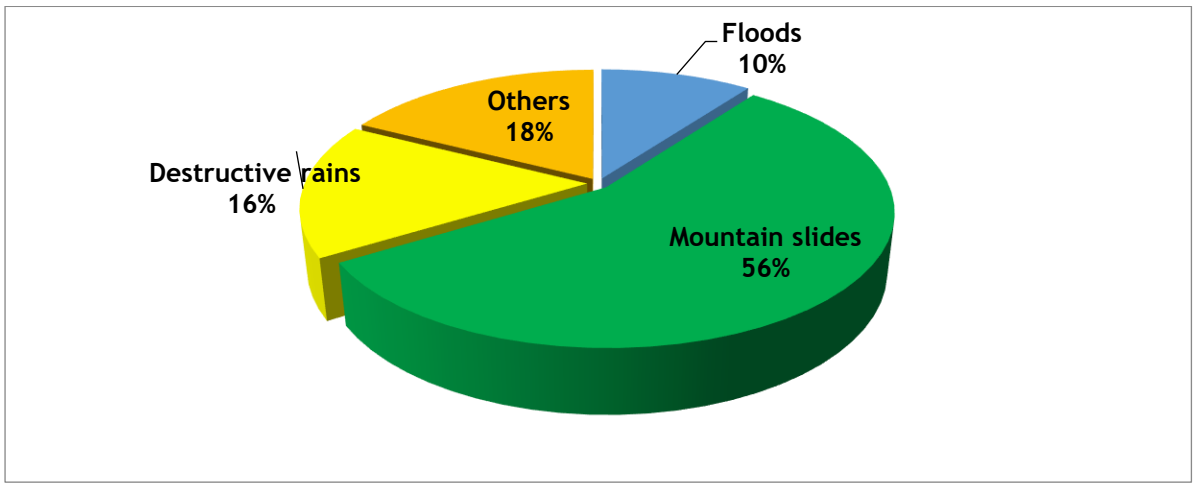


Figure 13: Environmental destruction of HHs in Musanze District
Source: NISR (2018c)

Soil infertility

In Musanze District, about 55% (127 households) of the respondents indicated that they observed soil infertility on their farmlands; this affected their agricultural production and productivity. The proportions of households that applied fertilizers remain low, but higher compared to Bugesera District. Results from the household survey indicated that 55% of the

sampled households applied chemical fertilizers, while 91.8% applied organic fertilizers on their plots.

According to NISR (2018c), application of inorganic fertilizers was practiced by 44.1% of the households while16.3% applied organic fertilizers in Musanze District. Additionally, the majority of households still used traditional seeds. According to the 2017 Agricultural Household Survey (NISR, 2017), 32% and 20.6% of the households used improved seeds in cropping seasons 2017 "A" and "B" respectively.

Water pollution

Water pollution in Musanze District was observed on 21 September 2018 when mass fish deaths and other aquatic species were found in different water bodies in this District (The New Times,[84] 29th October 2018). The death followed external toxic chemicals which were discharged by industries[85] into water bodies. The affected water bodies were rivers Mukungwa and Mugara; and three fish ponds which drew water from River Mugara, a tributary of River Mukungwa. COOPIBEFAMU (a cooperative - in fish pond farming), reported that they lost fish stocks from all their three fish ponds, a major blow to their business with the loss of quarterly harvest worth Frw 800,000 from the incident.

Table 35 summarizes the linkages between poverty and ENR and the precise impacts of ENRs on agriculture and livelihoods in Musanze District. The observed major environmental problems included floods, destructive rains and landslides, all contributing to the environmental problems in the District, in one way or another and consequently leading to household food insecurity in Musanze District.

Table 35: Linkages between poverty and ENRs in Musanze District

Environmental Problems (Causes)	Affected ENRs	Impact on Agriculture	Impact on HH Livelihood
Floods	Water: Overflow in Mukungwa River Soil: Soils are flooded and water logged in marshland along Mukungwa River; and erosion on mountain watersheds	Crop loss Low agriculture Production Fishery	Insufficient food for HH
Destructive Rain	Soil: landslides, erosion	Crop losses	Destruction of houses Loses of human lives Insufficient food for HH Damaged infrastructures (e.g.: feeder roads, bridges)
	Forest: reduction in forest cover or woodlots		Limited sources of cooking energy
Change in rainfall	Soil (Land): Change in moisture content, Irregular rainfall in the Birunga National Park destructed the fertile	Crop and products losses	Insufficient food for HH

[84] https://www.newtimes.co.rw/news/agric-body-disinfect-ponds-after-mass-fish-deaths-musanze
[85] https://mobile.igihe.com/ubukungu/ubucuruzi/article/ipereereza-ryanzuye-iki-kuri-ya-mafi-yagaragaye-muri-mukungwa-yipfishije

	land in Kinigi, Busogo and Gataraga sectors		
Soil erosion and over cultivation	Soil infertility	Low agricultural production	Food insecurity Lower incomes
Water pollution	Water: rivers and lakes	-	Low income

Source: PEA baseline study, 2020

4.8.2.3 Losses due to environment problems, 2016-2019

In Musanze District, MINEMA Assessments showed that ten (10) people lost their lives while 21 people got injured between 2016 and 2019 (See **Table 36**). In the same period, 1,044 houses were damaged, 1,270ha of crops were damaged, 20 types of livestock were killed and 27 infrastructures were affected (including 10 classrooms, 2 roads, a church, a bridge, 2 administration building and 11 transmission lines).

Table 36: Disaster effects in Musanze District (2016-2019)

Damages	2016	2017	2018	2019	Total
Death	7	2	1	0	10
Injured	2	8	10	1	21
Damaged Houses	103	231	540	170	1,044
Crops (Ha)	0	266.2	834.8	169	1,270
Livestock	3	11	3	3	20
Classrooms	0	6	3	1	10
Roads	0	1	1	0	2
Churches	0	0	1	0	1
Bridges	0	0	0	1	1
Admin. Buildings	0	0	1	1	2
Transmission lines	0	1	5	5	11

Sources: MIREMA Assessment (2016, 2017, 2018, 2019)

Though aggregated effects of disasters on human livelihoods have not yet been published by concerned bodies in the year 2020, some sources indicate that 28 households (with 147 members), around Mugogo valley in Busogo Sector of Musanze District, were hosted in the compounds of Busogo Secondary School after their houses were destroyed (6 houses) and damaged (22 houses were flooded) by heavy rains at the end of April 2020. 70ha of crops (Irish potato, beans and vegetables) were also covered by floods.[86]

Box 2: Testimonies regarding the ENRs-poverty linkages in Musanze District

Floods

"Citizens in high risk zones in Busogo, Gatagara and Kinigi sectors face erosion and flooding caused by non-canalized water from volcanoes. Sometimes their houses get destroyed, crops get damaged or stressed and feeder roads destroyed. For example, last year, the feeder road connecting Busogo Sector and Kinigi Sector via Gatagara and Shingiro Sectors was destroyed and citizens were unable to transport their agricultural products to the local markets of Byangabo,

[86] https://mobile.igihe.com/amakuru/u-rwanda/article/musanze-imiryango-28-yacumbikiwe-mu-kigo-cy-ishuri-kubera-amazi-y-imvura-yuzuye

Kinigi and Muhoza. They also affected health services, mainly the use of ambulance" for health emergencies.
"Sometimes rain is too much and crops are damaged by heavy rain. The most affected crops are Irish potatoes, beans and vegetables".
"In Rwaza Sector, overflows of Mukungwa River destroyed crops such as maize, soya and vegetables planted in the Mukungwa valley. Also, fishing activities in this river were affected after a high quantity of fish was found dead".

Destructive rains

"Our houses were completely wiped out and as we speak, we do not have where to stay, the future looks uncertain. I lost a house worth Rwf 8 million, which I had just completed, as well as a garden of beans. I am left with nothing other than the clothes I am wearing", indicated a resident from Muko Sector, Musanze District (The New Times[87] 5th Dec 2019).

Soil infertility

"Farmers experienced soil infertility due to over cultivation on their plots; erosion on hillsides and insufficient use of organic and inorganic fertilizers across the agriculture seasons have led to soil infertility".

4.8.3 Vulnerability Indices in Bugesera and Musanze Districts

The vulnerability results of this study are confirmed by other studies. By comparing the findings of this baseline study and those from the assessment of the climate change vulnerability in Rwanda (REMA, 2018), it is clear that the two studies are in correlation. As demonstrated from this baseline study, the vulnerability of Bugesera District is higher compared to that of Musanze District. The REMA (2018) study referenced above indicates that the vulnerability index of Bugesera District (0.498) is significantly higher than that of Musanze District, which is of 0.452.

4.8.4 ENRs- poverty linkages in both Bugesera and Musanze Districts

This section discusses the triangulated established linkages between ENRs and poverty in Bugesera and Musanze Districts, where the **Table 37** (summary of direct and indirect effects of ENRs on multi-dimensional poverty) and **Table 39** present the situation in both Districts.

Table 37: Summarized linkages between ENRs and poverty in Bugesera and Musanze Districts

ENR-Poverty Indicators			POVERTY DIMENSIONS		
			Standard of Living	Health	Education
ENRs DIMENSIONS	Soil	Land plots for farming and livestock	Environmental problems (EPs) affected fragmented land and livestock leading to low production and productivity	HH food insecurity (particularly in Bugesera) High rates of stunting among under-5 children	Indirect effect: Children from poor households (most of them are food insecure) irregularly attend class, which may result into dropping-out.

[87] https://www.newtimes.co.rw/news/landslides-displace-scores-musanze

ENR-Poverty Indicators			POVERTY DIMENSIONS		
			Standard of Living	Health	Education
		Drought events	They led to water shortage both at HH level (for use in HHs, for irrigation, livestock) and in water bodies They led to deforestation (particularly in Bugesera) They led to low productivity for women who spent much time collecting fire woods and fetching water	Water borne diseases HH food insecurity (particularly in Bugesera)	Children spent much time collecting fire woods and fetching water, which has increased drop-out rate due to irregular class attendance (particularly in Bugesera)
		Soil erosion and over cultivation	It depleted land (soil infertility), flooded crops, water logged It led to low water quality in water bodies	Water borne diseases HH food insecurity	Indirect effect
		Destructive rain	It led to soil erosion, destroyed infrastructures (houses, roads, bridges …), crop losses	Loss of human lives HH food insecurity	Indirect effect
		Landslide	It led to soil erosion, destroyed infrastructures (houses, roads, bridges …), crop losses	Loss of human lives (particularly in Musanze) HH food insecurity	Indirect effect
		Soil degradation	Caused by droughts, soil erosion, over cultivation, destructive rains or land slide, it has led to soil infertility limiting crop production and productivity	HH food insecurity	Indirect effect
		Agro-forestry	Fragmented land and droughts (in Bugesera) limit agro-forestry adoption which	High rates of stunting among under-5 children	Indirect effect
	Water	Water access	Water shortage let to limited access to water for HH use, livestock, irrigation, etc. It led to low productivity for women	HH food insecurity Water borne diseases	Children spent much fetching water and fishing, which has increased drop-out rate due to irregular class attendance (particularly in Bugesera) **Figure 11**
		Improved water access	Water shortage let to high use of unimproved water sources (lakes and rivers), particularly in Bugesera;	Water borne diseases	Children spent much fetching water and fishing, which has increased drop-out rate due to irregular

ENR-Poverty Indicators			POVERTY DIMENSIONS		
			Standard of Living	Health	Education
			Soil erosion, overflows and floods led to low water quality		class attendance (particularly in Bugesera)
		Water management	Poor water harvesting led to water run-off and soil erosion; Water is polluted by soil erosion and floods, which has led to loss of aquatic species (mainly fishes), It affected fishery and led to loss of income		Indirect effect
	Forest	Natural forest	Droughts led to reduced forest cover	-	-
		Forest and woodlots plantation	Droughts led to reduced cover of private forests (particularly in Bugesera District) Limited income from forest products	-	-
		Deforestation (firewood, construction)	Drought-led deforestation and forest degradation (due to high use of fire woods and charcoal) led to rain shortage Limited income from forest products (particularly in Bugesera) Strong winds resulting from reduced forests cover destroy crops and damage houses It led to reduced HH income for other services such as food and health care due to market transactions for fire woods.	Indirect effect: Deforestation and rain shortage negatively affected crop production, leading to HH food insecurity	Children spent much time collecting fire woods, which has increased drop-out rate due to irregular class attendance (particularly in Bugesera)
	Fishery	Overfishing	Following drought events and increased drop-outs many people engaged in overfishing which led government closing fishing activities in Bugesera District People lost jobs and income from fishing activities Overflows and floods led to overfishing activities	HH food Insecurity	Children near lakes and rivers for fishing, at the expense of attending school. This has contributed to increased drop-outs
		Change of water level of lakes and rivers	Drought events led to reduced water level in rivers and lakes Soil erosion, floods and overflows increases water levels, leading to low quality of water which may result into limited fishing activities in lakes, rivers and ponds.	Stunting among under 2-5 children Water born disease	Indirect effect

ENR-Poverty Indicators			POVERTY DIMENSIONS		
			Standard of Living	Health	Education
			People loose income from fishing activities		
		Temperature and windstorms in lake and rivers	The dry climate of Bugesera leads to increased temperature into the water bodies. This negatively affects growth of fishes, and limit fishing activities	Stunting among under 2-5 children Water born disease	Indirect effect
	Mining	Mines Quarries activities	Inappropriate or traditional mining led to soil erosion which affects agricultural activities and water bodies Soils are degraded Air and water pollution	Water born disease	Children near quarries prefer to work in quarries, at the expense of attending school. This has contributed to increased drop-outs/

Source: PEA baseline study, 2020

Table 38: Level of environmental problems experienced and affected household's livelihood

	Musanze District		Bugesera District		Total	
	Count	%	Count	%	Count	%
1.1 Soil infertility						
High negative impact	31	13.4	51	22.8	82	18.0
Moderate impacts	93	40.3	46	20.5	139	30.5
No impact	107	46.3	127	56.7	234	51.4
1.2 soil erosion						
High negative impacts	28	12.1	47	21.0	75	16.5
Moderate impacts	78	33.8	59	26.3	137	30.1
No impact	125	54.1	118	52.7	243	53.4
1.3 Shift in rainfall						
High negative impacts	91	39.4	79	35.3	170	37.4
Moderate impacts	114	49.4	88	39.3	202	44.4
No impact	26	11.3	57	25.4	83	18.2
1.4 Rainstorm intensity						
High negative impacts	102	44.2	66	29.5	168	36.9
Moderate impacts	104	45.0	93	41.5	197	43.3
No impact	25	10.8	65	29.0	90	19.8
1.5 Plant diseases						
High negative impacts	33	14.3	87	38.8	120	26.4
Moderate impacts	167	72.3	91	40.6	258	56.7
No impact	31	13.4	46	20.5	77	16.9
1.6 Plant pests						
High negative impacts	17	7.4	77	34.4	94	20.7
Moderate impacts	45	19.5	56	25.0	101	22.2
No impact	169	73.2	91	40.6	260	57.1
1.7 Bore-hole water						
High negative impacts	5	2.2	28	12.5	33	7.3
Moderate impacts	60	26.0	40	17.9	100	22.0
No impact	166	71.9	156	69.6	322	70.8

Source: PEA baseline study, 2020

The **Table 38** summarize the households' perceptions on the extent the environmental problems affected their livelihoods in the last two years. They reiterated the fact that the environmental problems experienced contributed negatively to the population's living conditions. By combining high and moderate impact, the study established that among the seven environmental problems identified, **soil infertility** contributed up to **48.5%**, **soil erosion up to 46.6%, shift in rainfall** (either starting early/later and ending early/later) **up to 81.8%, rainstorm intensity up to 80.2%, plant diseases up to 83.1%, plant pests up to 42.9%** and last but not least **bore-hole water at 29.3%.**

4.8.2.4 Degree of association between ENRs and poverty indicators

The analysis of ENR-poverty relationship used Chi-Square (χ^2) test in order to assess extent to which environmental problems are linked to livelihood indicators (i.e. degree of association between them). The χ^2 test shows whether, or not, the association is statistically significant based on the p-value ranging from 0.0 to 0.10. This means that, the confidence interval is ranging from 99% to 90%. Meaning that, the results in the table provide enough evidence to conclude that the indicators that rationalize the livelihood of the population in the Model have been affected by the environmental problems when the value of p-value falls in range of [0.1-0.01] and the theoretical chi-square values which is less than computed Chi-square values (See **Table 39**).

The null and alternative hypotheses for each χ^2 test can be stated as follows:

H_0: *There is no association between environmental problems and livelihood indicators*; and

H_1: *There is association between environmental problems and livelihood indicators*.

The p-value allows rejecting or accepting H_0 in favour of H_1. Two cases are possible:

- If the p-value range is [0.00 to 0.10[, the conclusion is to reject H_0 and accept H_1; with three possible levels of association:

(a) If the p-value range is [0.00 to 0.01[, there strong association, i.e. population livelihoods has been **strongly affected** by ENR-problems;

(b) If the p-value range is [0.01 to 0.05[, there moderate association, i.e. population livelihoods has been **moderately affected** by ENR-problems;

(c) If the p-value range is [0.05 to 0.10[, there weak association, i.e. population livelihoods has been **weakly affected** by ENR-problems;

- If the p-value range is [0.10to +∞], the conclusion is to accept H_0 and reject H_1;

For example, the computed χ^2 value between drought events and low agricultural production is 43.767. Given the p-value of 0.000, it shows that the computed χ^2 value is greater than theoretical χ^2 value; which allows reject null hypothesis (H_0), but accepting alternative hypothesis (H_1) and conclude that there is a strong statistically significant association between drought events and low agricultural production in Bugesera District; which is not the case in Musanze District where there is no statistically significant association between the two variables (p-value=0.983). In other words, in Bugesera District, and low agricultural production is strongly affected by drought events. Other variables can be interpreted in the same way.

Table 39: Degree of association between variables by Districts

ENR-Problems		Bugesera District						Musanze District					
		Affected areas of population livelihoods						Affected areas of population livelihoods					
		Low agricultural Production	*Food shortage*	*Health related problems*	*Unclean water*	*Shortage of water*	*Limited sources of cooking energy*	*Low agricultural Production*	*Food shortages*	*Health related problems*	*Unclean water*	*Shortage of waters*	*Limited sources of cooking energy*
Drought	Chi-square	43.767	24.338	7.552	-	36.164	35.649	2.430	12.946	1.759	-	60.865	18.43
	p-value	0.000	0.004	0.056		0.112	0.000	0.983	0.165	0.624		.001	0.622
Flood events	Chi-square	77.601	21.519	10.855	23.962	-	-	77.474	9.884	4.877	-	-	6.735
	p-value	0.000	0.011	0.013	0.295			0.000	0.36	0.181			0.999
Soil erosion	Chi-square	54.942	18.191	6.125	36.982	-	-	5.083	15.881	3.778	-	-	28.609
	p-value	0.000	0.033	0.106	0.017			0.827	0.069	0.286			0.124
Soil infertility	Chi-square	79.029	23.594	4.614	-	-	-	6.488	22.113	6.209	-	-	-
	p-value	0.000	0.005	0.202				0.690	0.009	0.102			
Windstorms	Chi-square	36.088	23.744	7.681	42.623	50.783	7.896	2.414	9.037	5.102	54.660	59.318	25.297
	p-value	0.000	0.005	0.053	0.004	0.004	0.793	0.983	0.434	0.164	.000*	0.001	0.235
Destructive Rains	Chi-square	17.064	19.719	0.923	6.564	-	4.024	20.344	2.581	0.125	13.907	-	7.849
	p-value	.001	0.000	0.337	0.476		0.403	.000	0.461	0.724	0.084		0.346
Landslides	Chi-square	32.362	6.258	4.877	-	-	11.74	5.019	10.958	2.488	-	-	20.439
	p-value	0.000	0.714	0.181			0.467	0.833	0.279	0.478			0.494
Reduced rainfall	Chi-square	68.138	27.189	-	-	74.702	36.872	2.601	10.212	-	-	20.095	20.085
	p-value	0.000	0.001			0.000	0.000	0.978	0.334			0.914	0.516
Reduction of forest/ woodlots	Chi-square	39.550	5.88	7.555	76.575	91.593	9.436	1.090	16.440	0.952	26.483	26.657	20.296
	p-value	0.000	0.752	0.056	0.000	0.000	0.665	0.999	0.058	0.813	0.329	0.641	0.503

Source: PEA baseline study, 2020

4.9 Status of agricultural production in Bugesera and Musanze Districts

The evidence from sub-sections **4.10** and **4.11** show that environmental problems resulted into low agricultural production, which has multiple effects on household livelihoods (such as low income, household food insecurity, migration to other areas, etc.). This section presents the current status of crop production in the Districts under this study.

The **Table 40** shows that ENRs (e.g.: land, forest, climate) have influence on crop cultivation. For example, in Musanze District, maturing is delayed for maize due to the tropical climate; availability of wooden sticks favours production of climbing beans; and the soils favour production of Irish potatoes. In Bugesera District, the dry climate favours production of maize and sorghum; lack of sticks does not favour production of bush beans; and soils favour production of groundnuts. In the occurrence of extreme environmental events (such as droughts and floods in Bugesera District, and excessive rains and landslides in Musanze District, crops are highly affected, and households suffer from food shortages.

Table 40: Household distribution by crops in Bugesera and Musanze Districts (%)

Crop category	Musanze	Bugesera	Rwanda
Maize	30.5	71.4	28.3
Sorghum	1.6	20.3	23.3
Paddy rice	-	1.9	2.5
Wheat	6.2	-	2.7
Cassava	1.7	9.1	14.1
Sweet potato	22.1	10.9	24.9
Irish potato	32.7	0.2	9.9
Yams and Taro	0.1	2.0	1.5
Cooking banana	6.6	7.9	8.6
Dessert banana	5.8	0.2	2.6
Banana for beer	4.2	9.5	9.1
Bush bean	5.6	87.7	48.8
Climbing bean	58.5	0.8	33.5
Pea	0.4	-	2.3
Groundnut	-	25.1	6.9
Soybean	0.2	5.5	8.6
Vegetables	7.4	3.9	3.7
Fruits	0.5	0.1	0.6

Source: NISR (2017)

Among the sampled households in Bugesera and Musanze Districts, majority of the households grew cereals (96.4% and 93.5% in Bugesera and Musanze Districts respectively), vegetables were placed second with 70.1% and 76.2% in Bugesera and Musanze Districts respectively) while roots were in third place with 25.9% and 65.4% in Bugesera and Musanze Districts respectively (See **Figure 14**).

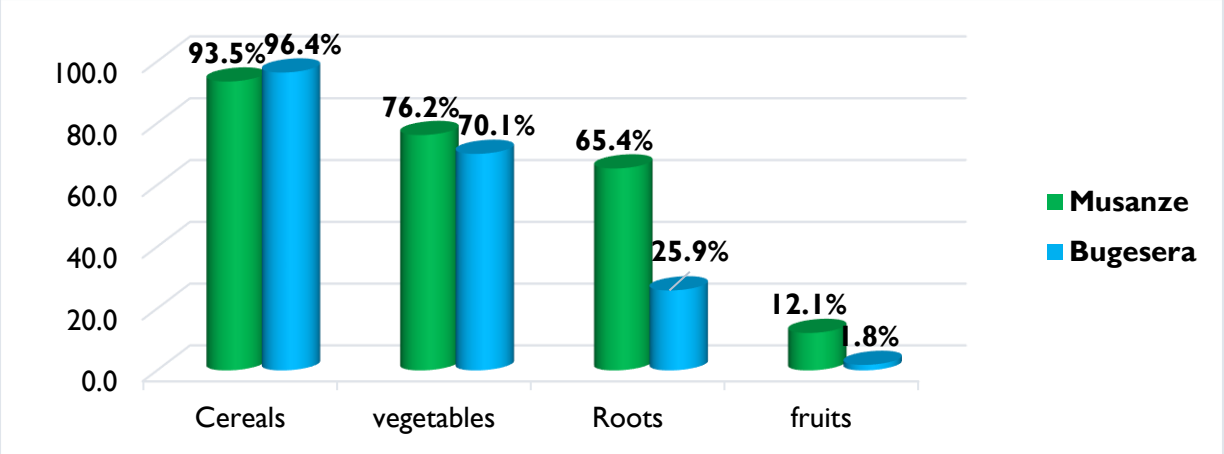


Figure 14: Distribution of sample HHs by type of crops grown
Source: PEA baseline study, 2020

In Rwanda, the average crop yields are low compared to potential yields (Bizimana et al., 2012; Giertz et al., 2015; USAID, 2016; MINAGRI, 2017). **Table 41** shows the same situation for farmers from both Districts of study. Low agricultural yields cannot only be attributed to environmental problems (e.g. droughts, floods, pests and diseases) but also, to household attributes (e.g. lack of access to and inability to use fertilizers and improved seeds; limited capacity to cope with environmental shocks, etc.), among others. With respect to soil erosion and soil fertility, studies (e.g.: Muñoz-Rojas et al., 2017) showed that soil erosion leads to soil losses which deplete soil nutrients, and this affects livelihoods.

For Rwanda, the estimates of 945,200tons of organic materials, 41,210tons of nitrogen, 200tons of phosphorus and 3,055tons of potash are predicted to erode annually, due to water erosion. This depletes the topsoil nutrients that ultimately lead to decline in crop productivity, with substantial implication on food security (Nambajimana et al., 2019). Review of the same study established that soil loss was statistically and significantly correlated with poverty, use of chemical fertilizers and especially in relation to extreme poverty (at 5% level of significance), where 1% increase in soil loss heightened poverty by 0.45%, use of chemical fertilizers by 0.77% and extreme poverty by 0.77%.

Table 41: Average yield (Kg/Ha) by crop type in both Districts

Crops / District	2018A		2018d		2019 A		2019 B		2020A		Potential (MT/ha)
	Musanze	Bugesera	Musanze	Bugesera	Musanze	Bugesera	Musanze	Bugesera	Musanze	Bugesera	
Maize	1,565	1,187	1,031	1,958	1,327	1,444	1,936	913	1,884	1,652	6.5
Sorghum	2,486	1,017	-	877	2,142	699	-	602	1,773	1,223	-
Wheat	1,908	-	1,150	-	1,531	-	1,271	-	1,161	-	4.0
Cassava	15,000	15,505	7,921	15,336	7,990	16,146	11,814	20,233	5,541	16,965	40.0
Sweet potatoes	6,601	7,707	5,633	6,591	7,716	7,259	10,524	3,660	8,075	7,199	-
Irish potatoes	7,895	2,348	9,811	-	12,147	2,965	12,482	2,744	11,797	2,833	40.0
Dessert banana	8,794	25,435	19,496	14,362	-	-	-	-	7,865	7,218	-
Banana for beer	14,945	12,132	10,840	6,960	-	-	-	-	11,078	8,563	30.0
Bush bean	1,181	662	732	988	-	-	-	-	529	712	1.6
Climbing bean	978	378	1,236	671	1,166	427	1,495	629	773	770	2.5
Ground nuts	-	719	-	375	-	390	-	380	-	304	-
Vegetables	8,883	13,175	5,848	7,015	7,806	6,702	10,915	7,434	7,225	10,070	-
Fruits	2,646	29,413	4,760	640	3,198	8,947	5,114	25,801	6,286	7,794	-

Source: Seasonal Agricultural Surveys (SAS, 2018A-2020A), MINAGRI (2015)

Figure 15 indicates that 73.7% of the sampled households in Musanze District, comparatively higher than in Bugesera District (37.7%) had access to markets for their agricultural produce; though contractual farming is critical in both Districts. About a half of the households earned income from selling their produce. However, they incurred losses because production costs could not be recovered from the sales as they fetched lower prices.

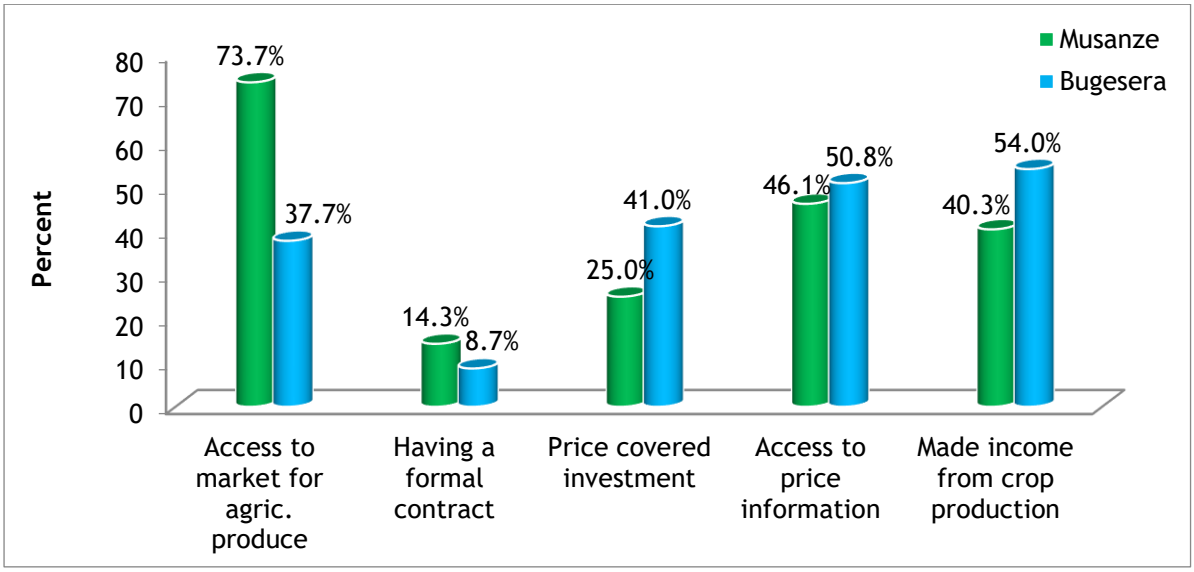


Figure 15: Access to market information among sampled HHs (%)
Source: PEA Baseline Survey (2020)

Livestock provides alternative source of income for farmers, and manure for soil health and improved crop production. About half of the sampled households from both Districts' owned cows, while 47.2% of the farmers from Bugesera District owned goats, and 35.2% of those from Musanze District owned pigs (**Figure 16**). Climatic conditions in both Districts define the variances in ownership of goats and pigs.

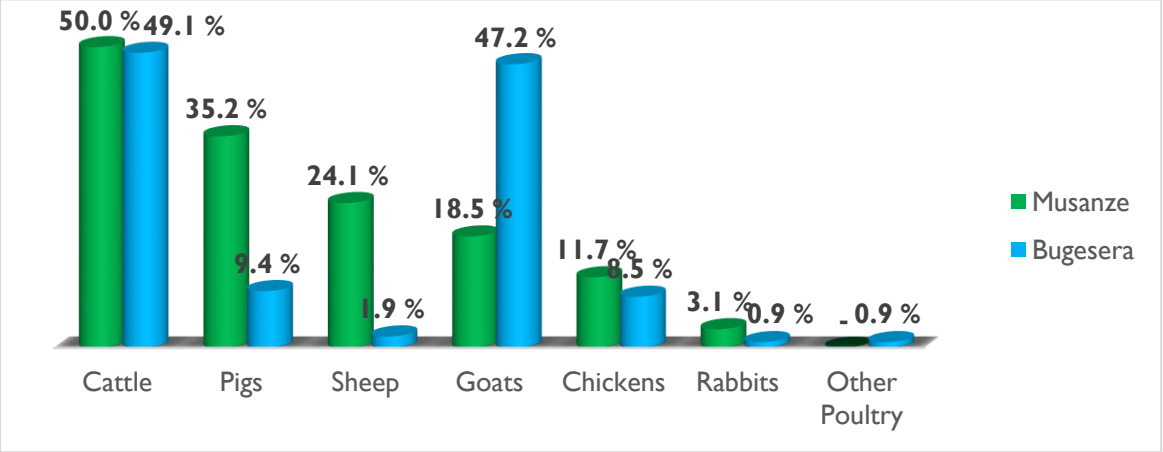


Figure 16: Livestock ownership among sample HHs (%)
Source: PEA baseline study, 2020

The **Table 42** shows the livestock production status in both Districts indicating that Musanze District had higher livestock population with 50% keeping cattle, 24.1% rearing sheep and 35.2% breeding pigs while Bugesera District dominated goats rearing by 47.6% of the population.

Table 42: Livestock in Musanze and Bugesera Districts

	Musanze District		Bugesera District		Total	
	Count	%	Count	%	Count	%
Households with Livestock						
Yes	162	70.1	106	47.3	268	58.9
No	69	29.9	118	52.7	187	41.1
Type of animal						
Cattle	81	50.0	52	49.5	133	49.6
Sheep	39	24.1	2	1.9	41	15.3
Goats	30	18.5	50	47.6	80	29.9
Pigs	57	35.2	10	9.5	67	25.0
Rabbits	5	3.1	1	1.0	6	2.2
Chicken	19	11.7	9	8.6	28	10.4

Source: PEA baseline study, 2020

4.10 Link between Education, ENRs and Poverty in Bugesera and Musanze Districts

Education refers to the skills (cognitive, educational, and physical) people have to access and use ENRs in a beneficial and sustainable manner ; and the awareness of people regarding the impacts of an unsustainable use of resources (like in the case of overfishing, deforestation, pollution, etc.). These aspects are of particular importance since unsustainable use of natural resources contributes to poverty (Thiry et al., 2018). This section discusses ENRs related causes for drop-outs in primary education in both Districts. **Table 4** indicates that dropout rates in primary and secondary levels of education was 9.6% and 2.5% respectively in Bugesera District; whereas these were 6.5% and 6.3% respectively in Musanze District. The information gathered from KIIs revealed the following ENRs related causes:

- ***Droughts*:** Following the occurrence of droughts in the year 2000, many households found themselves in difficulties to get food, and children and adults opted to massively go for fishing as alternative way of getting money to support their livelihoods. This increased drop-out rates among school children, and to overfishing in lakes and rivers.

- ***Fishing*:** When Nyabarongo and Akagera Rivers (in Bugesera District) and Mukungwa River (in Musanze District) overflow, their children do not go to school or digress from school in favour of fishing activities. These activities tempt children from households around lakes to put a stop to schooling, particularly when there is no food at home or when they are motivated by the need for money. Furthermore, d*rop*-outs, among other factors, led to overfishing in the lakes located in Bugesera District, a clear reason that drove the government to put restrictions on fishing activities in the year 2000.

- ***Fetching water and collection of fire wood***: Due to shortage of water and limited availability of fire wood in Bugesera District, children spent time fetching water and

gathering fire wood at the expense of attending school. This led to frequent absenteeism at school which may be attributed to dropping out school and children poor performance in class.

4.11 Status of food security in Bugesera and Musanze Districts

Results from the household survey indicate that, due to droughts, 52.7% of the households in Bugesera District had difficulties in feeding their families, 42.9% of them experienced soil infertility on their farmlands and 37.1% faced difficulties in feeding their animals. These findings indicate a higher prevalence of food insecurity in Bugesera District compared to Musanze District; a situation which is validated by the results in **Figure 17**. A computed Household Food Insecurity Access (HFIA) index shows that 51.3% of the sample households in Bugesera District are severely food insecure, compared to 32.2% of their counterparts in Musanze District.

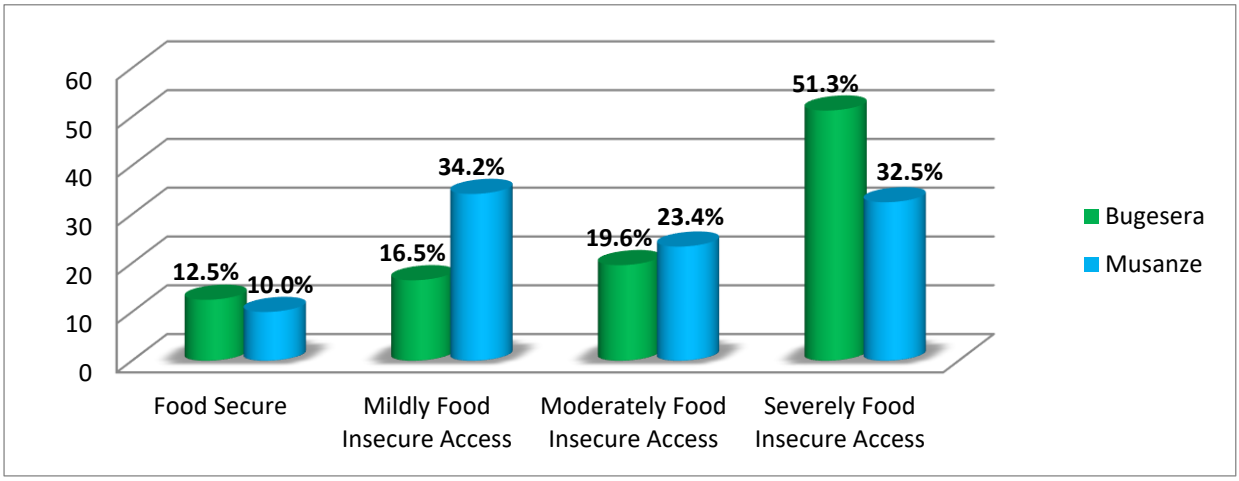


Figure 17: Status of food security among sample HHs
Source: PEA baseline study, 2020

National statistics from NISR (2018d) indicated that 8.9% of the households in Bugesera District were food insecure, poor/borderline food consumption was 12%, stunting among under-5 children was 25%. In Musanze District, the total household food insecurity was estimated at 11.5%, poor/borderline food consumption was 16% and stunting among under-5 children was 37%. Furthermore, 23% and 17% of the households respectively from Bugesera and Musanze Districts used crisis/emergencies livelihood coping strategies.[88]

4.12 Key message about ENRs-poverty linkages in the study area.

In summary, the results of this baseline study indicate that there is a strong link between environment, socio-economic and food security conditions. Poor management of ENRs coupled with their over-exploitation (mainly land) lead to environmental degradation which gives rise

[88] The livelihoods-based coping strategies module is used by NISR to better understand the longer-term coping capacity of households. The indicator is derived from a series of questions regarding household behaviours that lead to asset depletion, such as, selling productive assets or decreasing expenditure on productive inputs. ***Crisis***: HHs that Harvested immature crops, Consumed seed stock that were to be saved for the next season, decreased expenditure on productive inputs, (fertilizer, pesticide, fodder, etc.). ***Emergencies***: Sold the last female animals, migrated the entire household, and begged.

to food insecurity and decline in livelihoods conditions. In both Bugesera and Musanze Districts, the over-exploitation of the already fragmented land and depleted forest resources, with limited protection measures, has led to environmental degradation (soil erosion and depletion, landslides, droughts, floods and poor water quality among others), a situation which in turn, has reduced production capacities of households leading to low agricultural yields, thus affecting food security, socio-economic conditions and poverty (**Figure 18**). Measures that protect environment and reduce poverty are needed to turn around this cycle in with a view to bringing about positive results.

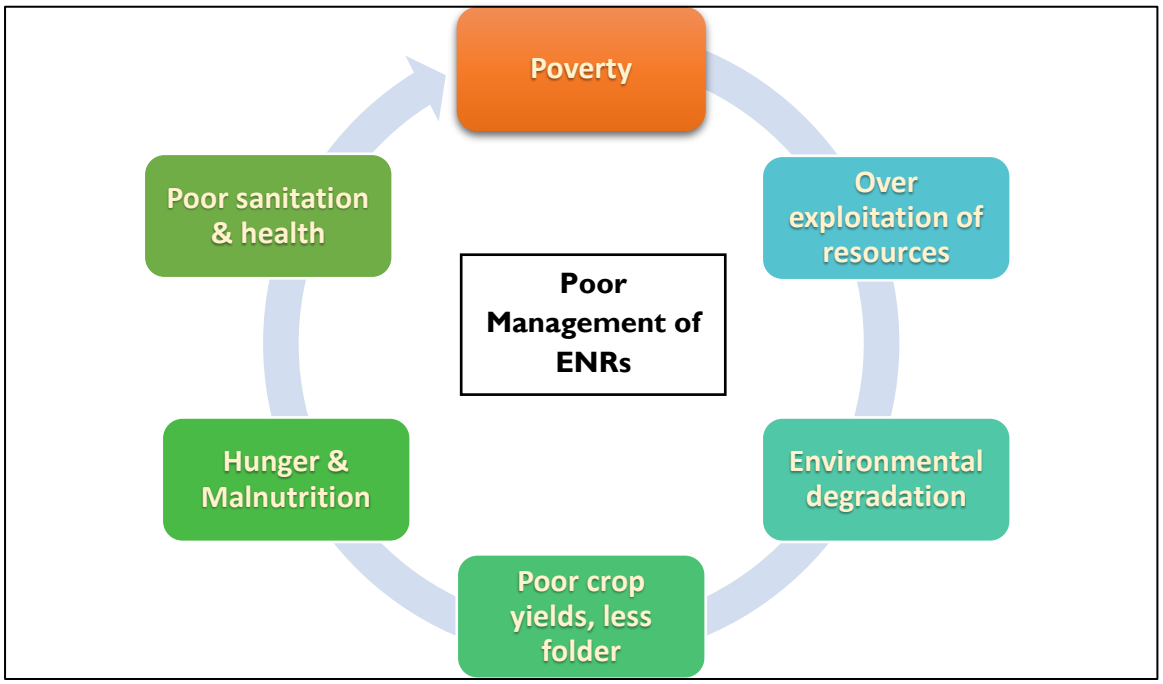


Figure 18: ENR-poverty linkages in Bugesera and Musanze Districts
Source: PEA baseline study, 2020

As outlined in the introduction of the chapter V information gathered in chapter IV has been used to feed adequate interventions explained in the chapter V. Indeed, interventions proposed for the two Districts are responding to the needs shown in the chapter IV.

CHAPTER V: PROPOSED INTERVENTIONS

5.1 Introduction

Taking into consideration the findings and linkages of this study, key interventions have been drawn to support on-going efforts for poverty alleviation and environment protection in line with various innovations for implementation. The information gathered from the study and data reviewed in the Districts of Bugesera and Musanze indicate that their economies are dominated by crop and livestock production. To a lesser extent, mining activities for minerals and building materials have also added a small value to the entire fragile and non-sustainable economy. Other economic activities including working in public and private sectors and small trading business is contributing at a very small percentage to the economy of the two (2) Districts. It is therefore important to keep in mind that, all those weak sectors shall be supported to provide a sustainable contribution to the entire economy. In addition, A sustainable development of Districts like Bugesera and Musanze are subjected to the influence of neighboring ones. For instance, the management of floods in Bugesera District cannot be sustainably achieved without considering the Districts located in the Nyabarongo up stream regions. This implies that some projects to be proposed are linked with other neighboring Districts.

The poverty-environment mainstreaming efforts shall take into account comprehensive areas and shall be multi-sectorial to better design ENR sustainable-poverty reduction interventions. For example, investments in providing clean water to households bring benefits to the health sector, with reduced incidence of water borne diseases. The priorities focused on under a national poverty-environment programme should be consistent with key Government development planning processes. Basically, the most important economic activity, which could help to reduce poverty, is to improve the land use and protection for sustainable and environmentally friendly agriculture businesses. One needs to keep in mind that Bugesera District is located in the Eastern Savana and its environment can be influenced by phenomena happening in the Central plateau, Eastern plateau as well as the Nile Watershed which are relatively high in altitude and rainfall amounts. Indeed, rainwater from those regions flows in to the Eastern Savannah where Bugesera District is located.

The two Districts have not only shown some differences in terms of quality of natural resources such as soil fertility and rainfall but also in terms of erosion risk, drought and flooding. Musanze District is mainly located in the volcanic region where soil fertility is relatively good for most of the highland crops. However, this District is prone to high erosion due to steep topography, high rainfall, seasonal agriculture and shale dominated geology underlying volcanic rocks and ash. On the other hand, Bugesera District is more adapted to sustainable development based on its relatively friendly topography and presence of some big rivers such as Nyabarongo-Akagera system as well as lakes (Rweru, Mugesera, Milayi, etc). It is important to note that some interventions shall be designed taking into consideration influences or impacts which may affect the Bugesera area differently from other regions of the country. It is therefore important to develop country-based interventions and region-based interventions. This chapter has considered both common interventions and District specific-based interventions. These interventions are based on general principles of development as well as specific aspects of each

of the Districts. The guiding principles are those which have been applied in many countries of the world and have managed to develop agriculture in sustainable and environmentally sound ways.

It is important to keep in mind that any intervention shall consider the timeframe because the population shall endure waiting for the outputs from long-term interventions. Therefore, (1) short and medium term and (2) a long-term common program shall be considered. In addition to the short- and medium-term interventions in both Districts, urgent projects are also proposed. The innovation for the interventions proposed in this study take into account key challenges which have weakened existing efforts. Indeed, strategies on how proposed interventions can be successful are highlighted, special consideration is given to high risk zones, special support to youth and other vulnerable groups is considered, short and medium term interventions and a long-term common program for the two districts which will be up-scaled to the entire country to ensure poverty reduction, sustainability and climate change resilience are proposed.

The innovation of the proposed interventions compared to existing ones in Bugesera and Musanze Districts is the preparedness of all stakeholders for the projects proposed. This study has demonstrated that some categories of stakeholders were not informed enough and trained in order to play their specific role. Before starting the implementation of each project, all stakeholders including: District authorities, District professionals, the Private sector and farmers cooperatives shall go through preparedness sessions where every category of stakeholder shall be explained to how to contribute to a given intervention. Learning from successful agriculture businesses in other countries, the role of the private sector has been shown to be crucial.

In the case of Rwanda, it is important to involve and enhance the role of the private sector in the agriculture sector. Definitely, the Districts can involve the Private sector starting from the extension of demonstration trials in the rural areas. The farmers shall learn best practices for irrigation, seeds selection, fertilizer application, weeds control, harvesting, yield handling, yield processing and even marketing. The Bugesera and Musanze Districts should encourage jobless trained agronomists to create private companies which can be involved in the above outlined areas of the agriculture value chain as well as environment protection. Another important aspect of the proposed interventions is that they should be designed to be implemented by different categories of stakeholders. Among those, the educated and non-educated youth shall be given special consideration. Gender balance shall characterize all steps of the proposed projects. Educated and jobless youth trained in environment and agriculture production areas shall receive refreshment training and be enrolled in the value chain.

Women cooperatives shall be established in order to better organize them to take part in various components of the value chain. The gradual development of Nyamata City shall facilitate the establishment of food processing units as well as food market system as it has already started. Persons With Disabilities (PWDs), women and youth shall be trained and motivated to

work in the new job opportunities emanating from the proposed projects. In addition, special consideration was also focussed on the high-risk zones of the two districts. They were identified and visualised using geospatial data taken during the field data collection. Those zones are qualified as high-risk zones because they are environmentally very sensitive **(see Map 10** and **Map 11)** and specific projects are proposed to be implemented in those zones as a matter of priority.

5.2 Short- and medium-term interventions

5.2.1 Proposed urgent projects for Bugesera District

Project 1: Nyabrongo-Akanyaru-Akagera watershed management for sustainable use of water and floods control downstream:

This project is expected to take into account the entire watersheds of Nyabarongo River because it is the main cause of the floods. Indeed, Nyabarongo River flows through 11 Districts. A comprehensive intervention could help to establish mini-valley dams in the entire watershed which could boost agriculture production in the eleven Districts it traverses including Bugesera. During heavy rains, those valley dams could be closed to reduce the water flow in Nyabarongo and this can reduce floods downstream. The water collected in valley dams can be used to irrigate crops during dry periods of the year. When the water quantity reduces in Nyabarongo, water stored in valley dams can be released to feed agriculture activities downstream.

Project 2: Development of an updated soil fertility assessment and management strategy in order to boost agriculture productivity in the District: The study noted that the existing data on soil conditions are not accurate enough to guide professional farming which can attract the private sector players to invest in agriculture. The model proposed in estimating the soil fertility for Bugesera and Musanze Districts in this study added value to the existing data but there is room to do better by conducting regular soil surveys and verification in the entire arable lands of the District.

For such suggested study, the following tasks are proposed to be performed:

- Soil samples collection and analysis in laboratory;
- Soil profiles description in areas where land degradation may have affected some important properties of the soil;
- Development of an updated soil database using findings from soil analysis and soil profile description information;
- Development of an updated land suitability for selected crops by MINAGRI-RAB;
- Development of fertilizer recommendation packages for the same selected crops;
- Improvement of existing irrigation schemes to better supply water in required quantities and timeliness;
- Run piloted trials in collaboration with crop growers and livestock farmers for practical learning (teach them by doing); and
- Engage in extension services by involving private investors and private agronomists for instance Farmer Field Schools and demo-centers.

The results of such a project shall make a difference since every step will be conducted based on evidence and accuracy.

5.2.1.1 Short and Medium-term interventions for Bugesera District

As already mentioned, some areas of Bugesera District are threatened by flooding caused by the Nyabarongo-Akagera rivers system. Some good agricultural lands are often flooded and this causes yield losses. It is practically very difficult to control those floods on site since the amount of water coming from other regions to overfill those rivers is currently unpredictable. Some measures can be proposed including the introduction of small valley dams in the upper and lower Nyabarongo watershed. Nyabarongo river traverses 11 Districts originating from Nyamasheke District.

The construction of small valley dams along the watershed would be very costly but on the long-term basis, it could significantly reduce the floods in Bugesera District and also irrigate land for crop production in the entire watershed. However, a cost-benefit analysis shall be undertaken to guide this process. As already outlined, the two Districts shall be involved in this strategic intervention. Another important intervention is proposed to be the improvement of already existing water harvesting systems and irrigation schemes in Bugesera District. The **Table 43** summarizes the short and medium-midterm interventions for Bugesera District.

Table 43:Environment related Short and medium-term interventions for Bugesera District

Challenges to be addressed by priority	Proposed short- and medium-term interventions
1.The flooding of the marshes which causes the destruction of crops	1a. Development of adequate infrastructure along Nyaborongo, Akanyaru and Akagera rivers to reduce floods which destroy crops: This intervention can only be effective once the first intervention for environment protection is implemented to reduce the quantity of water flowing in Akagera river system (establish adequate infrastructure to protect crops in the marshlands close to rivers and lakes). Borders of the rivers shall be elevated to limit over flows of water during rainy seasons. This intervention shall involve Government and the private sector. Once established, the private sector shall be given a mandate of maintenance. Strategies to mobilize funds for such a big project: A number of sources of funding shall be involved including: District budget, FONERWA, REMA budget, UNDP, MINAGRI, WB, SDSN, ETC,
2.Continued flooding of Nyabarongo and Akagera rivers and lakes that cause loss of yield and other damages	2a. Establish adequate infrastructure to protect crops in the marshlands close to rivers and lakes:
	This intervention shall be built on the existing plans and initiatives. Those plans and initiatives include radical terracing, progressive terracing and trenches on hillsides. A range of value addition techniques shall be introduced. These shall include: updating soil chemical and physical properties to guide decision on the type of infrastructure to use on a specific landscape. The technique used shall include: radical terracing, progressive terracing or tranches where appropriate. Agroforestry trees shall be planted along the edges of the terraces and or the trenches.

	1b. Create valley dams in relevant watersheds to reduce quantity of water entering the identified rivers: This intervention has already been initiated and it can be improved and extended/. Affordable containers and water collecting materials shall be provided by funding agencies (donors, Government, associations) and the private sector can be involved to implement those projects under close supervision of the District. The water can be used to solve a number of issues including: Home garden irrigation, domestic water need, improve health, e.t.c. A project on development of multipurpose dams and maintenance of existing ones shall be introduced in BUGESERA. Indeed, multi-purpose dams help for a number of objectives including: aquaculture and irrigation.
3.Insufficient forested areas for carbon sequestration, animal habitats and tourism. Limited production of fruits	3a. Development of multipurpose trees nurseries to feed forests creation and fruit trees plantations: Crop growers shall be trained by doing with regards to selection of adapted trees and fruits to be planned in their fields. Crop growers shall be trained in term of the quality of soil and how to apply organic and inorganic fertilizer on specific fields for specific trees. Most of trees planted have experienced destruction due to drought. Water harvested can be used to irrigate those trees for a better growth. 3b. Create forested areas, integrate agroforestry to agriculture lands: Plant trees along rivers and lakes. Rehabilitate abandoned mining sites and transform them into forest lands. Planting fruit trees. The value addition for this intervention shall include: to provide enough water to trees during water shortage periods, to protect the trees against destruction by livestock animals, allocate sections of forests to different villages for follow up, e.t.c. 3c. Increase the number of certified units making cooking stoves to preserve trees: Support the private sector to promote the use of cooking stove, educate the private sector with regards to gas production from animal dung, provide subsidy to private sector dealing with production and selling of cooking stove in order to reduce the price to an affordable level, promote biogas digesters and enhance their maintenance systems. 3d. Mobilize and sensitize HH for solar energy development: Engage the private sector in this initiative by training them and supporting them financially with loans. Introduce subsidy systems to progressively increase the financial and technical capacity of the private sector and cooperatives to engage in this intervention 3e. Develop project for the protection of animal species present in the region (kinds of birds, monkeys, inzobe) develop fish production in lakes and ponds: Organize training by doing approach for the cooperative and the private sector through tree planting, forest protection, ponds construction technology and maintenance. Promote tourism in the region as an income generation activity to fund the population initiatives. 3f. Develop adequate forested areas and marshlands management to increase tourism and irrigation around the lakes:

	Involve cooperatives and associations and the private sector to create biosphere reserves. The biosphere reserves play the roles of economic benefits coupled with biodiversity conservation. 3g. Integrated landscape Management for building community resiliency to climate change in Rweru, Rilima and Gashora Sectors in Bugesera District.Bugesera District has been experiencing Climate change effects characterised by persistent drought result into degradation of Rweru - Mugesera catchment. 20,000Ha of the catchment located in Rilima, Gashora & Rweru administrative Sectors of Bugesera District. This catchment has various ecosystems including Land, Forests, and lakes (Mirayi, Kidogo, Rumira,Gaharwa and Rweru). Due to Soil degradation, the population are facing continuous low crop and Livestock production. As the results, the population encroached lakes' buffer zones for their agricultural activities but the problems are not solved and Government is still providing food to the affected population. Through this project the following will be possible: population will equipped with tools and strategies to cope with impact of climate change, and sustainable income generating activities through farm and off farm activities. 2h. A project on tourism opportunity based on the occurrence of more than 9 lakes of Bugesera and the Bugesera International Airport under construction. 2i. Introduction of zero tillage and minimum tillage for both seasonal and perennial crops: This project shall address excessive mineralization which reduce the percentage of organic matter. This practice shall save a lot of nutrients from being eroded, leached or vitalisation. The soil structure shall be improved and soil degradation shall be avoided

Source: PEA baseline study, 2020

Table 44: Agriculture related Short and medium-term interventions for Bugesera District

Challenges to be addressed by priority	Proposed short- and medium-term interventions
1.Low Agriculture productivity/production	1a. Production of cassava cuttings: This initiative shall also involve the government and the private sector as well as farmers cooperatives. The private sector and the cooperative members shall be trained and given incentives in terms of loans and/or subsidy for sustainability of this initiative. This intervention is expected to yield a high production of cassava to cover the nutrition needs of the population and increase the income of people. In Bugesera District, we already have a factory for cassava processing. Increasing cassava yield production could provide more raw material for the processing factory and the capacity of the factory could upgrade as the production increases.

	1b. Agricultural Development through land consolidation, mechanization and irrigation: This intervention has already started in the region and needs to be strengthened by engaging the private sector and farmers cooperatives. This intervention shall result into a better production and hence reduce poverty of the population.
2.Low use of agriculture inputs such as fertilizers, pesticides, improved seeds)	2a. Testing the soils, developing fertilizer recommendations before adding fertilizer (mineral and organic fertilizers) and select environmental sounds pesticides and improved seeds Adding adequate amount of fertilizer shall enhance productivity and reduce poverty of people. This intervention can be implemented by farmers' cooperatives with support of the University of Rwanda laboratories and experts. The use of environmentally friendly chemicals for pest control shall be enhanced and farmers shall be trained to use them efficiently.
3.Arable lands are affected by erosion	3a. Construction and maintenance of radical and progressive terraces where appropriate: This intervention shall initiate new approaches in terms of technical improvement of the way radical terracing shall be constructed. Indeed, the top horizon shall be removed and stored aside, then the engineering work shall take place and after levelling the top fertile soil shall be brought back and cover the infertile soil. Soil testing shall be carried out. The soil testing may be expensive and thus the method used in this study can be an alternative. All those activities shall involve farmers' cooperatives and the private sector. 3b.A project of Integrated agriculture using irrigation technology: especially for vegetable, fruits and other income generating commodities targeting the Bugesera growing cities and related infrastructure like International Airport. 3c. At least one model village shall be established to address poverty and environment protection: Indeed, model villages are conceived to manage limited land resources in a way to ensure adequate accommodation for people, sustainable land use projects and environment protection. The district shall discuss with experts to decide the best location for such a model village.
	4d. Introduce rainwater harvesting systems project for reducing run-off: This intervention shall include: agroforestry and progressive terracing and increasing the soil organic matter by applying plant residues, compost, manure and mulching.
4.Food insecurity and insufficient livestock production	4a. Introduce small livestock species: rabbits, sheep goats, pigs in all villages of the district. The best way to implement this intervention shall include; Training farmers' cooperatives in collaboration with the private sector. The

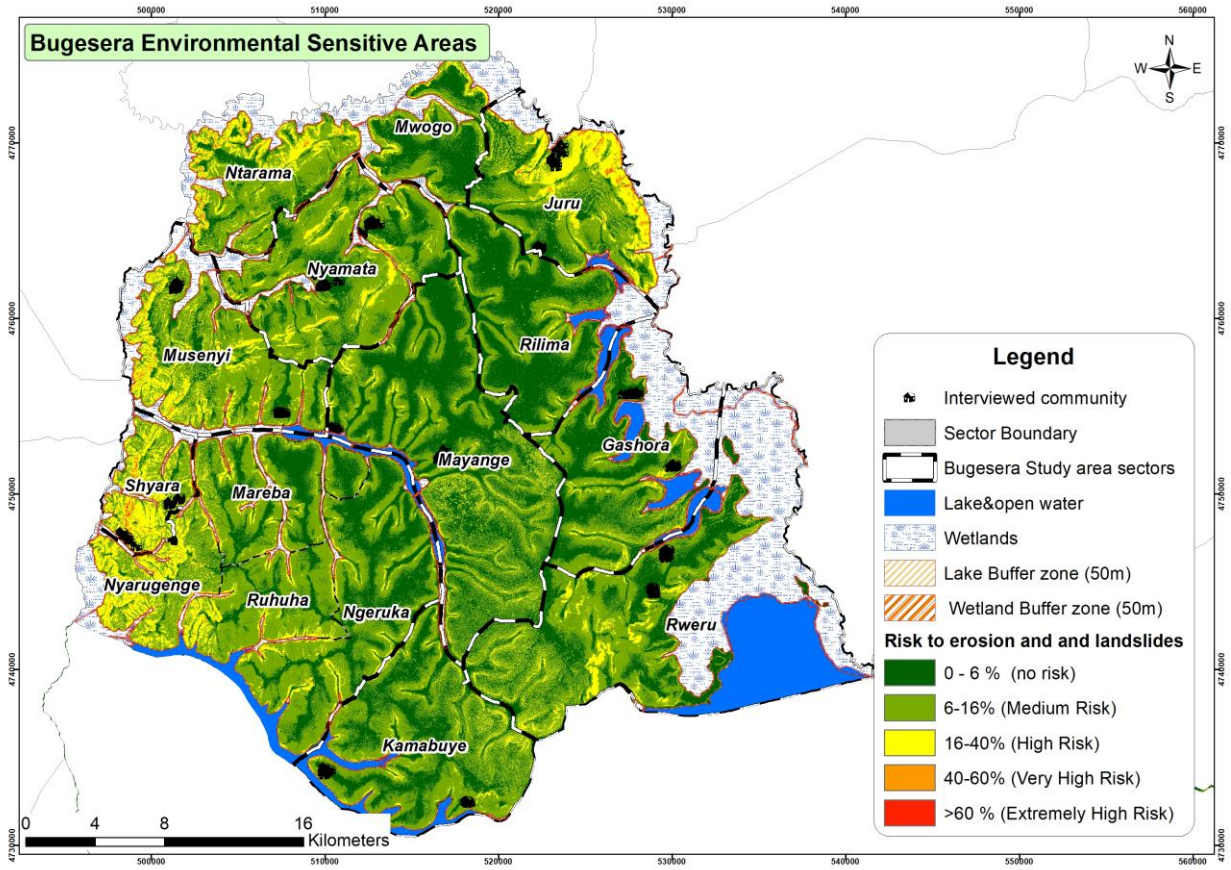
	market shall be better organized to allow a greater income for livestock keepers.
	4b. Increase production of garlic, enhance the production of mushrooms and other horticultural crops, vegetables and fruits: Those initiatives are already introduced in the District and they are not sustainable yet. The engagement of the private sector is key for sustainability. Efforts shall be deployed in introducing subsidy systems as well as market organization.

Source: PEA baseline study, 2020

5.2.1.2 High risk zones for Bugesera District

The below map and table show the high-risk zones of Bugesera District. In those zones, environmental problems provoke the increase of poverty due to the degradation of lakes, other water bodies, wetlands, lake buffer zones, and wetland buffer zones. This degradation can be attributed to local misuse but also the upstream of Nyabarongo river watershed land management and climate variation. In order to quickly resque those zones, projects related to water harvesting and irrigation shall be prioritized (see short- and medium-term interventions in Bugesera District, see **Table 43**).

Map 10: Bugesera Environnemental Sensitive Area



Source: PEA baseline study, 2020

Table 45: Bugesera District environmental hig risk zones

Sector	Environnemental Sensitive Areas in Bugesera	
	Wetland	**Lake**
Shyara	Akanyaru Nord, Ruvubu, Rwintare, Cyohoha Nord aval and Kiruhura-Gatare	-
Musenyi	Akanyaru Nord, Rucahabi, Cyohoha Nord Aval, Kiruhura, Murago, Mbonwa, Nyakajuli, Kagoma	Cyohoha Nord
Nyamata	Rucahabi, Kagoma, Muzi, Kiyogoma, Mwesa, Nyarubande, Umushimba-Rusagara	Cyohoha Nord
Juru	Nyabarongo aval, Mugesera aval, Gashanga	Gashanga
Gashora	Nyabarongo aval, Rweru-Mugesera-Nyabarongo	Rumira, Mirayi
Mayange	Nyarubande, Umushimba-Rusagara,	Cyohoha Nord
Rweru	Rweru-Mugesera-Nyabarongo, Mbuganzera	Rweru
Kamabuye	Nyarubande, Gakurazo, Mparo, Kigeli-Muyigi	Cyohoha Sud

Source: PEA baseline study, 2020

5.2.2 Proposed urgent projects for Musanze District

The Proposeed project is: Sustainable and environmentally friendly use of the watershed of Gacaca, Cyuve, Nyange, Kinigi and Shingiro Sectors for agriculture production:

This project aims at enhancing the protection of all the watersheds of the Sectors listed above, for sustainable development of the region. Based on our findings, the region offers a great potential for agriculture which needs to be sustained. The project is very urgent because if one observes the way the land is being degraded presently, it shows that the land may cease to be arable any time soon. Indeed, poor agriculture practices and poor land protection may result into a situation where soil will be washed away due to erosion and landslides.

Considering the steep topography of the area, coupled with high rainfall and relatively fragile geology (volcanic rocks/ash, shales, e.t.c.) there is an urgent need to introduce a model of agriculture where perennial crops and fruit trees shall be given priority. Indeed, fruit trees are a source of income which can be used by farmers to buy supplementary food crops for a healthy diet.

5.2.2.1 Short and Medium– term interventions for Musanze District

The District of Musanze has already played and is still playing a major role in feeding the Rwandan population with many products including Irish potato. This is as a result of high soil fertility experienced in the volcanic zones. Indeed, volcanic soils are very rich in basic nutrients and other elements. Sufficient rains are also irrigating that region and support crop production. It is however very important to mention that the agricultural lands are threatened by the steep topography, high rainfall and poor agricultural practices.

The baseline study established that all the geographic areas of Musanze District must be prioritized for integration given the topography. The study also established that several areas within the District have high mountains experiencing gulley erosions and landslides. The natural resources in the dominant steep slopes with marshland and valleys abound with reckless human activities were damaged long before the implementation of various policies, laws and regulations. The study emphasized the poverty causing factors in the eight Sectors of focus in the study which call for quick action to improve the well-being of the citizens.

Results from the field data collection process identified prioritized zones for intervention, for instance rainwater from the Volcanoes National Park (VNP) which causes floods, landslides, soil erosion and phenomenal damage to crops in Kinigi, Nyange, Shingiro and Gataraga Sectors faced with direct interaction with the Volcanoes Park and further downstream damage to crops in Busogo (Mogogo valley of 70ha), Musanze, Cyuve, Muko and Nkotsi Sectors, besides buffalos, jackals, gorillas, inkima, and antelopes in the four Sectors around VNP. Other flood prone locations included Buramira and Nyakarambi valleys. The baseline study also took stock of the landslides observed in the high mountains of Gisoro, Rubona, Rugalika and Songa and the floods in Mukungwa's, specifically in Murago, Ndali, Rucyurano and Buhanga.

Indeed, most of the agricultural lands are on very steep topography. The seasonal cropping exposed soils to erosion and tons of fertile soils are being exported outside of the country via Nyabarongo River. It is very difficult to reduce the seasonal agriculture and replace it with a more sustainable agriculture, which is based on perennial crops. The practice of perennial crops allows the protection of the soil because it is covered by natural vegetation and/or mulch. It is expected that this practice will significantly protect the land against erosion and land slide. As already mentioned, important interventions can only be successful if other parts of the country are involved. For instance, given the relatively large population to feed in the District of Musanze, reducing seasonal crops would have a negative impact. Interventions in other Districts which are less prone to erosion would increase the production of food crops to compensate the inadequacies of food crops production in Musanze District. By producing perennial crops under the SEAB-Rwanda program, they will make enough money to buy food crops from other Districts and this shall be managed at country level. **Table 46**Error! Reference source not found. and **Table 47** emphasizes the most important short and medium- term interventions proposed for Musanze District.

Table 46: Environment related short and medium-term interventions for Musanze District

Challenges to be addressed by priority	Proposed short term intervention
1.The rainwater flowing from volcanoes causes erosion, landslides and floods which destroy crops, houses and other infrastructure.	1a. Introduce a project of tree plantation. around the Volcanoes National Park, edges of rivers and Ruhondo Lake: The project shall include: terraces (radical and/or progressive where appropriate), fruits trees, drainage system for irrigation, management of Ruhondo lake islands for tourism (Beach resort), purposes, Transformation of Mukungwa swamp into touristic area by plantation of indigenious trees that will attract beds for tourism, For sustainability purposes, this project shall involve the private and cooperatives of farmers. All need to be trained properly with regards to types of trees, adaptability to climate and soil as well as management of such projects. The expected outcomes of this intervention include: Land conservation, sustainability of soil fertility and houses. The sustainability of soil fertility shall impact on yield increase. The yield increase shall result into improved nutrition and health of people and hence and reduce poverty.
2.Flooding of the valleys of Gacaca, Cyuve, Nyange, Kinigi and Shingiro Sectors for agriculture production due to rainwater runoff from the volcanic Park.	2a. Introduce a project to protect the valleys of Gacaca, Cyuve, Nyange, Kinigi and Shingiro Sectors for agriculture production: Various methods shall be used including; Progressive terraces and channels on hillside. Those initiatives shall increase the infiltration of rainwater and this shall benefit the crops on hillside and in the marshlands. On hillside, the water holding capacity of soils will increase and crops will benefit from that. In the marshland, crops will not be destroyed by erosion, floods and landslide. The management of rain water from volcanoes that cause flood in Musanze city Construction of of concrete dam to retain that water for reuse purpose (irrigation in dry season to increase production of vegetables in that area) 2b.A project for municipal waste water and sludge management shall be introduced. Based on the geological nature of the land, relatively high infiltration rate is expected. The infiltration of polluted water would contribute to ground water and hence negatively affect the

	health of the population which is using that water downstream for domestic use
3.In a number of sites of Musanze, erosion is taking place due to poor land management and over cultivation, high rainfall and vulnerable soils.	3a. Progressive terraces are advocated in combination with agroforestry trees: In some areas where erosion has already removed the fertile top horizon, it is recommended that perennial crops replace seasonal ones to keep the land productive and protected. Progressive terraces are expected to limit run off and hence limits erosion. Trees biomass will progressively mineralize in the soil and recharge the soil with lost nutrients
4.Insufficient tourism activities in rural areas	4a. Projects to expand tourism activities in the District are advocated to attract visitors to stay for longer and pay more money. This will require the management of entertainment spaces, introduction of various types of entertainment, create biosphere reserve infrastructure, promote Rwanda culture, and bring more income to reduce poverty. Indeed, it has been observed that tourists like the Rwandan culture related various entertainments. In order to promote that opportunity, the private sector shall be involved and the District could better organize it and make sure there is incentives to attract private sector investments.
5.Non-existence of household waste management techniques	5a. A project of garbage & waste management for Musanze city, Byangabo Centre and UR-CAVM Busogo campus. The project shall include composting and biogas production units. This initiative shall contribute to reduce poverty and also preserve the environment and produce organic amendments for crop production.
6.Insufficient agroforestry trees in agriculture lands which increases soil erosion followed by progressive infertility	6a. Introduce a Project for agroforestry development in the District: The introduction of agroforestry trees shall benefit the population in many ways including: reducing soil erosion and land slide, production of folder and mulching biomass and composting. As a result, the soil fertility improvement via compost and mulching, will increase the productivity and hence reduce the poverty reduction.
7.Insufficient use of volcanic rocks for other production and construction	7a. Introduce a project to transform the lava stones into pavers: This initiative shall be organized at District level and involve private sector wich is technically tooled in this matter. This project could provide employment opportunities for the population. Raw materials are enough since the overlaying geology of the district is made of volcanic roks 7b. Enhance the existing project to transform volcanic stones into cement:

	This project already exist and the District shall be directly involved in order to promote the participation of local private sector. The District shall organize the population and connect with the company dealing with the project. The employment shall reduce the poverty of the population.

Source: PEA baseline study, 2020

Table 47: Agriculture related short and medium-term interventions for Musanze District

Challenges to be addressed by priority	Proposed short term intervention
1.Insufficient use of agriculture inputs such as fertilizers, pesticides, improved seeds)	1a. Introduce the soil testing system and the development of fertilizer recommendation and promote the use of agricultural inputs (mineral fertilizer and organic manures, improved seeds)
2.Insufficient agriculture systems organization taking into account a number of key factors (seeds, pest and diseases control. yield management, fertilizers management)	2a. Introduce sustainable subsidy systems allowing benefits for the crop growers and limit losses by the Government: Any sustainable agriculture development system shall be supported by systems intervening during difficult circumstances Subsidy systems by the Government has shown positive effect on building in some cases and during some periods, the agriculture production may not be economically beneficial, in other, cases, the agriculture businesses become very profitable. The Government shall establish a system for compensating the loss and recover the compensation from farmers during profitable periods. 2b. Advocate for trained agronomists to engage in agriculture related businesses and Introduction of policies and regulations allowing trained agronomists and land owners work together The agriculture businesses require a number of skills and technologies which are not easy to be understood by non-educated farmers: Trained agronomists who are jobless emphasizing on youth and special groups including people with disabilities and women in order to allow them being progressively involved in the agriculture sector. Farmers shall benefit because production would increase based on best practices implementation. This intervention can only be sustainable if based on relevant policies and regulations. 2c. Regularly collect weeds from Mukungwa river which will be used in production of organic fertilizer. Indeed, this site is very productive in terms of a variety of weeds which can be used for composting.

	2d. Enhance the project providing small livestock to the population to increase meat production, income generation and organic fertilizers production. Indeed, the technology of using animal manure to produce high quality organic amendments needs to be enhanced. These amendments are generally rich in Nitrogen and Phosphorus which are needed for crops growing in the District. Since small livestock could be affordable by a number of farmers in terms of technology, more initiatives could be deployed in all villages of the district. 2e. Promote banana production and build a complete value chain for banana. In addition to a processing unit, other sectors including: production phase and agribusiness phase shall be introduced.

Source: PEA baseline study, 2020

5.2.2.2 High risk zones for Musnze district

The map and table shown below highlight the high-risk zones in the District of Musanze. In this area, land use options and climate changes factors have drastically degraded the environment and could even do worse. This area needs to be protected urgently.

The area includes: Wetlands, volcanoes National Park, Volcano Expansion lands, Lake Buffer Zone, and Wetland Buffer zones. Similar to the case of Bugesera, urgent projects shall be implemented to avoid further degradation of the environment in Musanze Distric. The following projects shall pioneer in the mentioned high risk zones: (1) Introduce rainwater harvesting systems to reduce run-off and avail water for irrigation, (2) Introduce a project of tree plantation around the Volcanoes National Park, edges of rivers and Ruhondo Lake and (3) Build on already on going initiative in the volcanoes region supported by the World Bank.

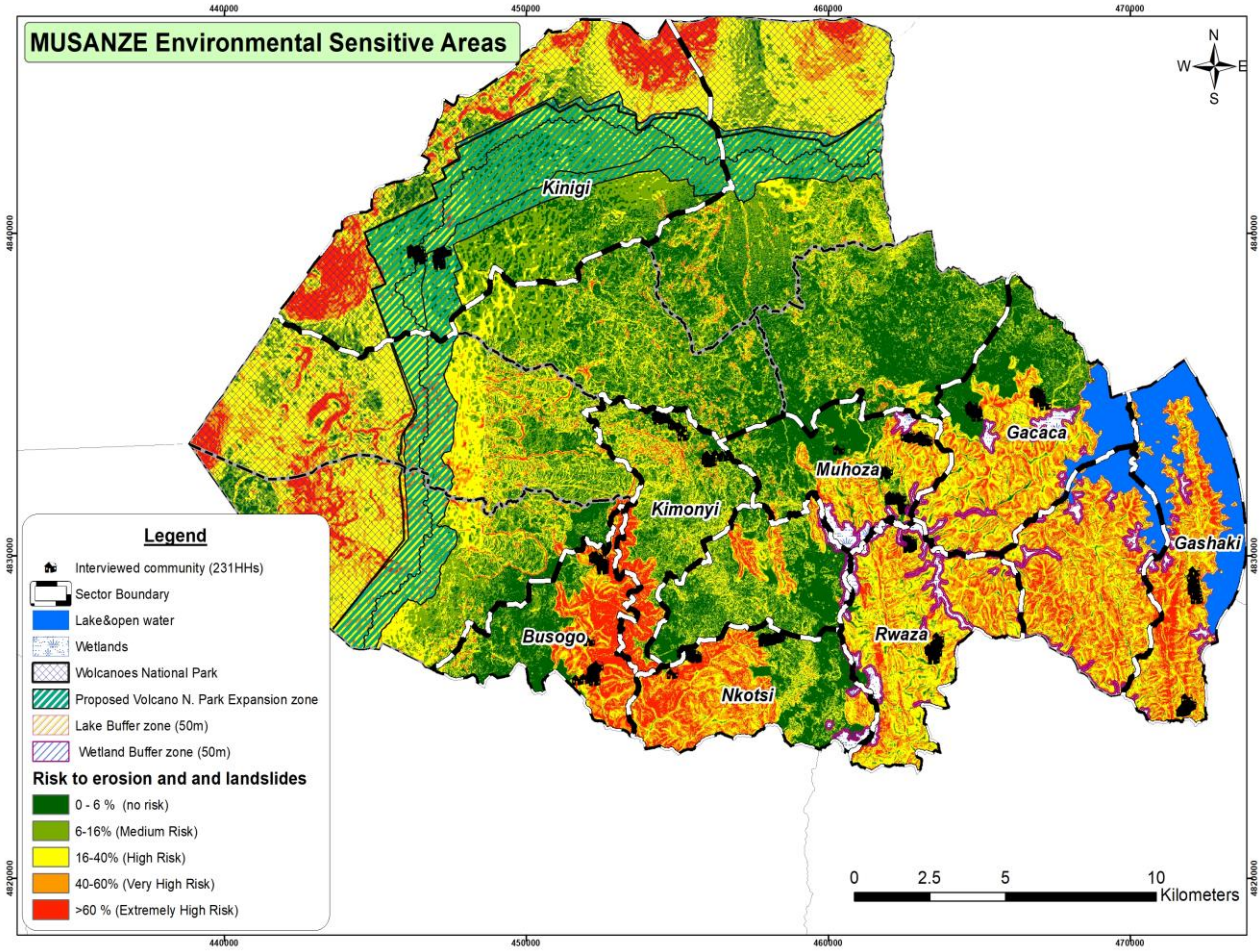
Table 48: Environmental Sensitive Areas in Musanze District

Sector	Environnemental Sensitive Areas in Musanze		
	Wetland	**Lake**	**Park**
Kinigi	-	-	Volcano National Park
Nkotsi	Mukungwa,	-	-
Muhoza	Mugara-Mubona, Mukungwa, Cyabararika, Nyamutukura	-	-
Rwaza	Mukungwa, Mukinga, Nyagahongo, Shabogo, Rushwashwa	-	-

Gacaca	Kigugu, Gacaca, Shobogo, Mukungwa, Nyamutukura,	-	-
Gashaki	Mukinga, Mubindi, Lake Ruhondo wetland	Ruhondo	-

Source: PEA baseline study, 2020

Map 11:Musanze Environnemental Sensitive Area



Source: PEA baseline 2020

5.3 Long-term common interventionfor Bugesera and Musanze Districts

In addition to the short and medium-term interventions outlined above, there is a need to develop and implement a more sustainable program which shall ensure the establishment of a professional agriculture with high income. The program proposed is intitled; Sustainable and Environmentally friendly Agriculture Businesses in Rwanda (SEAB-Bugesera/Musanze). The development and implementation of this program shall be carried out in different interventions outlined below.

Step 1

Development of the programme titled Sustainable and Environmentally friendly Agriculture Business in Rwanda (SEAB-Bugesera/Musanze): Knowledgeable people who fully understand global relevant programmes and the context of the concerned District shall develop this programme. The programme shall be approved and adopted by relevant public institutions and organs. They may include Ministries and agencies dealing with land management, environment, disaster management, agriculture, finance and trading and MINECOFIN. Relevant tools shall be

developed to enable the smooth implementation of the program. It is important to understand that such an intervention shall be pioneered in the Districts of Bugesera and Musanze as District level programmes. While implementing this programme, some lessons will be drawn which will help to improve the programme for the whole country.
Fortunately, the Government of Rwanda through the MINAGRI and other institutions has developed some programmes and projects from which the SEAB-Rwanda can be built. Those programmes and projects include; PSTA4, Girinka munyarwanda, Smart Nkunganire, Tubura, One-acre fund, hinga weze, RDDP, PAST, PRICE, KIWP, IITA, CIP, etc. The four priorities of the PSTA4 include; (i) Innovation and Extension; (ii) Productivity and Resilience; (iii) Inclusive markets and value addition; (iv) Enabling Environment and Responsive leadership.

Step 2

Development of comprehensive and multidisciplinary training tools which shall be used to train all stakeholders for understanding and implementation of the SEAB-Rwanda: Some of the tools will be used to teach crop growers and animal keepers with regards to the Sustainable and Environmentally friendly Agriculture Business (SEAB) adapted to each agro-ecological zone. Some tools shall also tackle aspects related to poverty reduction including cost benefit analysis, distributional impacts and monitoring of ENR linked multi-dimensional poverty.

Training of trainers will be the first step. Those will include extension staff, District and Sector agronomists who shall then impart the skills learnt to crop growers and livestock producers. The aim of this training section is to create awareness to crop growers and animal producers regarding the complexity of agriculture business. It is expected that they will understand that they cannot play some important roles of the Value Chain (VC) and then start thinking of inviting other stakeholders with required specific knowledge to fill the gaps. The training shall clearly emphasize on the role to be played by partners of every component of the SEAB-Rwanda VC.

The main components may include: (1) Inputs management (seeds, fertilizers, pesticides), (2) Soil management (soil fertility assessment, specific crop fertilizer requirement, fertilizer recommendation, fertilizer application for specific crops, etc.), (3) water management (water requirement, irrigation and drainage, potential water sources, flooding, droughts,), (4) Cropping systems management, (4) Harvesting, transport and storage of fresh yield/produce, (5) Yield and food processing management, (6) Market management, (7) Credits, subsidy and insurance management, (8) EIA, EMP development and implementation and Environmental Audit for SEAB-Rwanda. Crop growers and animal keepers will understand that they can only play some roles and other roles shall be played by knowledgeable people in different areas. Those gaps can be filled by more trained people including: TIVET, BSc, MSc and PhD holders in agriculture sciences and agribusiness, agri-engineering, economics, policies and environmental sciences.

Step 3

This intervention shall be concerned with launching pilot SEAB trials in Bugesera and Musanze Districts. The trial shall be fully managed by the Government to make sure that all components are well established and are well running. Priority crops shall be selected and developed in the framework of SEAB-Rwanda programme.

Step 4

Based on the lessons provided by the intervention three (3) above, the interventions one (1) and two (2) will be improved to better fit the reality on the ground. At this stage, the country will be having a workable, practical and demonstrated model to be introduced in the whole country through other agro-ecological zones. The following step will be adoption and scaling up in the whole country. This is explained in the chapter 6 of this document.

Step 5

This intervention shall be focused on bringing innovations to allow pragmatism and efficiency of existing projects as explained below. The innovations shall emphasize on acting knowledgeably and comprehensively. The most important activities are concerned with improving land resources management including water, soil, etc. This exercise shall include the construction of radical and progressive terraces where applicable, enhancing rain water harvesting in appropriate ponds and valley dams; improve irrigation schemes adapted to hillside and flat lands; introduce and enhance agroforestry; enhance quality seeds management; support research centres for fundamental and adaptive research specific to the two Districts (quality seeds, organic and inorganic soil amendments, water management, agroforestry, yield management, food processing, food science, food and yield marketing, insurance and subsidy); rehabilitate special sites including Mugogo valley (Musanze) of 70ha for fruit and vegetables production.

5.4 Appropriate land husbandry interventions for sustainable land management

In Bugesera and Musanze Districts, there is need to protect the land with appropriate land husbandry measures enabling sustainable management of natural resources and increasing productivity. CROM tool reported the range of medium to extreme high erosion risk zones. The interventions on land husbandry are recommended based on the variations on gradients of the slopes and soil depth but also taking into consideration other edaphic[89] and socio-economic factors. The following land husbandry practices are recommended in the proposed land units:

- **Land unit 1: Lands with slope** gradient of 0-6 %, regardless of soil depth in exception rocks comprise the cultivation integrating good agricultural practices with hedgerows and grass strips.

[89] Physical, Chemical and Biological Properties of Soil

- **Land unit 2: Lands with** Slope gradients between 6-16% are proposed for progressive terraces (hedgerows, grass strips, ditches and trenches) integrated with agroforestry and grass species.
- **Land unit 3: Lands with s**lope gradients between 16-40 and 40-60% and soil depth >1 m, can receive radical terraces with agroforestry (AF)/grasses. This has to comply with particularity of the field such as presence of water seepage to cause landslide.
- **Land unit 4: Lands with s**lope gradients between 16-40 and 40-60% and soil depth <1 m, progressive terraces integrated with agroforestry/grasses are proposed.
- **Land unit 4:** Lands with slope gradient >60% are recommended for the plantation of forest, rangeland and perennial.

Some exceptions can be considered for outcrop rocks and other environmental reasons. Additional interventions can be adopted such as buffer zones, forest cover, and national parks. The combination of measures has to be set in the way of minimizing erosions at hillsides and adapting to the actual farming systems in the area.

In the findings of CROM assessment, the results illustrated that the land husbandry interventions in place with coverage of savannah, contour bands, shrub, bench terraces, forestry, stood at 2%, 27%, 0%, 17%, forest 54%, respectively (**Figure 19)**. Erosion control activities in Bugesera should be promoted in an integrated approach combining soil fertility aspects and catchment approach. Since there is strong consideration for irrigation in the area, there is need to integrate it with land husbandry interventions at hillside surrounding irrigation schemes. In this context, there is still a need to protect areas as presented in the **Figure 20** to sustainably manage the environment and increase productivity to attain high yields.

The biggest area of the District, 70% (30,264ha) requires the promotion of progressive terraces which obviously receive agroforestry, grass and fodder species in addition to developed trenches and protection of risers along contourlines as reported by Ndayizigiye (1993). The authors proved how three types of living hedges on the contourlines (leucaena, calliandra, calliandra + setaria) are preserving soil capability but not really increasing productivity (Roose and Ndayizigiye, 1997; Ndayizigiye, 1993). The 10% of coverage area need to be protected by only agroforestry species at scattered landscape without following countour lines.

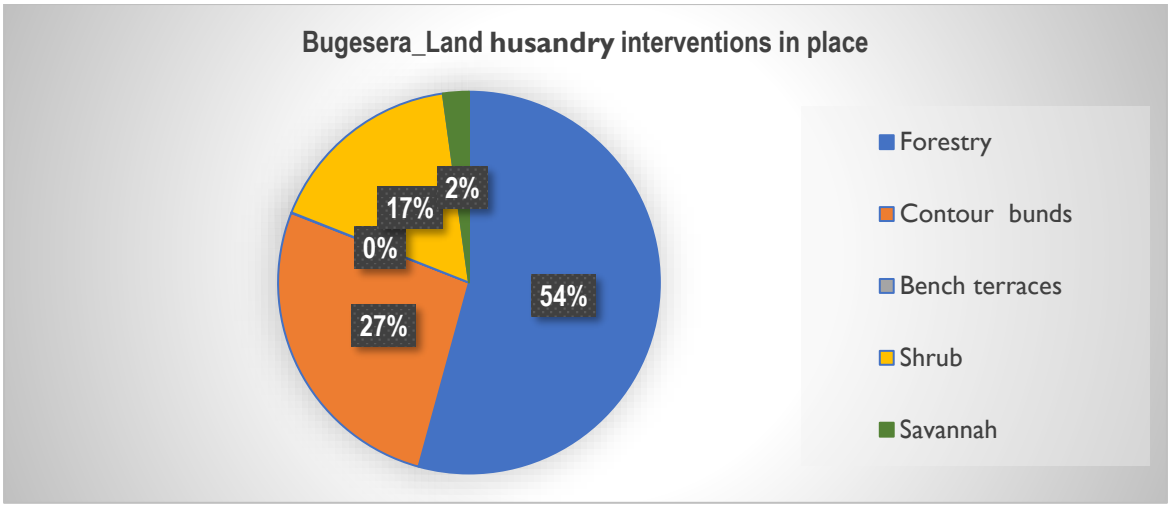


Figure 19: Bugesera District ongoing Land husbandry interventions
Source: CROM Tool, MOE 2020

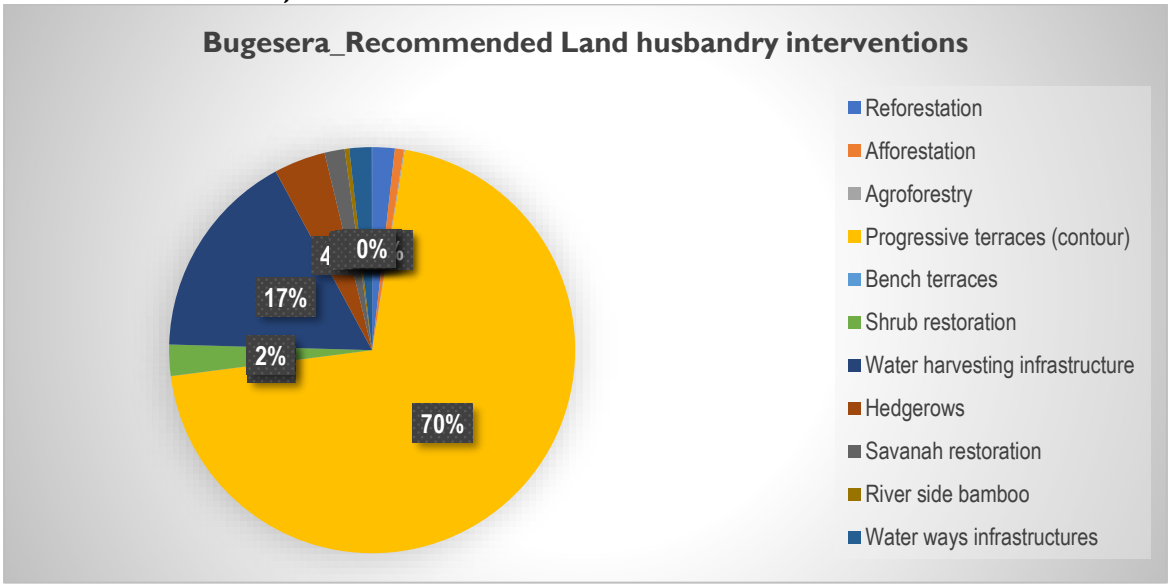


Figure 20: Bugesera District Recommended interventions for Land husbandry
Source: MOE 2020 (B)

While, the biggest part of Musanze District with very steep slopes is covered by natural forest and vegetation that are very effective to control erosion and improve the ecosystems, the CROM tool helped to populate inventory of the protected and non-protected land in the District as well proposed interventions by considering the biophysical conditions such as topography, soil types and depth. The soils from volcanic materials are less structured and mainly located on steep slopes and the local farmers referred to such soils as *"Ruseseka"* in Kinyarwanda. Therefore, these particular soils require particular management for different interventions including physical infrastructures (terraces) and biological measures (hedgerows). The proposed land units are similar to Bugesera District but also it has to consider the aspect of fragility of soils and the intense rainfall experienced. The proper management of these fertile soils potentially productive for agriculture have been proposed in the CROM tool (MoE, 2020).

The tool first determined areas with effective erosion control measures in place in each sector of the Musanze District (**Figure 21**) which is equivalent to 2,500 ha dominated by forest and terraces.

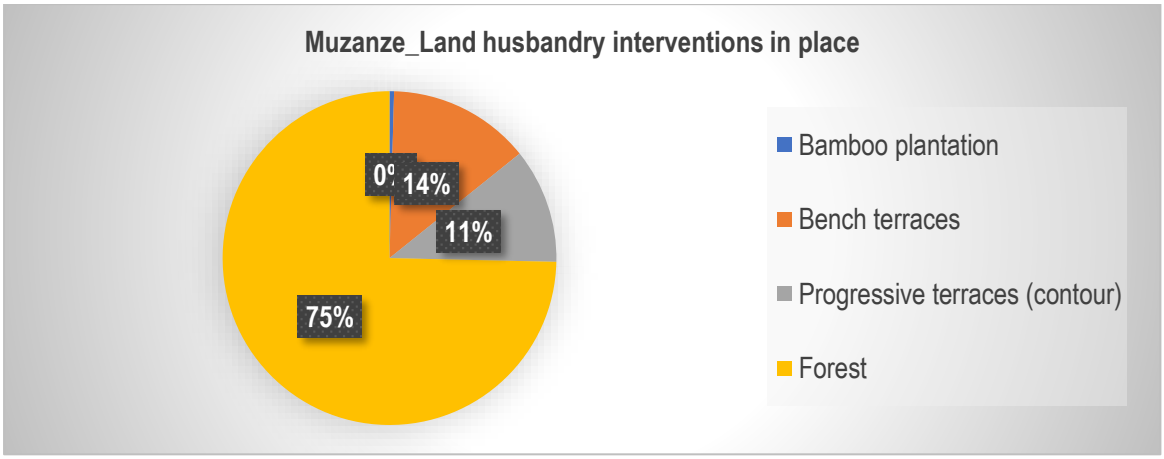


Figure 21: Erosion control measures in Musanze District
Source: MOE, 2020

Thereafter the recommended interventions were proposed in the remaining unprotected areas at 9,053ha (**Figure 22)** with dominance of progressive terraces such as integration of contour bank terraces, hedgerows and agroforestry systems at 94% of the total area.

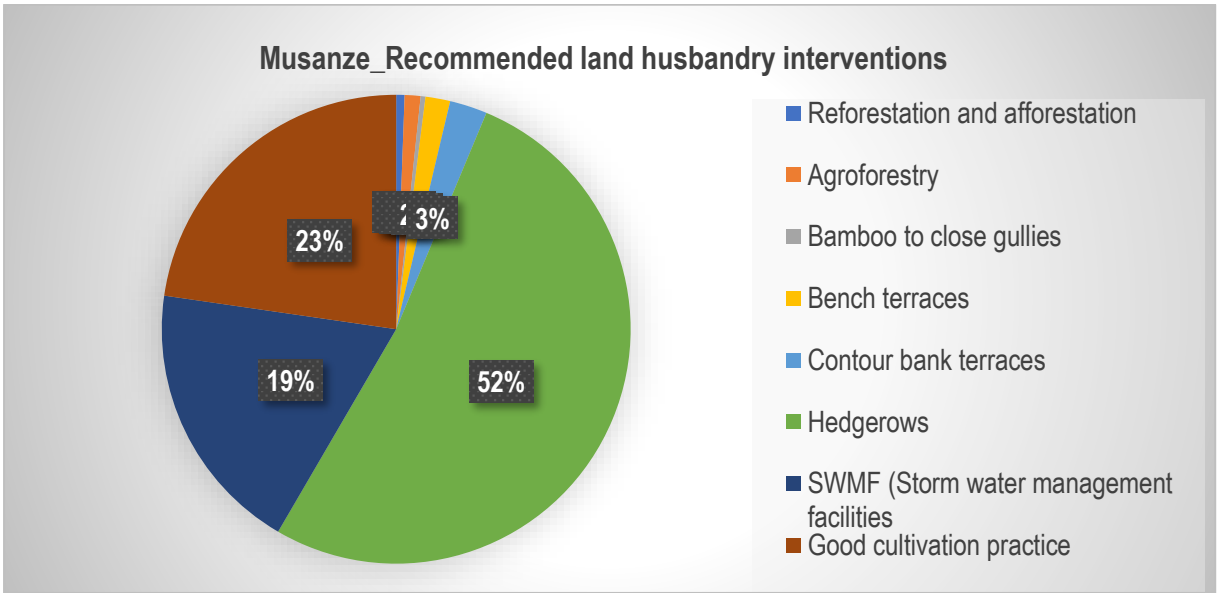


Figure 22: Distribution of established (A) and recommended (B) land husbandry interventions in Musanze District
Source: MOE, 2020

Interventions for Forestry Resources:

a) Appropriate regulatory instruments will be developed and implemented to ensure sustainable and efficient biomass supply
b) Biodiversity and ecosystems services and values will be enhanced in accordance with sectorial agenda

c) Active participation of stakeholders in Sustainable Forest Management to ensure ownership and proper benefit sharing at the sector level.
d) The adoption of Agroforestry and Trees Outside Forest techniques will be enhanced to contribute to overall forest resources and agriculture productivity at District level

5.5 Possible synergies for effective collaboration

The best strategy of synergy and approaches for capacity building on Poverty reduction Environment integration in the District Development plans will need to put in place Technical Working Group (TWG) from these listed stakeholders: MOE, REMA, MINECOFIN, PROVINCES, DISTRICTS, JADF (DISTRICT), MINAGRI, MINALOC, MININFRA, RDB, and JADF. To eradicate poverty, the following are synergy activities that need to be performed through collaboration of different stakeholders: [90]

- The District needs to increase the number of TVETs (carpentry workshop, tailoring, mechanics, brick laying, as well as welding and construction) so as to equip people with necessary skills for acquiring off-farm jobs offered by projects like the industrial park and the international airport undergoing construction in Bugesera District.

DDS identify the Lack of entrepreneurship skills as one of many weaknesses of Private Development & Youth Employment Sector. To avoid that, the District intends to support and to empower youth and women to create and run businesses through entrepreneurship skills development and access to finance:

(1) Trainings farmers on good agricultural practices;
(2) Training citizens on kitchen gardening;
(3) Training of farmers on use of organic fertilizers;
(4) Training of famers on post-harvest handling and storage facilities.
(5) Mobilization of the population on reproductive health programs involving all stakeholders to fight against demographic growth;
(6) Strengthening food security;
(7) Increasing opportunities/destinations and promoting tourism;
(8) Strengthening industrial zones and the other factories in the neighborhoods must to settle down in this area;
(9) Improving cycling tourism, infrastructures for the Youth (entertainment industry/field, innovations, talent development);
(10) Re-examining eligibility criteria to obtain loans to BDF for Youth, men and women,
(11) Creating employment in rural areas;
(12) Decreasing tax by RRA to facilitate the youth to invest in business and possibly create employment themselves;
(13) Providing improved seeds on time and reducing the purchasing price of farm inputs (seeds, fertilizers and medicines so that people can practice farming as a profession and the Government can support the cost on 75% and the cultivator on 25%).

[90] Qualitative Surveys (2020)

(14) Draining Mugogo Valley (70ha) and manage the ditch caused by the rainwater from the Volcanoes National Park
(15) Strengthening Monitoring and Evaluation process of the Development Partners in District
(16) Bringing big and small projects to rural areas to enhance the well-being of the people who live there;
(17) Giving the subsidies under VUP and one cow by family without taking into account the Ubudehe 1 and 2 categories because there are households which are in the categories which do not suit them so that they should benefit from this subsidy;
(18) Interesting investors to come invest in Musanze District, Ruhondo Lake, various valleys, volcanoes stones; and
(19) Project which can multiply and distribute fruit seedlings in all Sectors.

5.6 Available tools to mainstream ENRs interventions

(a) Available tools

(1) DDS strategic planning documents (DDS Policy action matrix, DDSs Logical frame work /outcome, output and indicator matrix, **(2)** MTEF, **(3)** District performance contracts (Imihigo), **(4)** Annual JADF forums and monitoring action plans, and **(5)** *Imihigo* monitoring action plans cascaded from the Provincial to District levels.

(b) Suggested tools

(1) Analytical and decision-making analysis framework & modelling tools (quantitative, and transparent approach to making decisions under uncertainty. The fundamental tool of decision analysis is a decision-analytic model. A decision model provides a way to visualize the sequences of events that can occur following alternative decisions (or actions) in a logical framework);

(2) Case studies and best practices (a process or record of research in which detailed consideration is given to the development of a particular person, group, or situation over a period of time.);

(3) Economic, social and ENRs assessments tools such as cost-benefit analysis. This will use inter-sectoral approaches that will allow to address the land use-livelihood system as a whole. In this process, ENRs and socio-economic benefits that can be obtained from more integrated land use systems will be taken into account. This will also include better resource management practices in terms of improved efficiency and ecological functions of sustainable, diversified systems. Given the above, it is expected that low cost sustainable production combined with land conservation and ecosystem services will be promoted.

(4) Monitoring & Evaluation tools (refer to all the indicators, tools and processes that will be used to measure if a program has been implemented according to the plan (monitoring) and is having the desired result (evaluation). ... An M&E framework is one part of that plan) and;

(5) Research tools: this will include anything that becomes a means of collecting information for a study. Cost - benefit analysis studies will be undertaken for informed decision making on environmental costs and benefits and distributional impacts, including Environmental Impact Assessments.

The approaches and methods to be used are as follows:

- Farmer field schools
- Community active planning
- Watershed management
- Tools for land resources assessment
- Payment for ecosystem services

5.7 Available capacity to mainstream ENRs interventions in the two Districts

This sub section discusses results of Organizational Capacity Assessments for the two Districts with focus on planning, budgeting, spending and undertaking requisite assessments.[91] In this section, focus shall also be oriented to the capacity available to apply the tools, the capacity to apply multi-dimensional poverty measurement and the capacity to prepare results-based proposals for investment.

It has been shown in this study that existing capacity in all the sectors needs to be improved in order to feed a sustainable and environmentally friendly development. The reality is that the capacity to apply the proposed tools are expected to be improved through the interventions mentioned in the section above. Skills related to measuring and understanding the multidimensional poverty indicators shall be provided through the trainings proposed in the interventions.

The baseline study established that all the positions were occupied by qualified staff who have been recruited according to a pre-established selection criterion. It was noted that the organizational structure for the District was very well organized based on the national Districts' model. It was also noted that the personnel capacities available to the District on planning, budgeting, spending on environmental matters and natural resources blended well into the structure in place. The study noted that anchored on the overall planning of the District, environment and natural resources aptly fitted into the functions of the office of the Director of Agriculture and Natural Resources and the sub-section of Forests and Natural Resources. The six (6) years life span of the DDS 2018 – 2024 aligns it very well with the NST1 and is critical in its orientation with the Sector.

The study noted that the District priority for a green economy approach is underscored in its Economic Transformation pillar that promotes "Sustainable Management of Natural Resources and Environment to Transition Rwanda towards a Green Economy." Moreover, environment and climate change were highlighted in NST1 as cross-cutting areas of policy concern which can

[91] DDS, Imihigo and Qualitative Surveys (2020)

be positively impacted by a range of development activities with priority given to agriculture, urbanization, industries and energy. The right investments in relation to environment and natural resources have been identified with incisive reference to the baseline study assessment results and consultation of various existing literature reviewed. It is the opinion of the consultants that the DDS, operational planning, performance contracts (*Imihigo*) and M&E plans are sufficient tools for implementation of poverty and ENR interventions at District level.

5.8 Indicators for monitoring and evaluation

The baseline study identified various indicators which will help JADF to monitor and evaluate environment and natural resources projects/activities being implemented by different partners in the Districts including:

Table 49: ENR – MPI Indicators

ENR – MPI Indicator	Measurement
Livelihoods	Proportion of poor who depend directly on natural resources for their livelihoods;
	Distribution & types of property rights/access on natural resources;
Food security	% of household income spent on food
	% of population below minimum level of dietary energy consumption.
Access to drinking water	% of the poor with access to safe drinking water;
	Time/distance spent per day collecting water and trend over time (by women and children);
	% of poor households' income spent on water
Access to water for irrigation	% of poor farmers with access to sufficient water
Access to energy resources	% of poor using firewood and/or charcoal as major source of energy;
	Average time/distance spent per day collecting fuelwood (esp. women, children) and trend over time;
	% of household income spent on fuelwood;
	% of poor households using improved stoves or cleaner fuel;
Land/soil degradation	% of the poor living in degraded areas/marginal land (e.g. eroded lands)
	Average cultivated area (ha) of poor households;
	Soil nutrient levels.
	Soil erosion rates
	Average yields
	Deforestation rates;
ENR related health impacts	Respiratory infections incidence;
	Water borne diseases incidence
	Mortality rate for children under five years

ENR – MPI Indicator	Measurement
	DALYs lost (Disability Adjusted Life Years)
	Malnutrition
	Childhood stunting
Natural disasters (e.g.: landslides, drought, floods, plant diseases…etc.)	Incidence and severity of environmentally related disasters
	Number of deaths from environmentally related disasters;
	Number of people made homeless by environmentally related disasters
	% of population living in vulnerable areas prone to natural disasters
	Incidences of conflict in use of natural resources
	Number of plants affected by diseases
Inclusion of poverty-environment objectives at national levels	Number of poverty-environment objectives in policies plans
	Budget, donor & other financial allocations for poverty-environment objectives

Source: PEA baseline study, 2020

The chapter VI was developed on the basis of expected results from chapter V. The expected good experiences and success stories from the trials carried out in Bugesera and Musanze Districts will feed into scale up projects in the remaining Districts of the country.

CHAPTER VI: SCALE UP OF PROPOSED INTERVENTIONS

6.1 Introduction and general concepts

The analysis results from the first objective of the study has comprehensively informed the interconnection between the status of the environmental resources (ENRs) and the poverty situation of the population in the two Districts. Any scale up of a successful program and/or intervention shall take into account the status of the environmental natural resources (ENRs) and the level of preparedness of the District concerned. The preparedness is very important and it concerns public sectors, private sectors and the entire population. Every category among those cited here shall fully understand its role and get the capacity to perform it. In most cases, the five (5) long term interventions to be carried out in order to fulfill the program proposed shall be introduced in every District. Depending on the level of preparedness of each category, efforts to be deployed are expected to be relatively different.

The mechanisms and strategies for reducing poverty shall apply rural development principles taking into account; existing resources, environmental features and socio-economic challenges. The implementation of the proposed interventions has been demonstrated to be the back born of any environmentally friendly and sustainable rural development worldwide. They shall adapt to the context of each District based on already existing initiatives initiated by the Government of Rwanda, NGOs and private sector. This chapter aims to guide the way those common interventions could be scale-up to other Districts of Rwanda. Apart from the common long-term interventions, short term interventions have also been proposed to build the basis for the more sustainable long-term interventions. In order to better scale up the successful interventions, the following factors have been taken into account; rainfall, erosion risks, landslide risks, floods risks, level of soil fertility, slope gradient, temperature, biodiversity, geology, land occupation, population density and growth rate, status and availability of water bodies, forestry, land cover, agriculture practices, public and private sectors existing initiatives, mining, crop adaptation, etc. Other important items to be considered include: potential and existing tools to be used to support the scalee-up of the interventions such as: indicators to be used for monitoring and evaluation of the progress of the implementation.

6.2 Scale up of common long term interventions

The strategies proposed for scaling up these interventions shall borrow and adapt worldwide experiences where similar interventions have been implemented. Any sustainable development needs to be based on sustainable management of natural resources to make sure that investments made will not be useless once the raw materials are no longer available due to degradation and/or affordability. The other important pillar is the progressive development of human resources capacity to enable them practice professional land use and upgrade from the existing subsistence style of land use including farming towards a sustainable and environmentally sound model.

The lessons collected from the implementation of the proposed interventions in the Districts of Bugesera and Musanze will help to better implement various projects to fight against poverty as *well as preserving the ENR.* The first intervention will be initiated and implemented by the public sector, following similar trends of development as for other programs which shall have been successful in Districts. The achievements of the first intervention in the pilot Districts of Bugesera and Musanze are expected to be easily replicated in other Districts without many difficulties.

The training materials shall be updated in line with specific District. Training materials shall be updated for each District in line with the level of experience of the stakeholders to be trained including: (1) relevant policy makers, (2) public professionals, (3) agronomists at all levels of the District, (4) relevant local government officials, (5)potential future farmers (educated in agriculture), (6) crop growers and animal keepers, (7) land owners, (8) potential yield/food buyers, (9) Insurance bodies, and (10) Subsidy and credits bodies. In brief, people working as a result and thoseinvolved in different components of the agriculture value chain shall understand how the new system shall work and understand the risks and opportunities by engaging in such a business, through experiential learning.

In addition to the training exercise, lessons learnt from the pilot SEAB from Musanze and Bugesera Districts shall be used to better establish a similar program in another District. As mentioned, the pilot studies in Musanze and Bugesera Districts will be fully managed by the public sector but the scale up shall bring on board the best performing private bodies, and support them until such time thatthey will be mature and experienced enough to manage the entire business chain. It is therefore recommended that in each new District, the steps adopted be exactly the same as for the pilot Districts.

It is important to note that" Districts located in the Western highland zone shall copy most of the practices from Musanze District. The Districts located in the Eastern Savanna and Eastern plateau shall be guided by the successful practices experimented in Bugesera District".

6.3 Scale up of short – term and medium -term interventions

The short-term specific interventions in Bugesera Districts are drawn from its specific features, environment opportunities and challenges, natural resources, ongoing initiatives and Government policies and pre-programmes oriented towards Bugesera District. For instance, the rapid interventions in Districts of the Eastern Savana and Eastern plateau shall take into account challenges such as: (1) Insufficient forested areas for carbon sequestration, animal habitats and tourism and limited production of fruits, (2) Continued floods from rivers and lakes that cause loss of yield, (3) Shortage of water during some periods at household level, (4) Low Agriculture productivity, (5) Insufficient irrigation infrastructure, (7) low use of agriculture inputs including fertilizers and others. Indeed, Districts located in the Eastern savanna and Eastern plateau have a lot of similarities with Bugesera District and can easily scale up successful practices from Bugesera.

Among others the following interventions could be scaled up: Afforestation, agroforestry, water harvesting infrastructure, irrigation infrastructure, livestock systems, water bodies protection to avoid floods, fisheries production, market development, use of cooking stoves to save fire wood energy and reduce deforestation, fertilizer recommendation based on similar type of soils. Soil testing verification for updating soil information, promote horticulture, promote mushrooms production, etc.

Similarly, successful interventions from Musanze District shall be scaled up to other Districts showing almost similar features as Musanze Districts. This scale up shall concern Districts located in the Congo-Nile watershed highland. The scale up in those Districts shall take into consideration significance differences including the soil properties which are more favorable in Musanze than other Districts in the region. Among others, the following interventions can be scaled up with adequate adaptation to concerned District: (1) Enhance the project providing small livestock to the population to increase organic fertilizers sources; (2)Promote small animals livestock projects for meat production; (3) Introduce a Project for agroforestry development in the District; (4) Establish factories or food processing units relevant to the type of important types of production in the District; (5) To test the production of new crops varieties and upscale them once successful; (6) Progressive terraces are advocated in combination with agroforestry trees; (7) In some areas where erosion has already removed the fertile top horizon, it is recommended that perennial crops replace seasonal ones to keep the land productive and protected; (8) Development of small livestock species such as rabbits, sheep goats and pigs; and lastly (9) Promote nursery seeds of fruit, promote mushroom production, promote horticulture production.

6.4 Scale up of tools for implementation

The scale up exercise will need adequate tools and strategies adapted to every District and for specific intervention. The lessons, which will be drawn from the pilot trials in Musanze and Bugesera Districts, will help to better implement the interventions in other districts. Some tools tried by the Government of Rwanda have already demonstrated some relative success and shall continue to be experimented in the scale up process.

Those tools include: Those tools include: the DDS strategic planning, DDS policy action matrix, DDS logical framework/outcome, output and indicator matrix, MTEF document, DP Contract (District Performance Contract=Imihigo), Annual JADF forums and monitoring action plan, Imihigo monitoring from Province to District level, improved Farmer field school system, improved community activity planning, improved watershed management plans, improved tools land resources assessment, Enhance the payment for ecosystem services, Sustainable Management of Natural Resources and Environment to Transition Rwanda towards a Green Economy, District governance structure, directorate of Agriculture and Natural Resources and the sub-section of Forests and Natural Resources, DDS 2018 – 2024 and District M&E Plans. The above-mentioned tools if well used are capable of strengthening the capacity to implement the interventions proposed in all Districts.

6.5 Scale up of indicators for Monitoring and evaluation

The indicators identified by this study to be used to assess the progress of interventions are also proposed to for monitoring and evaluating the scale up activities. Those indicators include: Livelihoods, Food security, Access to domestic water, Access to water for irrigation, Access to energy resources, Land/soil health, natural disasters incidence, Inclusion of poverty-environment objectives at national levels, level of integration on poverty environment in policies/programs/projects/budgets/donors' funds. The strengths and weaknesses observed during the pilot trials in Bugesera and Musanze Districts will help to better scale up the interventions in other Districts of the country. The above-mentioned indicators will be improved and/or adapted where and when necessary depending on the reality on ground.

The chapter VII on conclusions draws from the entire report and this connects with the findings in chapter IV, the proposed interventions in chapter V and the scale up section in chapter VI.

CHAPTER VII: CONCLUSIONS

This chapter aims to double-check the level of achievement of the expected outputs of this study. Looking at the three objectives of this study and the findings and discussions developed around the major findings to answer the research questions. It is evident that they were achieved as outlined below:

Objective (1): The conclusion of the ENR-MPI baseline refers to the baseline findings and information gathered in different sources. The analysis was done specifically to District; the ENR-MPI findings revealed that Bugesera District is more vulnerable than Musanze District with regards to this objective. The index of Head count ratio (H) and adjusted head Count ratio (Mo) in Bugesera District is higher than that of Musanze District. The ENR-MPI results have a similar trend as the data from the National surveys' findings that have been conducted and published by The National Institute of Statistics of Rwanda (EICV5, DHS, RLFS, others). To conclude, the picture of findings from ENR-MPI baseline indicated that,

(1) Bugesera District has greater ENR-poverty rate (more ENR-poor) than Musanze District, due to more environmental problems in the District;
(2) The ENR-poverty led to food insecurity which is higher in Bugesera than in Musanze.
(3) Citizens in both Districts have limited response and adaptation capacities to poverty because the rates of those who use crisis/emergencies livelihood coping strategies are relatively high.
(4) The ENR-MPI baseline conducted in households and information collected from District documents (DDs, Imihigo and other shared unpublished documents) show the situation of ENR-poverty, the adopted strategies and policies to fight poverty. This study show that it is not enough compared to the level needed. As demonstrated in the findings of this study.
(5) Environmental problems are aggravated by poor management and utilization of ENRs including: excessive seasonal cropping which loosen the soil top horizon, not enough perennial crops which strengthen soil top horizons, deforestation, low afforestation, poor terracing, insufficient up stream land protection
(6) Soil, on which the majority of the households depend for agricultural activities, is the most affected by environmental problems, which make it infertile. Farmers experienced crop failures, which have exacerbated their poverty.
(7) The main environmental problems that drive poverty in Bugesera District are droughts, floods and soil erosion, destructive rains and land slide drive poverty in Musanze District, poor knowledge of crop growers and animal keepers.
(8) The high dependence of citizen on fire woods and charcoal as source of energy for cooking calls for attention in order to strengthen the use of energy saving and renewable energy technologies, particularly in Bugesera District.
(9) The problem of waste management is a critical concern since the many households still throw domestic wastes in bushes, which lead both to air and water pollution (through erosion).

(10) The incidences of droughts in Bugesera are not a recent phenomenon. Limited access to water (for household use, irrigation, etc.) and limited extensive reforestation are an indication of institutional failure (resulting from insufficient funds or lack of coordination among development partners) to address this problem.

(11) Groundwater, harvested water and surface water in both districts are to some extent chemically and physically polluted due to different anthropogenic activities carried out in its surrounding areas like farming, fishing, and improper disposal of solid waste which were transported through soil erosion and agriculture runoff.

(12) The information gathered from Musanze District of highlighted the following challenges: poor watershed management on the Volcanic Mountains and hillsides, poor mitigation of soil erosion, rampant landslides that destroyed houses and damaged feeder roads, other infrastructure and weak structures and strategies to improve ENRs practices aimed at addressing environmental problems.

(13) The buffer protection zones were made a need felt by the respondents of the FGD's of Musanze District. The natural forest of Volcanoes National Park (VNP) is habitat for certain species of game animals: buffalos, gorillas, inkima, antelopes, jackal, that frequently cross this forest to damage crops of the population occupying the areas around the VNP in Nyange, Kinigi, Shingiro and Gataraga sectors.

(14) For protecting lakes and its shores from agricultural activities there should be fruits farming within 50m from the lake in Bugesera District, additionally protecting Gako natural forest, and the Akagera River where the FGD discussants in Bugesera District noted that the lakes were flooded by mud extending to the Akagera valley.

The baseline study has produced important information which can be used to propose innovative approaches to improve the ENRs sector in Bugesera District. The following challenges were identified: low yield, poor use of chemical and organic fertilizers, lack of systematic and organized soil fertility assessment, lack of fertilizer recommendation, shortage in water for crops caused by shortage of rains, insufficiency fish due to overfishing that led prohibition to overfish IN KIDOGO, RWERU, MIRAYI AND CYOHOHA lakes, the windstorms and high temperature in the lake, and reduced water level of the lakes led to low procreation of fishes, high deforestation, overflows and flooding of Akagera and Nyabarongo rivers led to big losses of crops grown in the Marshlands in MWOGO, GASHORA, and Low support to improve ENRs practices.

Objective (2): The cost-effective projects interventions were proposed from the results of the objective (1) based on information gathered through HHs survey, FGDs, KIIs and desk review and; Indeed, two style of interventions were proposed including: Short and medium term interventions for each District and a long term common program for the two district. Special aspects were taken into account such as: innovative way of being successful, yoth and other sensitive groups were taken into account, gender, high risks zones of the two districts as

well as existing and priority initiative from the two districts. Deep explanations were devoted on what makes a difference between existing and proposed interventions. Multidiciplinary training for different stakeholders dealing with specific components of agriculture and environment related projects were provided. Existing and proposed tools enabling the success of interventions were also highlighted.

Objective (3): all proposed interventions will be scaled up considering other Districts having the same characteristics similar to Bugesera and Musanze Districts.

Adequate interventions are proposed to be first of all tried in Bugesera and Musanze Districts as in order to get improved and be scaled up in other districts of the country. The scale up is proposed to follow exactly the same steps as in Bugesera and Musanze trials. Districts showing almost similar features as Bugesera and Misanze will adopt almost similar steps for implementing the interventions with relatively minor adaptations. The scale up shall follow the lessons from the trials and it is proposed that districts located in the Congo-Nile watersheds follow the experience of Musanze while districts located in the eastern savanna and eastern plateau and Imbo region shall follow the experience of Bugesera. The scale up for the districts located in the central plateau shall be done using a little bit of experiences from Musanze and some from the district of Bugesera based on their middle position in terms of rainfall, drought, erosion, landslides, floods, topography, temperature, etc, …

Though this study was limited to Bugesera and Musanze Districts poverty and environment problems, those challenges remain a major concern for the peoples' livelihoods in the country. Potential hazards shall be expected to be observed in any agro-ecological zone of the country at any time. For example, heavy rains killed 72 in one night (6-7th May 2020) across the country, damaging infrastructures such as roads, water supply channels, 7 bridges and over 850 houses. The worst affected districts were Gakenke (with 23 people of whom 8 family members), Nyabihu, Muhunga, Musanze (with 6 people), Ngororero, Rulindo, Ruhango, and Rubavu. Also, more than 60ha of crops and vegetation were destroyed. It is expected that if the proposed interventions in the chapter V are taken seriously and implemented, one may expect a significant reduction of poverty as well as a better natural resources management and environment protection. It is therefore clear that the expected results of this study is achieved and it is strongly recommended that interventions proposed be translated into projects proposals to be presented for funding in various funding institutions including public (local Government, central Government, external funding organisations, etc,…)

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APPENDICES

Appendix 1: *ENR- MPI – Dimensions, indicators, deprivations weights, and cut-offs*

Appendix table 1: Dimensions, indicators, deprivations weights, and cut-offs

Dimensions	*Indicators*	*Deprivations weights*	*Indicator Weights*	*Dimension weights*
SOIL RESOURCE	Soil infertility	Population experienced and has been affected by soil infertility in their livelihoods,	4.4%	**40%**
	Drought events	Population experienced and has been affected by droughts for their agriculture, livestock and forest activities;	4.4%	
	Soil erosion	Population experienced and has been affected by soil erosion in their livelihood	4.6%	
	Destructive rain	Population experienced and has been by destructive rainfall in their livelihood;	4.4%	
	Landslide	Population experienced and has been affected by landslide in their livelihoods;	4.4%	
	Nutrition	- Population experienced and has been affected by poor nutrition in their livelihood;	4.4%	
	Health	Population experienced and has been affected by health problems;	4.4%	
	Soil degradation	Population experienced and has been affected by soil degradation in their livelihood	4.4%	
	Agro foresting	Population experienced and has been affected by not planting the agroforestry trees in their farming plots,	4.4%	
WATER RESOURCE	Water access	Population experienced and has been affected by inaccessibility of water (Long distance to water sources);	6.6%	**20%**
	Improved water access	Population experienced and has been affected by use and drinking of dirty water (unimproved water sources).	6.8%	
	Water management	Population experienced and has been affected by poor management of water in their livelihood,	6.6%	
FOREST RESOURCE	Natural forest	Population experienced and have been affected by animals from the park that damage crops and livestock, and prohibition to exploit it.	6.6%	**20%**

Dimensions	*Indicators*	*Deprivations weights*	*Indicator Weights*	*Dimension weights*
	Forest and woodlots plantation	Population experienced and affected of not having forest and woodlots plantation	6.6%	
	Deforestation (firewood, construction)	Population experienced and affected deforestation, damaged forests, woodlots and reduce of forest size;	6.8%	
FISHERY RESOURCE	Overfishing	Population experienced and has been affected by overfishing in lakes and rivers;	2%	**10%**
	Nutrition	Population experienced and has been affected by reduce of the production of fish.	2%	
	Education (Dropout and irregular class attendance)	Population experienced drop out and low school attendance.	2%	
	Change of water level of Lake and river water	Population experienced and affected by the changes of water level of rivers/ lakes in time of rainfall and rainstorms) or diminishing of levels due to droughts disturb fishery and affected household's livelihoods	2%	
	Temperature and windstorms in lake and rivers	Population experienced and affected by the effects of the change of temperature; windstorms and changing of water levels in fishing activities;	2%	
MINERALS AND NATURAL STONES RESOURCE	Quarries activities	Population experienced and has been affected by the extraction of minerals, natural stones (explosion; air pollution by stone crushing and soil degradation by quarrying)	5%	**10%**
	Education (Dropout and irregular class attendance)	Population experienced the drop out and low school attendance	5%	

Source: PEA baseline study, 2020

Appendix 2: Theories and steps for measuring ENR- MPI

In the scope of this study, a particular point in time, the wellbeing of "*n*" people in Bugesera and in Musanze districts, were evaluated and associated to the ENR by "*d*" indicators.[92] The analysis denoted the achievement of person "*i*" in indicator "*j*" by $x_{ij} \in \square$ for all $i = 1,\ldots,n$ and $j = 1,\ldots,d$. The achievements of "*n*" persons in "*d*" indicators were then summarized by $n \times d$ dimensional matrix X, where rows denoted persons and columns denoted indicators. Each ENR-associated indicator was assigned a weight based on the value of a deprivation relative to other deprivations. The relative weight attached to each indicator J the same across all persons and was denoted by w_j, such that $w_j > 0$ and $\sum_{j=1}^{d} w_j = 1$.

For single-dimensional analysis, people were identified as ENR-poor as long as they failed to meet a threshold called the 'deprivation Cut-off/ENR-poor' and non-poor otherwise. In the ENR- multidimensional analysis based on a counting approach – as with the adjusted headcount ratio – a person was identified as ENR-poor or ENR-non-poor in two steps. ***In the first step***, a person was identified as deprived or not in each indicator subject to a deprivation cut-off. The analysis denoted the deprivation cut-off for indicator j by z_j and the deprivation cut-offs were summarized by vector "z." Any person "i" deprived in any indicator j if $x_{ij} < z_j$ and non-deprived otherwise. It also assigned a *deprivation status score* g_{ij} to each person in each dimension based on the deprivation status. If person "i" was deprived in indicator j, then $g_{ij} = 1$; and $g_{ij} = 0$ otherwise. ***The second step*** *applied* the weighted deprivation status scores of each person in all "*d*" indicators to identify the person as poor or not. An overall *deprivation score* $c_i \in [0,1]$ was computed for each person by summing the deprivation status scores of all "*d*" indicators, each multiplied by their corresponding weights, such that $c_i = \sum_{j=1}^{d} w_j g_{ij}$. A person was identified as ENR poor if $c_i \geq k$, where $k \in (0,1]$; and non-poor, otherwise.[93] The deprivation scores of all "*n*" persons were summarized by vector c. After identifying the set of poor and their deprivation scores, the analyst obtained the adjusted headcount ratio (M_0). The *focus* axiom requires that while measuring poverty the focus should remain only on those identified as poor.[94] This entitles us to obtain the censored deprivation score vector $c(k)$ from c, such that $c_i(k) = c_i$ if $c_i \geq k$ and $c_i(k) = 0$, otherwise. The (M_0) is equal to the average of the censored deprivation scores: $M_0 = MPI = \frac{1}{n}\sum_{i=1}^{n} c_i(k)$.

[92] The meaning of the terms 'dimension' and 'indicator' are slightly different in Alkire and Foster (2011) and in Alkire and Santos (2010). In Alkire and Foster (2011), no distinction is made between these two terms. In Alkire and Santos (2010), however, the term 'dimension' refers to a pillar of wellbeing and a dimension may consist of several indicators.

[93] For $k = 100\%$, the identification approach is referred to as the *intersection approach*; for $0 < k \leq \min\{w_1,\ldots,w_d\}$, it is referred to as the *union approach* (Atkinson, 2003); and for $\min_j\{w_1,\ldots,w_d\} < k < 1$, it is referred to as the dual cut-off approach by Alkire and Foster, or more generally as the *intermediate approach*.

[94] In the multidimensional context, there are two types of focus axioms. One is deprivation focus, which requires that any increase in already non-deprived achievements should not affect a poverty measure. The other is poverty focus, which requires that any increase in the achievements of non-poor persons should not affect a poverty measure. See Bourguignon and Chakravarty (2003), and Alkire and Foster (2011).

Appendix 3: Tables for linkage between ENRs and poverty

Appendix table 2: Environmental problems, Soil and Agriculture activities

	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
Changes in rainfall quantity Changes in rainfall quantity						
HH experienced a change in the number of agricultural products	53	76.8	55	76.4	108	76.6
Agriculture harvest was not sufficient to feed HH members	187	85.0	131	71.6	318	78.9
Change in rainfall intensity						
Change in rainfall or rainstorm intensity	127	58.3	83	48.0	210	53.7
Drought events						
HH observed any soil infertility	58	66.7	96	55.8	154	59.5
Agriculture harvest was not sufficient to feed HH members	80	92.0	118	68.6	198	76.4
HH make does not own any livestock	34	39.1	89	51.7	123	47.5
Flood or Overflows events						
HH observed any Crop-damaging weeds	2	3.1	125	83.3	127	59.1
HH experienced a big crop loss	19	29.2	79	52.7	98	45.6
Soil erosion						
HH observed any soil infertility	62	50.8	70	60.3	132	55.6
HH observed any Landslides	90	73.8	16	13.8	106	43.8

Source: PEA baseline study, 2020

Appendix table 3: Environmental problems affected forests and woodlots

	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
Changes rainfall amount	43	19.5	40	21.9	83	20.6
Change in rainfall or rainstorm intensity	42	19.3	37	21.4	79	20.2
Drought events	26	29.9	39	22.7	65	25.1
Soil erosion	33	27.0	32	27.6	55	27.3

Source: PEA baseline study, 2020

Appendix table 4: Environmental problems and Water resources

Drought events	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
HH observed any Change in rainfall	84	96.6	142	82.6	226	87.3
HH observed any change of water level in rivers/lakes	31	35.6	65	37.8	96	37.1
HH observed any Bore-hole water level change	67	30.5	69	37.7	136	33.7

Source: PEA baseline study, 2020

Appendix table 5: Household experienced with destructive rainfall or rainstorm intensity by contraction materials of their house

	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
The main construction material of wall						
Mud bricks	117	53.9	59	34.3	176	44.1
Mud bricks with cement	30	13.8	94	54.7	124	34.25
Oven fired bricks with mud	1	0.5	2	1.2	3	0.85
Oven fired bricks with/ cement	5	2.3	0	0.0	5	1.15
Tree trunks with mud	53	24.4	12	7.0	65	15.7
Tree trunks with mud and cement	11	5.1	5	2.9	16	4
The main material for roofing						
Metal sheets/corrugated iron	116	53.2	168	97.1	284	75.15
Local clay tiles	102	46.8	5	2.9	107	24.85

Source: PEA baseline study, 2020

Appendix table 6: Distribution of HHs affected by floods by habitat types

	Musanze		Bugesera		Total	
Flood events	**Count**	**%**	**Count**	**%**	**Count**	**%**
New recommended settlement	5	7.7	16	10.7	21	9.2
Unplanned clustered	22	33.8	70	46.7	92	40.25
Isolated rural housing	38	58.5	62	41.3	100	49.9
Urban informal/ unplanned	0	0.0	2	1.3	2	0.65

Source: PEA baseline study, 2020

Appendix table 7: Distribution of HHs affected by reduced forest size

Change of forest or woodlot size	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
Types of primary cook stove						
Three stone/ fire stove	42	93.3	34	81.0	76	87.15
Another self-built stove	1	2.2	6	14.3	7	8.25
Manufactured stove	1	2.2	0	0.0	1	1.1
Charcoal/fire stove	1	2.2	2	4.8	3	3.5
Source of cooking						
Firewood	44	97.8	42	100.0	86	98.9
Charcoal	2	4.4	8	19.0	10	11.7
Straw/shrub/grass	2	4.4	0	0.0	2	2.2

Source: PEA baseline study, 2020

Appendix table 8: Characteristics of HHs with health problems

	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
Main source of water used by your household						
Piped to yard/plot	8	6.8	3	3.1	11	4.95
Public Tap/Standpipe	30	25.6	5	5.2	35	15.4
Protected Well	49	41.9	5	5.2	54	23.55
Surface Water	16	13.7	4	4.1	20	8.9
River/Lake/Pond/Stream	0	0.0	73	75.3	73	75.3
Main source of drinking water						
Public Tap/Standpipe	*30*	*25.6*	*7*	*7.2*	*37*	*16.4*
Protected Well	*51*	*43.6*	*5*	*5.2*	*56*	*24.4*
Unprotected Well	*10*	*8.5*	*7*	*7.2*	*17*	*7.85*
(River/Lake/Pond/Stream	*0*	*0.0*	***62***	***63.9***	*62*	***63.9***

Source: PEA baseline study, 2020

Appendix 4: Socio-economic characteristics of sampled households

Appendix table 9: Status of food insecurity among sample HHs

Household Food Insecurity Access (HFIA)	Musanze (n= 231)		Bugesera (n= 224)		Total (n= 455)	
	Count	%	Count	%	Count	%
Food Secure	23	10.0	28	12.5	11.25	11.25
Mildly Food Insecure Access	79	34.2	37	16.5	25.35	25.35
Moderately Food Insecure Access	54	23.4	44	19.6	21.5	21.5
Severely Food Insecure Access	75	32.5	115	51.3	41.9	41.9

Source: PEA baseline study, 2020

Appendix table 10: Food insecurity and households' characteristics in Musanze District

	Food Secure		Mildly Food Insecure Access		Moderately Food Insecure Access		Severely Food Insecure Access		Total	
	Count	%	Count	%	Count	%	Count	%	Count	%
Gender of household head										
Male	18	11.2	59	36.6	43	26.7	41	25.5	161	100
Female	5	7.1	20	28.6	11	15.7	34	48.6	70	100
Age group of HHH										
< 35 years	2	6.3	7	21.9	10	31.3	13	40.6	32	100
36 - 55 years	12	10.7	44	39.3	30	26.8	26	23.2	112	100
Over 56 years	9	10.3	28	32.2	14	16.1	36	41.4	87	100
Main occupation of Headed of household										
Wage farm	0	0.0	4	28.6	4	28.6	6	42.9	14	100
Wage non-farm	6	33.3	5	27.8	3	16.7	4	22.2	18	100
Independent farmer	9	9.9	27	29.7	27	29.7	28	30.8	91	100
Unpaid family farm worker	2	13.3	6	40.0	3	20.0	4	26.7	15	100
Another unpaid worker	1	14.3	2	28.6	1	14.3	3	42.9	7	100
Fishing	1	14.3	3	42.9	1	14.3	2	28.6	7	100
Land ownership										
Own	21	10.0	70	33.2	52	24.6	68	32.2	211	100
Lent	2	10.0	9	45.0	2	10.0	7	35.0	20	100
Ubudehe category of Household										
Ubudehe CAT 1	1	3.2	7	22.6	5	16.1	18	58.1	31	100
Ubudehe CAT 2	9	8.6	33	0.3	27	0.3	36	0.3	105	100
Ubudehe CAT 3	13	0.1	39	0.4	22	0.2	21	0.2	95	100
Type of habitat										
New recommended settlement	0	0.0	4	0.6	0	0.0	3	0.4	7	100
Unplanned clustered	12	0.1	38	0.4	28	0.3	30	0.3	108	100
Isolated rural housing	10	0.1	33	0.3	26	0.2	41	0.4	110	100
Urban informal/ unplanned	0	0.0	3	0.8	0	0.0	1	0.3	4	100
Modern planned urban area	1	0.5	1	0.5	0	0.0	0	0.0	2	100
Distance in meters between dwelling and source of water										
0-500m	11	0.1	33	0.3	17	0.2	38	0.4	99	100
500m-1km	9	0.1	40	0.4	26	0.2	33	0.3	108	100
1km-3km	3	0.1	6	0.3	10	0.4	4	0.2	23	100
More than 5Km	0	0.0	0	0.0	1	1.0	0	0.0	1	100
Crop cultivated										
Crops Cereals	22	0.1	72	0.3	50	0.2	72	0.3	216	100
Crops Roots	21	0.1	55	0.4	43	0.3	32	0.2	151	100
Crops fruits	10	0.4	7	0.3	8	0.3	3	0.1	28	100
Crops vegetables	20	0.1	60	0.3	43	0.2	53	0.3	176	100
Animal husbandly	18	11.1	61	37.7	42	25.9	41	25.3	162	100

Source: PEA baseline study, 2020

Appendix table 11: Food insecurity and households' characteristics in Bugesera District

	Food Secure		Mildly Food Insecure Access		Moderately Food Insecure Access		Severely Food Insecure Access		Total	
	Count	%	Count	%	Count	%	Count	%	Count	%
Gender of household head										
Male	24	15.6	23	14.9	33	21.4	74	48.1	154	100
Female	4	5.7	14	20.0	11	15.7	41	58.6	70	100
Age group of HHH										
Age below 35 years old	3	13.6	2	9.1	6	27.3	11	50.0	22	100
Between 36 and 55 years old	13	12.3	19	17.9	25	23.6	49	46.2	106	100
Over 56 years old	12	12.5	16	16.7	13	13.5	55	57.3	96	100
Main occupation of Headed of household										
Wage farm	1	3.6	10	35.7	6	21.4	11	39.3	28	100
Wage non-farm	4	50.0	0	0.0	1	12.5	3	37.5	8	100
Independent farmer	6	12.0	4	8.0	9	18.0	31	62.0	50	100
Unpaid family farm worker	1	5.9	5	29.4	3	17.6	8	47.1	17	100
another unpaid worker	0	0.0	1	50.0	0	0.0	1	50.0	2	100
Fishing	2	12.5	0	0.0	7	43.8	7	43.8	16	100
Land ownership										
Own	25	12.0	36	17.2	40	19.1	108	51.7	209	100
Lent	3	25.0	1	8.3	2	16.7	6	50.0	12	100
Free	0	0.0	0	0.0	2	66.7	1	33.3	3	100
Ubudehe category of Household										
Ubudehe CAT 1	0	0.0	6	15.8	2	5.3	30	78.9	38	100
Ubudehe CAT 2	11	12.9	15	17.6	19	0.2	40	0.5	85	100
Ubudehe CAT 3	17	16.8	16	15.8	23	0.2	45	0.4	101	100
what is the type of habitat										
New recommended settlement (Umudugudu)	6	21.4	5	17.9	4	14.3	13	46.4	28	100
Unplanned clustered	7	7.6	16	17.4	17	18.5	52	56.5	92	100
Isolated rural housing	11	12.6	15	17.2	16	18.4	45	51.7	87	100

Urban informal/ unplanned	4	23.5	1	5.9	7	41.2	5	29.4	17	100
Distance in meters between dwelling and source of water										
0-500m	9	20.9	11	25.6	14	32.6	9	20.9	43	100
500m-1km	9	11.5	13	16.7	14	17.9	42	53.8	78	100
1km-3km	10	11.8	12	14.1	13	15.3	50	58.8	85	100
3km-5km	0	0.0	1	7.7	2	15.4	10	76.9	13	100
More than 5Km	0	0.0	0	0.0	1	20.0	4	80.0	5	100
Crop cultivated										
Crops Cereals	26	12.0	35	16.2	42	19.4	113	52.3	216	100
Crops Roots	8	13.8	12	20.7	11	19.0	27	46.6	58	100
Crops fruits	1	25.0	1	25.0	1	25.0	1	25.0	4	100
Crops vegetables	19	12.1	29	18.5	30	19.1	79	50.3	157	100
Animal husbandly	13	12.4	16	15.2	24	22.9	52	49.5	105	100

Source: PEA baseline study, 2020

Appendix table 12: Food insecurity and environmental problems in Musanze District

	Food Secure		Mildly Food Insecure Access		Moderately Food Insecure Access		Severely Food Insecure Access		Total	
	Count	%	Count	%	Count	%	Count	%	Count	%
HH experienced drought events	6	6.9	36	41.4	15	17.2	30	34.5	87	100
HH observed any soil erosion	14	11.5	41	33.6	30	24.6	37	30.3	122	100
HH observed any Change in rainfall or rainstorm intensity	20	9.2	76	34.9	50	22.9	72	33.0	218	100
HH experienced flood events	5	7.7	23	35.4	15	23.1	22	33.8	65	100
HH observed any landslides	8	6.3	43	34.1	30	23.8	45	35.7	126	100

Source: PEA baseline study, 2020

Appendix table 13: Food Security and environmental problems in Bugesera District

	Food Secure		Mildly Food Insecure Access		Moderately Food Insecure Access		Severely Food Insecure Access		Total	
	Count	%	Count	%	Count	%	Count	%	Count	%

HH experienced drought events	14	8.1	28	16.3	33	19.2	97	56.4	172	100
HH observed any soil erosion	6	5.2	19	16.4	23	19.8	68	58.6	116	100
HH observed any Change in rainfall or rainstorm intensity	13	7.5	27	15.6	30	17.3	103	59.5	173	100
HH experienced flood events	12	8.0	29	19.3	24	16.0	85	56.7	150	100
HH observed any landslides	0	0.0	3	17.6	5	29.4	9	52.9	17	100

Source: PEA baseline study, 2020

Appendix table 14:Correlation of ENRs and Livelihood Indicators

		Livelihood indicator			
ENR-Indicators	**Test**	**productivity**	**Clean water**	**Food security**	**sanitation**
Soil infertility	Pearson Correlation	-.137**	0.034	-.094*	0.076
	P-value	0.004	0.475	0.044	0.107
	N	455	455	455	455
soil erosion	Pearson Correlation	-.093*	0.024	-0.082	-.154**
	P-value	0.047	0.614	0.081	0.001
	N	455	455	455	455
Landslides	Pearson Correlation	-.120*	-.230**	-0.004	.097*
	P-value	0.010	0.000	0.939	0.038
	N	455	455	455	455
Drought events	Pearson Correlation	-.127**	.294**	-.164**	-.226**
	P-value	0.007	0.000	0.000	0.000
	N	455	455	455	455
Deforestation	Pearson Correlation	-0.066	.109*	-.099*	.133**
	P-value	0.159	0.020	0.035	0.004
	N	455	455	455	455
Destructive rain	Pearson Correlation	-.217**	-.109*	-.180**	-0.032
	P-value	0.000	0.020	0.000	0.491
	N	455	455	455	455
Flood events	Pearson Correlation	-.098*	.210**	-.157**	-.322**
	P-value	0.037	0.000	0.001	0.000
	N	455	455	455	455
windstorms	Pearson Correlation	-0.090	.259**	-.202**	-.122**
	P-value	0.056	0.000	0.000	0.009
	N	455	455	455	455

**. Correlation is significant at the 0.01 level

*. Correlation is significant at the 0.05 level

Appendix 5: Environmental aspects tables

Appendix table 15: Availability and time delivery of inorganic fertilizers

Do you assess the fertility of your soil before planting?	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
Yes	11	4.8	24	10.7	35	7.7
No	220	95.2	200	89.3	420	92.3
Total	**231**	**100**	**224**	**100**	**455**	**100**

Source: PEA baseline study, 2020

Appendix table 16: The extent on the use of organic/manure fertilizers in the surveyed households

Do you add organic fertilizer to your soil	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
Yes	212	91.8	151	67.4	363	79.8
No	19	8.2	73	32.6	92	20.2
Total	**231**	**100**	**224**	**100**	**455**	**100**
How organic fertilizer/manure did you and your household family members use						
A large amount more manure used	45	21.2	21	13.9	66	18.2
A small amount more used	71	33.5	66	43.7	137	37.7
No change/same	67	31.6	55	36.4	122	33.6
A small amount less used	26	12.3	4	2.6	30	8.3
A large amount less manure used	3	1.4	5	3.3	8	2.2
Total	**212**	**100**	**151**	**100**	**363**	**100**
Which of the three options (chemical alone organic alone)						
Chemical	0	0	10	15.9	10	5.4
Organic	5	4.1	1	1.6	6	3.2
Chemical + organic fertilizers	118	95.9	52	82.5	170	91.4
Total	**123**	**100**	**63**	**100**	**186**	**100**
Types of chemical fertilizers used						
NPK	67	52.8	30	40.5	97	48.3
DAP	92	72.4	60	81.1	152	75.6
Urea	72	56.7	57	77.0	129	64.2
lime	1	0.8	0	0.0	1	0.5
Have you observed any Soil infertility in the last 2-3 years?						
Yes	127	55	114	50.9	241	53.0
No	104	45.0	110	49.1	214	47.0
Total	231	100	224	100	455	100
Has much change in soil fertility in your farm plots has there been?						
Highly negative impacts	66	28.6	45	20.1	111	24.4
Negative impacts	58	25.1	66	29.5	124	27.3
No impact	107	46.3	113	50.4	220	48.4
How has the Soil fertility reduction affected your household's livelihood?						
Highly negative impacts	31	13.4	51	22.8	82	18.0
Negative impacts	93	40.3	46	20.5	139	30.5
No impact	107	46.3	127	56.7	234	51.4

Source: PEA baseline study, 2020

Appendix table 17: Environmental aspects that resulted from environmental disasters

	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
Has your dwelling faced any problems that resulted from environmental disasters						
Yes	58	25.1	99	44.2	157	34.5
No	173	74.9	125	55.8	298	65.5
Total	**231**	**100**	**224**	**100**	**455**	**100**
Have you observed any changes in temperature in the last 2-3 years?						
Yes	39	16.9	159	71	198	43.5
No	192	83.2	65	29	257	56.5
Total	**231**	**100**	**224**	**100**	**455**	**100**
Have you observed any changes rainfall amount in the last 2-3 years?						
Yes	220	95.2	183	81.7	403	88.6
No	11	4.8	41	18.3	52	11.4
Total	**231**	**100**	**224**	**100**	**455**	**100**
How has the rainfall amount been changing?						
Much	156	67.5	80	35.7	236	51.9
Moderate	53	22.9	97	43.3	150	33.0
Less	22	9.5	47	21.0	69	15.2
How has the rainfall amount change affected your household's livelihood?						
Highly negative impacts	96	41.6	71	31.7	167	36.7
Negative impacts	111	48.1	94	42.0	205	45.1
No impact	24	10.4	59	26.3	83	18.2
How has the Shift in rainfall start date been changing?						
Highly negative impacts	135	58.4	75	33.5	210	46.2
Negative impacts	73	31.6	104	46.4	177	38.9
No impact	23	10.0	45	20.1	68	14.9
How has the Shift in rainfall start date change affected your household's livelihood?						
Highly negative impacts	91	39.4	79	35.3	170	37.4
Negative impacts	114	49.4	88	39.3	202	44.4
No impact	26	11.3	57	25.4	83	18.2
How has the Change in rainfall or rainstorm intensity been changing?						
Highly negative impacts	138	59.7	65	29.0	203	44.6
Negative impacts	65	28.1	104	46.4	169	37.1
No impact	28	12.1	55	24.6	83	18.2
How has the Change in rainfall or rainstorm intensity affected your household's livelihood?						
Highly negative impacts	102	44.2	66	29.5	168	36.9
Negative impacts	104	45.0	93	41.5	197	43.3
No impact	25	10.8	65	29.0	90	19.8
How has the frequency of rainfall (rain storms) changed?						
Much more frequent	124	53.7	75	33.5	199	43.7
Somewhat more frequent	73	31.6	86	38.4	159	34.9
Somewhat less frequent	28	12.1	56	25.0	84	18.5
Much less frequent	6	2.6	7	3.1	13	2.9

Source: PEA baseline study, 2020

Appendix table 18: Households observed and experienced and observed soil erosion

Have you observed any soil erosion in the last 2-3 years?	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
Yes	122	52.8	116	51.8	238	52.3
No	109	47.2	108	48.2	217	47.7
Total	231	100	224	100	455	100
How has the soil erosion been changing?						
Highly negative impacts	41	17.7	42	18.8	83	18.2
Negative impacts	60	26.0	69	30.8	129	28.4
No impact	130	56.3	113	50.4	243	53.4
How has the soil erosion change affected your household's livelihood?						
Highly negative impacts	28	12.1	47	21.0	75	16.5
Negative impacts	78	33.8	59	26.3	137	30.1
No impact	125	54.1	118	52.7	243	53.4
How have the frequency of Landslides changed?						
Much	48	20.8	7	3.1	55	12.1
Moderate	65	28.1	8	3.6	73	16.0
Less	118	51.1	209	93.3	327	71.9
How has the Landslides affected your household's livelihood?						
Highly negative impacts	34	14.7	8	3.6	42	9.2
Negative impacts	81	35.1	7	3.1	88	19.3
No impact	116	50.2	209	93.3	325	71.4
How extensive have the changes						
Highly negative impacts	49	21.2	8	3.6	57	12.5
Negative impacts	64	27.7	9	4.0	73	16.0
No impact	118	51.1	207	92.4	325	71.4

Source: PEA baseline study, 2020

Appendix table 19: Households observed and experienced deforestation in village

	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
Have you observed any deforestation in this village in the last 2-3 years?						
yes	45	19.5	42	18.8	87	19.1
No	186	80.5	182	81.3	368	80.9
How has the deforestation been changing?						
Highly negative impacts	7	3.0	15	6.7	22	4.8
Negative impacts	33	14.3	25	11.2	58	12.7
No impact	191	82.7	184	82.1	375	82.4
Have you observed any Crop-damaging weeds in the last 2-3 years?						
yes	7	3.0	161	71.9	168	36.9
No	224	97.0	63	28.1	287	63.1
How has the Crop-damaging weeds been changing?						
Much	1	0.4	47	21.0	48	10.5
Moderate	3	1.3	110	49.1	113	24.8
Less	227	98.3	67	29.9	294	64.6
How has the Crop-damaging weeds change affected your household's livelihood?						
Highly negative impacts	1	0.4	57	25.4	58	12.7
Negative impacts	5	2.2	94	42.0	99	21.8
No impact	225	97.4	73	32.6	298	65.5
How has the Plant diseases been changing?						
Much	75	32.5	83	37.1	158	34.7
Moderate	118	51.1	99	44.2	217	47.7
Less	38	16.5	42	18.8	80	17.6
Have you observed any Plant diseases in the last 2-3 years?						
yes	204	88.3	184	82.1	388	85.3
No	27	11.7	40	17.9	67	14.7
How has the Plant diseases change affected your household's livelihood?						
Highly negative impacts	33	14.3	87	38.8	120	26.4
Negative impacts	167	72.3	91	40.6	258	56.7
No impact	31	13.4	46	20.5	77	16.9
Have you observed any Plant pests in the last 2-3 years?						
yes	70	30.3	134	59.8	204	44.8
No	161	69.7	90	40.2	251	55.2
How has the Plant pests been changing?						
Much	34	14.7	65	29.0	99	21.8
Moderate	27	11.7	69	30.8	96	21.1
Less	170	73.6	90	40.2	260	57.1
How has the Plant pests change affected your household's livelihood?						
Highly negative impacts	17	7.4	77	34.4	94	20.7
Negative impacts	45	19.5	56	25.0	101	22.2
No impact	169	73.2	91	40.6	260	57.1

Source: PEA baseline study, 2020

Appendix table 20: Households observed and experienced Bore-hole water and Water catchment

	Musanze		Bugesera		Total	
	Count	%	Count	%	Count	%
How has the Bore-hole water level been changing?						
Much	13	5.6	35	15.6	48	10.5
Moderate	52	22.5	39	17.4	91	20.0
Less	166	71.9	150	67.0	316	69.5
How has the Bore-hole water level change affected your household's livelihood?						
Highly negative impacts	5	2.2	28	12.5	33	7.3
Negative impacts	60	26.0	40	17.9	100	22.0
No impact	166	71.9	156	69.6	322	70.8
How has the Water catchment (storage bins, or small ponds/ dams) of fields been changing?						
Much	0	0.0	7	3.1	7	1.5
Moderate	5	2.2	14	6.3	19	4.2
Less	226	97.8	203	90.6	429	94.3
How has the Water catchment (storage bins, or small ponds/ dams) change affected your household's livelihood?						
Highly negative impacts	0	0.0	6	2.7	6	1.3
Negative impacts	6	2.6	6	2.7	12	2.6
No impact	225	97.4	212	94.6	437	96.0

Source: PEA baseline study, 2020

Appendix 6: Fertilizer recommendation

1. Bugesera District

1.1 Fertilizer recommendation for Maize

Through water supply. Maize cropping in the tropics can result into a high biomass yield as well as grain yield ranging from 2 to 12 tons per ha depending on the soil nutrient status as well as fertilizer application coupled with other technologies. The determination of fertilizers shall consider: the soil stock, the expected Nitrogen removal by plant.

Maize fertilizer recommendation computation

1.1.1 Nitrogen required for Soil Units identified Bugesera

The nutrients removal through maize grains is estimated to 13.1 Kg, per ton of grains (14% dry matter). Similarly, the nutrients removal in maize residues is estimated to 12.8kg per ton of maize residues (14% dry matter) for Nitrogen. If the yield target is 7 tons of maize grain per Ha, the residues will be estimated to 1.45 as proposed by several authors including (Fleischel *et al*., 2014). Therefore, the target of 7 tons of grain per ha will correspond to a mass of residues equivalent to 10.15 tons

The total removal of N= 7* 13.1+ 10.15*12.8= 120 kg of N

The total N fertilizer to target a yield of 7 tons' grain per ha is than estimated to 120 kg per Ha.

Appendix table 21: Calculation of soil weight per hectare

SOIL UNIT	Weight of 1Ha soil (Kg)
Terric Histosols	2,480,000
Humic (Dystric) Cambisols	2,580,000
Humic Acrisols (Sombric)	2,540,000
Dystric Regosols / Dystric Leptosols	2,540,000
Humic Ferralsols	2,560,000
Humic Cambisols	2,560,000
Humic Ferralsols / Humic Cambisols	2,620,000
Humic Acrisols / Humic Ferralsols / Humic Alisols	2,660,000
Humic Acrisols / Humic Ferralsols	2,580,000
Plinthic Alisols/Plinthic Acrisols	2,640,000
Haplic Acrisols / Ferralic Cambisols	2,500,000
Umbric Gleysols	2,480,000
Gleyic / Dystric Cambisols	2,420,000
Mollic Gleysol	2,540,000
Rhodic Ferralsols / Haplic Acrisols / Xanthic Ferralsols	2,520,000
Humic (Haplic) Ferralsols	2,540,000
Haplic Lixisols / Luvic Phaeozems	2,580,000
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	2,620,000
Humic Ferralsols / Ferralic Cambisols	2,520,000
Haplic (Gleyic) Luvisols	2,580,000
Humic Alisols / Humic Acrisols	2,500,000
Vertic Luvisols / Vertic Cambisols	2,560,000
Dystric (Humic) Cambisols	2,660,000

Humic Alisols/Humic Cambisols	2,560,000
Rhodic Ferralsols	2,580,000
Humic Acrisols / Humic (Ferralic) Cambisols	2,600,000
Humic (Rhodic) Ferralsols	2,660,000
Humic (Ferralic) Cambisols	2,560,000
Humic Alisols / Rhodic (Haplic) Luvisols	2,560,000
Haplic (Humic) Ferralsols / Haplic Lixisols	2,520,000
Humic (Eutric) Cambisols	2,640,000
Haplic Acrisols	2,620,000
Humic Ferralic Cambisols / Ferric Lixisols	2,560,000
Humic Dystric Cambisols	2,500,000

Source: PEA baseline study, 2020

Appendix table 22: Nitrogen fertilizer requirement for Maize production in Bugesera District

Type of Soils	Tot N g/100g	Mineralized N kg/kg soil at 2 %	Target N kg/ha	Average Weight of1 Ha soil	Mineralized N kg /ha	**Required N kg/ha**
Terric Histosols	0.17	0.000034	120	2,480,000	84.32	**35.68**
Humic (Dystric) Cambisols	0.17	0.000034	120	2,580,000	87.72	**32.28**
Humic Acrisols (Sombric)	0.17	0.000034	120	2,540,000	86.36	**33.64**
Dystric Regosols / Dystric Leptosols	0.17	0.000034	120	2,540,000	86.36	**33.64**
Humic Ferralsols	0.17	0.000034	120	2,560,000	87.04	**32.96**
Humic Cambisols	0.17	0.000034	120	2,560,000	87.04	**32.96**
Humic Ferralsols / Humic Cambisols	0.18	0.000036	120	2,620,000	94.32	**25.68**
Humic Acrisols / Humic Ferralsols / Humic Alisols	0.18	0.000036	120	2,660,000	95.76	**24.24**
Humic Acrisols / Humic Ferralsols	0.18	0.000036	120	2,580,000	92.88	**27.12**
Plinthic Alisols/Plinthic Acrisols	0.18	0.000036	120	2,640,000	95.04	**24.96**
Haplic Acrisols / Ferralic Cambisols	0.14	0.000028	120	2,500,000	70	**50**
Umbric Gleysols	0.16	0.000032	120	2,480,000	79.36	**40.64**
Gleyic / Dystric Cambisols	0.23	0.000046	120	2,420,000	111.32	**8.68**
Mollic Gleysol	0.17	0.000034	120	2,540,000	86.36	**33.64**
Rhodic Ferralsols / Haplic Acrisols / Xanthic Ferralsols	0.16	0.000032	120	2,520,000	80.64	**39.36**
Humic (Haplic) Ferralsols	0.15	0.00003	120	2,540,000	76.2	**43.8**
Haplic Lixisols / Luvic Phaeozems	0.17	0.000034	120	2,580,000	87.72	**32.28**
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	0.18	0.000036	120	2,620,000	94.32	**25.68**

Humic Ferralsols / Ferralic Cambisols	0.15	0.00003	120	2,520,000	75.6	**44.4**
Haplic (Gleyic) Luvisols	0.12	0.000024	120	2,580,000	61.92	**58.08**
Humic Alisols / Humic Acrisols	0.16	0.000032	120	2,500,000	80	**40**
Vertic Luvisols / Vertic Cambisols	0.17	0.000034	120	2,560,000	87.04	**32.96**
Dystric (Humic) Cambisols	0.17	0.000034	120	2,660,000	90.44	**29.56**
Humic Alisols/Humic Cambisols	0.16	0.000032	120	2,560,000	81.92	**38.08**
Rhodic Ferralsols	0.18	0.000036	120	2,580,000	92.88	**27.12**
Humic Acrisols / Humic (Ferralic) Cambisols	0.18	0.000036	120	2,600,000	93.6	**26.4**
Humic (Rhodic) Ferralsols	0.17	0.000034	120	2,660,000	90.44	**29.56**
Humic (Ferralic) Cambisols	0.18	0.000036	120	2,560,000	92.16	**27.84**
Humic Alisols / Rhodic (Haplic) Luvisols	0.17	0.000034	120	2,560,000	87.04	**32.96**
Haplic (Humic) Ferralsols / Haplic Lixisols	0.16	0.000032	120	2,520,000	80.64	**39.36**
Humic (Eutric) Cambisols	0.18	0.000036	120	2,640,000	95.04	**24.96**
Haplic Acrisols	0.18	0.000036	120	2,620,000	94.32	**25.68**
Humic Ferralic Cambisols / Ferric Lixisols	0.15	0.00003	120	2,560,000	76.8	**43.2**
Humic Dystric Cambisols	0.13	0.000026	120	2,500,000	65	**55**

Source: PEA baseline study, 2020

1.1.2 Phosphorus requirement for Maize production

The soil data show that phosphorus content is low compared to the optimum rate. Research has shown that a rate of P shall be 51 kg / ha to allow reasonable plant nutrition (Daniel et al., 2011).

Appendix table 23: Calculation of required Phosphorus

Types of soil	**P required**
	kg/ ha
Terric Histosols	44.0064
Humic (Dystric) Cambisols	40.551
Humic Acrisols (Sombric)	41.856
Dystric Regosols / Dystric Leptosols	41.8306
Humic Ferralsols	41.6816
Humic Cambisols	41.6816
Humic Ferralsols / Humic Cambisols	42.0134
Humic Acrisols / Humic Ferralsols / Humic Alisols	43.3658
Humic Acrisols / Humic Ferralsols	43.6212
Plinthic Alisols/Plinthic Acrisols	42.9216
Haplic Acrisols / Ferralic Cambisols	37.475
Umbric Gleysols	43.5104
Gleyic / Dystric Cambisols	45.3856
Mollic Gleysol	41.094
Rhodic Ferralsols / Haplic Acrisols / Xanthic Ferralsols	41.2728
Humic (Haplic) Ferralsols	41.0686
Haplic Lixisols / Luvic Phaeozems	42.873
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	42.485
Humic Ferralsols / Ferralic Cambisols	40.0884
Haplic (Gleyic) Luvisols	35.1846
Humic Alisols / Humic Acrisols	43.725
Vertic Luvisols / Vertic Cambisols	41.1184
Dystric (Humic) Cambisols	43.4988
Humic Alisols/Humic Cambisols	40.9136
Rhodic Ferralsols	43.131
Humic Acrisols / Humic (Ferralic) Cambisols	40.418
Humic (Rhodic) Ferralsols	41.7698
Humic (Ferralic) Cambisols	41.2208
Humic Alisols / Rhodic (Haplic) Luvisols	40.9392
Haplic (Humic) Ferralsols / Haplic Lixisols	44.1708
Humic (Eutric) Cambisols	42.4728
Haplic Acrisols	44.1356
Humic Ferralic Cambisols / Ferric Lixisols	40.2992
Humic Dystric Cambisols	42.1

Source: PEA baseline study, 2020

1.1.3 Maize Potassium requirement

Potassium is considered as one of the major nutrients needed by crop to grow and produce yield. The soil potassium content considered for general crop production ranges from 150 to 300 mg/ kg depending on the targeted yield per hectare and 150 kg / Ha is considered as optimum for maize production. If one takes an example of the *Gleyic / Dystric Cambisols* the total available K on 1 Ha is estimated to 386,958 kg

The test has shown that K value of soil unit 1 is 0.8 $cmol_c$ per kg of soil which is equivalent to (0.8*390/1000000) kg per kg of soil=0.000312kg/kg of soil. This value is already much higher than the required amount, so no need of K fertilization.

Appendix table 24: Calculation of Potassium Maize requirement

	Exch K+	Targeted K	K present	Weight of	K present	K required
FAO_CLASSIFICATION	Cmolc/ kg	kg/ ha	kg/kg soil	1 Ha soil	kg /ha	kg /ha
Terric Histosols	0.80	150	0.000312	2480000	773.76	0
Humic (Dystric) Cambisols	0.55	150	0.0002145	2580000	553.41	0
Humic Acrisols (Sombric)	0.55	150	0.0002145	2540000	544.83	0
Dystric Regosols / Dystric Leptosols	0.49	150	0.0001911	2540000	485.394	0
Humic Ferralsols	0.55	150	0.0002145	2560000	549.12	0
Humic Cambisols	0.52	150	0.0002028	2560000	519.168	0
Humic Ferralsols / Humic Cambisols	0.44	150	0.0001716	2620000	449.592	0
Humic Acrisols / Humic Ferralsols / Humic Alisols	0.50	150	0.000195	2660000	518.7	0
Humic Acrisols / Humic Ferralsols	0.49	150	0.0001911	2580000	493.038	0
Plinthic Alisols/Plinthic Acrisols	0.50	150	0.000195	2640000	514.8	0
Haplic Acrisols / Ferralic Cambisols	0.64	150	0.0002496	2500000	624	0
Umbric Gleysols	0.59	150	0.0002301	2480000	570.648	0
Gleyic / Dystric Cambisols	0.41	150	0.0001599	2420000	386.958	0
Mollic Gleysol	0.54	150	0.0002106	2540000	534.924	0
Rhodic Ferralsols / Haplic Acrisols / Xanthic Ferralsols	0.63	150	0.0002457	2520000	619.164	0
Humic (Haplic) Ferralsols	0.66	150	0.0002574	2540000	653.796	0
Haplic Lixisols / Luvic Phaeozems	0.59	150	0.0002301	2580000	593.658	0
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	0.52	150	0.0002028	2620000	531.336	0

Humic Ferralsols / Ferralic Cambisols	0.58	150	0.0002262	2520000	570.024	0
Haplic (Gleyic) Luvisols	0.58	150	0.0002262	2580000	583.596	0
Humic Alisols / Humic Acrisols	0.60	150	0.000234	2500000	585	0
Vertic Luvisols / Vertic Cambisols	0.64	150	0.0002496	2560000	638.976	0
Dystric (Humic) Cambisols	0.50	150	0.000195	2660000	518.7	0
Humic Alisols/Humic Cambisols	0.60	150	0.000234	2560000	599.04	0
Rhodic Ferralsols	0.50	150	0.000195	2580000	503.1	0
Humic Acrisols / Humic (Ferralic) Cambisols	0.57	150	0.0002223	2600000	577.98	0
Humic (Rhodic) Ferralsols	0.44	150	0.0001716	2660000	456.456	0
Humic (Ferralic) Cambisols	0.75	150	0.0002925	2560000	748.8	0
Humic Alisols / Rhodic (Haplic) Luvisols	0.54	150	0.0002106	2560000	539.136	0
Haplic (Humic) Ferralsols / Haplic Lixisols	0.63	150	0.0002457	2520000	619.164	0
Humic (Eutric) Cambisols	0.52	150	0.0002028	2640000	535.392	0
Haplic Acrisols	0.54	150	0.0002106	2620000	551.772	0
Humic Ferralic Cambisols / Ferric Lixisols	0.69	150	0.0002691	2560000	688.896	0
Humic Dystric Cambisols	0.72	150	0.0002808	2500000	702	0

Source: PEA baseline study, 2020

1.2 Coffee fertilizer recommendation

1.2.1 Nitrogen requirement for Coffee in Bugesera

Coffee Nitrogen requirement varies from year 1 to year 3 where a rate of 220 kg is recommended at third year (VOLHOUBARE LANDBOU, RSA. Processed by Frans Lourens, Haifa, RSA May, 1999)

Since most of Rwandan coffee plantation are more than 3 years old the amount of nitrogen required in Bugesera is computed here by targeting 220 kg / Ha.

Appendix table 25: Calculation of Coffee Nitrogen

Type of Soils	Tot N g/100g	Mineralized N kg/kg soil at 2 %	Target N kg/ha	Average Weight of1 Ha soil	Mineralized N kg /ha	Required N kg/ha
Terric Histosols	0.17	0.000034	220	2,480,000	84.32	135.68
Humic (Dystric) Cambisols	0.17	0.000034	220	2,580,000	87.72	132.28
Humic Acrisols (Sombric)	0.17	0.000034	220	2,540,000	86.36	133.64
Dystric Regosols / Dystric Leptosols	0.17	0.000034	220	2,540,000	86.36	133.64
Humic Ferralsols	0.17	0.000034	220	2,560,000	87.04	132.96
Humic Cambisols	0.17	0.000034	220	2,560,000	87.04	132.96
Humic Ferralsols / Humic Cambisols	0.18	0.000036	220	2,620,000	94.32	125.68
Humic Acrisols / Humic Ferralsols / Humic Alisols	0.18	0.000036	220	2,660,000	95.76	124.24
Humic Acrisols / Humic Ferralsols	0.18	0.000036	220	2,580,000	92.88	127.12
Plinthic Alisols/Plinthic Acrisols	0.18	0.000036	220	2,640,000	95.04	124.96
Haplic Acrisols / Ferralic Cambisols	0.14	0.000028	220	2,500,000	70	150
Umbric Gleysols	0.16	0.000032	220	2,480,000	79.36	140.64
Gleyic / Dystric Cambisols	0.23	0.000046	220	2,420,000	111.32	108.68
Mollic Gleysol	0.17	0.000034	220	2,540,000	86.36	133.64
Rhodic Ferralsols / Haplic Acrisols / Xanthic Ferralsols	0.16	0.000032	220	2,520,000	80.64	139.36
Humic (Haplic) Ferralsols	0.15	0.00003	220	2,540,000	76.2	143.8
Haplic Lixisols / Luvic Phaeozems	0.17	0.000034	220	2,580,000	87.72	132.28

Dystric (Humic) Cambisols / Haplic (Humic) Alisols	0.18	0.000036	220	2,620,000	94.32	125.68
Humic Ferralsols / Ferralic Cambisols	0.15	0.00003	220	2,520,000	75.6	144.4
Haplic (Gleyic) Luvisols	0.12	0.000024	220	2,580,000	61.92	158.08
Humic Alisols / Humic Acrisols	0.16	0.000032	220	2,500,000	80	140
Vertic Luvisols / Vertic Cambisols	0.17	0.000034	220	2,560,000	87.04	132.96
Dystric (Humic) Cambisols	0.17	0.000034	220	2,660,000	90.44	129.56
Humic Alisols/Humic Cambisols	0.16	0.000032	220	2,560,000	81.92	138.08
Rhodic Ferralsols	0.18	0.000036	220	2,580,000	92.88	127.12
Humic Acrisols / Humic (Ferralic) Cambisols	0.18	0.000036	220	2,600,000	93.6	126.4
Humic (Rhodic) Ferralsols	0.17	0.000034	220	2,660,000	90.44	129.56
Humic (Ferralic) Cambisols	0.18	0.000036	220	2,560,000	92.16	127.84
Humic Alisols / Rhodic (Haplic) Luvisols	0.17	0.000034	220	2,560,000	87.04	132.96
Haplic (Humic) Ferralsols / Haplic Lixisols	0.16	0.000032	220	2,520,000	80.64	139.36
Humic (Eutric) Cambisols	0.18	0.000036	220	2,640,000	95.04	124.96
Haplic Acrisols	0.18	0.000036	220	2,620,000	94.32	125.68
Humic Ferralic Cambisols / Ferric Lixisols	0.15	0.00003	220	2,560,000	76.8	143.2
Humic Dystric Cambisols	0.13	0.000026	220	2,500,000	65	155

Source: PEA baseline study, 2020

1.2.2 Phosphorus Requirement for Coffee

Coffee phosphorus requirement varies from year 1 to year 3 where a rate of 50 kg is recommended at third year (VOLHOUBARE LANDBOU, RSA. Processed by Frans Lourens, Haifa, RSA May, 1999)

Since most of Rwandan coffee plantation are more than 3 years old the amount of nitrogen required in Bugesera was computed by targeting 50 kg / Ha.

Appendix table 26: Calculation of Phosphorus for coffee

Typesof soil	AP (mg/kg)	Targeted kg/ha	av. P Kg/Ha	Weight of 1 Ha soil	P required kg/ ha
Terric Histosols	2.82	50	6.9936	2,480,000	43.0064
Humic (Dystric) Cambisols	4.05	50	10.449	2,580,000	39.551
Humic Acrisols (Sombric)	3.6	50	9.144	2,540,000	40.856
Dystric Regosols / Dystric Leptosols	3.61	50	9.1694	2,540,000	40.8306
Humic Ferralsols	3.64	50	9.3184	2,560,000	40.6816
Humic Cambisols	3.64	50	9.3184	2,560,000	40.6816
Humic Ferralsols / Humic Cambisols	3.43	50	8.9866	2,620,000	41.0134
Humic Acrisols / Humic Ferralsols / Humic Alisols	2.87	50	7.6342	2,660,000	42.3658
Humic Acrisols / Humic Ferralsols	2.86	50	7.3788	2,580,000	42.6212
Plinthic Alisols/Plinthic Acrisols	3.06	50	8.0784	2,640,000	41.9216
Haplic Acrisols / Ferralic Cambisols	5.41	50	13.525	2,500,000	36.475
Umbric Gleysols	3.02	50	7.4896	2,480,000	42.5104
Gleyic / Dystric Cambisols	2.32	50	5.6144	2,420,000	44.3856
Mollic Gleysol	3.9	50	9.906	2,540,000	40.094
Rhodic Ferralsols / Haplic Acrisols / Xanthic Ferralsols	3.86	50	9.7272	2,520,000	40.2728
Humic (Haplic) Ferralsols	3.91	50	9.9314	2,540,000	40.0686
Haplic Lixisols / Luvic Phaeozems	3.15	50	8.127	2,580,000	41.873
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	3.25	50	8.515	2,620,000	41.485
Humic Ferralsols / Ferralic Cambisols	4.33	50	10.9116	2,520,000	39.0884
Haplic (Gleyic) Luvisols	6.13	50	15.8154	2,580,000	34.1846
Humic Alisols / Humic Acrisols	2.91	50	7.275	2,500,000	42.725
Vertic Luvisols / Vertic Cambisols	3.86	50	9.8816	2,560,000	40.1184
Dystric (Humic) Cambisols	2.82	50	7.5012	2,660,000	42.4988
Humic Alisols/Humic Cambisols	3.94	50	10.0864	2,560,000	39.9136
Rhodic Ferralsols	3.05	50	7.869	2,580,000	42.131
Humic Acrisols / Humic (Ferralic) Cambisols	4.07	50	10.582	2,600,000	39.418
Humic (Rhodic) Ferralsols	3.47	50	9.2302	2,660,000	40.7698
Humic (Ferralic) Cambisols	3.82	50	9.7792	2,560,000	40.2208
Humic Alisols / Rhodic (Haplic) Luvisols	3.93	50	10.0608	2,560,000	39.9392
Haplic (Humic) Ferralsols / Haplic Lixisols	2.71	50	6.8292	2,520,000	43.1708

Humic (Eutric) Cambisols	3.23	50	8.5272	2,640,000	41.4728
Haplic Acrisols	2.62	50	6.8644	2,620,000	43.1356
Humic Ferralic Cambisols / Ferric Lixisols	4.18	50	10.7008	2,560,000	39.2992
Humic Dystric Cambisols	3.56	50	8.9	2,500,000	41.1

Source: PEA baseline study, 2020

1.2.3 Potassium Requirement for Coffee

Coffee Potassium requirement varies from year 1 to year 3 where a rate of 50 kg is recommended at third year (VOLHOUBARE LANDBOU, RSA. Processed by Frans Lourens, Haifa, RSA May, 1999)

Since most of Rwandan coffee plantations are more than 3 years old the amount of nitrogen required in Bugesera was computed by targeting 250 kg / Ha. The data we have shown that K value of most of the soil units are high compared to the required amount. This implies that there is no need to add more potassium

Appendix table 27: Calculation of Potassium Requirement

	Exch K+	Targeted K	K present	Weight of	K present	K required
FAO_CLASSIFICATION	Cmolc/kg	kg/ ha	kg/kg soil	1 Ha soil	kg /ha	kg /ha
Terric Histosols	0.8	250	0.000312	2,480,000	773.76	0
Humic (Dystric) Cambisols	0.55	250	0.0002145	2,580,000	553.41	0
Humic Acrisols (Sombric)	0.55	250	0.0002145	2,540,000	544.83	0
Dystric Regosols / Dystric Leptosols	0.49	250	0.0001911	2,540,000	485.394	0
Humic Ferralsols	0.55	250	0.0002145	2,560,000	549.12	0
Humic Cambisols	0.52	250	0.0002028	2,560,000	519.168	0
Humic Ferralsols / Humic Cambisols	0.44	250	0.0001716	2,620,000	449.592	0
Humic Acrisols / Humic Ferralsols / Humic Alisols	0.5	250	0.000195	2,660,000	518.7	0
Humic Acrisols / Humic Ferralsols	0.49	250	0.0001911	2,580,000	493.038	0
Plinthic Alisols/Plinthic Acrisols	0.5	250	0.000195	2,640,000	514.8	0
Haplic Acrisols / Ferralic Cambisols	0.64	250	0.0002496	2,500,000	624	0
Umbric Gleysols	0.59	250	0.0002301	2,480,000	570.648	0
Gleyic / Dystric Cambisols	0.41	250	0.0001599	2,420,000	386.958	0
Mollic Gleysol	0.54	250	0.0002106	2,540,000	534.924	0
Rhodic Ferralsols / Haplic Acrisols / Xanthic Ferralsols	0.63	250	0.0002457	2,520,000	619.164	0
Humic (Haplic) Ferralsols	0.66	250	0.0002574	2,540,000	653.796	0
Haplic Lixisols / Luvic Phaeozems	0.59	250	0.0002301	2,580,000	593.658	0

Dystric (Humic) Cambisols / Haplic (Humic) Alisols	0.52	250	0.0002028	2,620,000	531.336	0
Humic Ferralsols / Ferralic Cambisols	0.58	250	0.0002262	2,520,000	570.024	0
Haplic (Gleyic) Luvisols	0.58	250	0.0002262	2,580,000	583.596	0
Humic Alisols / Humic Acrisols	0.6	250	0.000234	2,500,000	585	0
Vertic Luvisols / Vertic Cambisols	0.64	250	0.0002496	2,560,000	638.976	0
Dystric (Humic) Cambisols	0.5	250	0.000195	2,660,000	518.7	0
Humic Alisols/Humic Cambisols	0.6	250	0.000234	2,560,000	599.04	0
Rhodic Ferralsols	0.5	250	0.000195	2,580,000	503.1	0
Humic Acrisols / Humic (Ferralic) Cambisols	0.57	250	0.0002223	2,600,000	577.98	0
Humic (Rhodic) Ferralsols	0.44	250	0.0001716	2,660,000	456.456	0
Humic (Ferralic) Cambisols	0.75	250	0.0002925	2,560,000	748.8	0
Humic Alisols / Rhodic (Haplic) Luvisols	0.54	250	0.0002106	2,560,000	539.136	0
Haplic (Humic) Ferralsols / Haplic Lixisols	0.63	250	0.0002457	2,520,000	619.164	0
Humic (Eutric) Cambisols	0.52	250	0.0002028	2,640,000	535.392	0
Haplic Acrisols	0.54	250	0.0002106	2,620,000	551.772	0
Humic Ferralic Cambisols / Ferric Lixisols	0.69	250	0.0002691	2,560,000	688.896	0
Humic Dystric Cambisols	0.72	250	0.0002808	2,500,000	702	0

Source: PEA baseline study, 2020

1.3 Fertilizer recommendation for Cabbage

1.3.1 Nitrogen Requirement for Cabbage

According to the Fertilizer Society of South Africa, (2000), to produce optimum yields of good quality cabbages, often high amounts of nitrogen fertilizer is applied. It was however, found that yield improvements from 100 to 150 kg $\cdot ha^{-1}$ were not significantly different. Gupta (1987) reported maximum cabbage head mass at 150 kg $\cdot$ha-1 N. The maximum yields from 150 kg $\cdot ha^{-1}$ N were attributed mainly to increase in head mass. Otherwise, the recommended total amounts of nitrogen fertilizer for cabbage are ranged from 160 to 260 kg $\cdot ha^{-1}$. Hence, 160 kg/ Ha was used to compute for nitrogen requirement for Cabbage. Using the same computation procedures, the following table of fertilizer requirement was produced

Appendix table 28: Calculation of Nitrogen Requirement

Type of Soils	Tot N g/100g	Mineralized N kg/kg soil at 2 %	Target N kg/ha	Average Weight of1 Ha soil	Mineralized N kg /ha	Required N kg/ha
Terric Histosols	0.17	0.000034	160	2,480,000	84.32	75.68
Humic (Dystric) Cambisols	0.17	0.000034	160	2,580,000	87.72	72.28
Humic Acrisols (Sombric)	0.17	0.000034	160	2,540,000	86.36	73.64
Dystric Regosols / Dystric Leptosols	0.17	0.000034	160	2,540,000	86.36	73.64
Humic Ferralsols	0.17	0.000034	160	2,560,000	87.04	72.96
Humic Cambisols	0.17	0.000034	160	2,560,000	87.04	72.96
Humic Ferralsols / Humic Cambisols	0.18	0.000036	160	2,620,000	94.32	65.68
Humic Acrisols / Humic Ferralsols / Humic Alisols	0.18	0.000036	160	2,660,000	95.76	64.24
Humic Acrisols / Humic Ferralsols	0.18	0.000036	160	2,580,000	92.88	67.12
Plinthic Alisols/Plinthic Acrisols	0.18	0.000036	160	2,640,000	95.04	64.96
Haplic Acrisols / Ferralic Cambisols	0.14	0.000028	160	2,500,000	70	90
Umbric Gleysols	0.16	0.000032	160	2,480,000	79.36	80.64
Gleyic / Dystric Cambisols	0.23	0.000046	160	2,420,000	111.32	48.68
Mollic Gleysol	0.17	0.000034	160	2,540,000	86.36	73.64
Rhodic Ferralsols / Haplic Acrisols / Xanthic Ferralsols	0.16	0.000032	160	2,520,000	80.64	79.36
Humic (Haplic) Ferralsols	0.15	0.00003	160	2,540,000	76.2	83.8
Haplic Lixisols / Luvic Phaeozems	0.17	0.000034	160	2,580,000	87.72	72.28

Dystric (Humic) Cambisols / Haplic (Humic) Alisols	0.18	0.000036	160	2,620,000	94.32	65.68
Humic Ferralsols / Ferralic Cambisols	0.15	0.00003	160	2,520,000	75.6	84.4
Haplic (Gleyic) Luvisols	0.12	0.000024	160	2,580,000	61.92	98.08
Humic Alisols / Humic Acrisols	0.16	0.000032	160	2,500,000	80	80
Vertic Luvisols / Vertic Cambisols	0.17	0.000034	160	2,560,000	87.04	72.96
Dystric (Humic) Cambisols	0.17	0.000034	160	2,660,000	90.44	69.56
Humic Alisols/Humic Cambisols	0.16	0.000032	160	2,560,000	81.92	78.08
Rhodic Ferralsols	0.18	0.000036	160	2,580,000	92.88	67.12
Humic Acrisols / Humic (Ferralic) Cambisols	0.18	0.000036	160	2,600,000	93.6	66.4
Humic (Rhodic) Ferralsols	0.17	0.000034	160	2,660,000	90.44	69.56
Humic (Ferralic) Cambisols	0.18	0.000036	160	2,560,000	92.16	67.84
Humic Alisols / Rhodic (Haplic) Luvisols	0.17	0.000034	160	2,560,000	87.04	72.96
Haplic (Humic) Ferralsols / Haplic Lixisols	0.16	0.000032	160	2,520,000	80.64	79.36
Humic (Eutric) Cambisols	0.18	0.000036	160	2,640,000	95.04	64.96
Haplic Acrisols	0.18	0.000036	160	2,620,000	94.32	65.68
Humic Ferralic Cambisols / Ferric Lixisols	0.15	0.00003	160	2,560,000	76.8	83.2
Humic Dystric Cambisols	0.13	0.000026	160	2,500,000	65	95

Source: PEA baseline study, 2020

1.3.2 Recommended phosphorus for Cabbage

L. O. Duarte et al. (2019) has shown that application rate of 80 kg/ Ha of phosphorus was optimum for Cabbage production. Thus, to calculate the required phosphorus, 80 kg/ Ha was used as target. Following the similar procedure, the table below was produced.

Appendix table 29: Calculation of phosphorus requirement

Types of soil	AP (mg/kg)	Targeted kg/ha	av. P Kg/Ha	Weight of 1 Ha soil	P required kg/ ha
Terric Histosols	2.82	80	6.9936	2480000	73.0064
Humic (Dystric) Cambisols	4.05	80	10.449	2580000	69.551
Humic Acrisols (Sombric)	3.6	80	9.144	2540000	70.856
Dystric Regosols / Dystric Leptosols	3.61	80	9.1694	2540000	70.8306
Humic Ferralsols	3.64	80	9.3184	2560000	70.6816
Humic Cambisols	3.64	80	9.3184	2560000	70.6816
Humic Ferralsols / Humic Cambisols	3.43	80	8.9866	2620000	71.0134
Humic Acrisols / Humic Ferralsols / Humic Alisols	2.87	80	7.6342	2660000	72.3658
Humic Acrisols / Humic Ferralsols	2.86	80	7.3788	2580000	72.6212
Plinthic Alisols/Plinthic Acrisols	3.06	80	8.0784	2640000	71.9216
Haplic Acrisols / Ferralic Cambisols	5.41	80	13.525	2500000	66.475
Umbric Gleysols	3.02	80	7.4896	2480000	72.5104
Gleyic / Dystric Cambisols	2.32	80	5.6144	2420000	74.3856
Mollic Gleysol	3.9	80	9.906	2540000	70.094
Rhodic Ferralsols / Haplic Acrisols / Xanthic Ferralsols	3.86	80	9.7272	2520000	70.2728
Humic (Haplic) Ferralsols	3.91	80	9.9314	2540000	70.0686
Haplic Lixisols / Luvic Phaeozems	3.15	80	8.127	2580000	71.873
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	3.25	80	8.515	2620000	71.485
Humic Ferralsols / Ferralic Cambisols	4.33	80	10.9116	2520000	69.0884
Haplic (Gleyic) Luvisols	6.13	80	15.8154	2580000	64.1846
Humic Alisols / Humic Acrisols	2.91	80	7.275	2500000	72.725
Vertic Luvisols / Vertic Cambisols	3.86	80	9.8816	2560000	70.1184
Dystric (Humic) Cambisols	2.82	80	7.5012	2660000	72.4988
Humic Alisols/Humic Cambisols	3.94	80	10.0864	2560000	69.9136
Rhodic Ferralsols	3.05	80	7.869	2580000	72.131
Humic Acrisols / Humic (Ferralic) Cambisols	4.07	80	10.582	2600000	69.418
Humic (Rhodic) Ferralsols	3.47	80	9.2302	2660000	70.7698
Humic (Ferralic) Cambisols	3.82	80	9.7792	2560000	70.2208
Humic Alisols / Rhodic (Haplic) Luvisols	3.93	80	10.0608	2560000	69.9392
Haplic (Humic) Ferralsols / Haplic Lixisols	2.71	80	6.8292	2520000	73.1708
Humic (Eutric) Cambisols	3.23	80	8.5272	2640000	71.4728
Haplic Acrisols	2.62	80	6.8644	2620000	73.1356
Humic Ferralic Cambisols / Ferric Lixisols	4.18	80	10.7008	2560000	69.2992

Humic Dystric Cambisols	3.56	80	8.9	2500000	71.1

Source: PEA baseline study, 2020

1.3.3 Potassium Recommendation for Cabbage

Wijevardena and Amarasiri (1993), mention that cabbage removes higher amounts of potassium from soil than other vegetable crops, due especially to the very high amount of biomass it produces. Thus, a rate ranging between 250 to 300 kg/ha was proposed to compute for required potassium for Cabbage. As shown on the table below, all the soil units have more than required K, so no K fertilizer is needed.

Appendix table 30: Calculation of Potassium Requirement

	Exch K+	Targeted K	K present	Weight of	K present	K required
FAO_CLASSIFICATION	Cmolc/kg	kg/ ha	kg/kg soil	1 Ha soil	kg /ha	kg /ha
Terric Histosols	0.8	300	0.000312	2,480,000	773.76	0
Humic (Dystric) Cambisols	0.55	300	0.0002145	2,580,000	553.41	0
Humic Acrisols (Sombric)	0.55	300	0.0002145	2,540,000	544.83	0
Dystric Regosols / Dystric Leptosols	0.49	300	0.0001911	2,540,000	485.394	0
Humic Ferralsols	0.55	300	0.0002145	2,560,000	549.12	0
Humic Cambisols	0.52	300	0.0002028	2,560,000	519.168	0
Humic Ferralsols / Humic Cambisols	0.44	300	0.0001716	2,620,000	449.592	0
Humic Acrisols / Humic Ferralsols / Humic Alisols	0.5	300	0.000195	2,660,000	518.7	0
Humic Acrisols / Humic Ferralsols	0.49	300	0.0001911	2,580,000	493.038	0
Plinthic Alisols/Plinthic Acrisols	0.5	300	0.000195	2,640,000	514.8	0
Haplic Acrisols / Ferralic Cambisols	0.64	300	0.0002496	2,500,000	624	0
Umbric Gleysols	0.59	300	0.0002301	2,480,000	570.648	0
Gleyic / Dystric Cambisols	0.41	300	0.0001599	2,420,000	386.958	0
Mollic Gleysol	0.54	300	0.0002106	2,540,000	534.924	0
Rhodic Ferralsols / Haplic Acrisols / Xanthic Ferralsols	0.63	300	0.0002457	2,520,000	619.164	0
Humic (Haplic) Ferralsols	0.66	300	0.0002574	2,540,000	653.796	0
Haplic Lixisols / Luvic Phaeozems	0.59	300	0.0002301	2,580,000	593.658	0
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	0.52	300	0.0002028	2,620,000	531.336	0
Humic Ferralsols / Ferralic Cambisols	0.58	300	0.0002262	2,520,000	570.024	0
Haplic (Gleyic) Luvisols	0.58	300	0.0002262	2,580,000	583.596	0
Humic Alisols / Humic Acrisols	0.6	300	0.000234	2,500,000	585	0
Vertic Luvisols / Vertic Cambisols	0.64	300	0.0002496	2,560,000	638.976	0
Dystric (Humic) Cambisols	0.5	300	0.000195	2,660,000	518.7	0

Humic Alisols/Humic Cambisols	0.6	300	0.000234	2,560,000	599.04	0
Rhodic Ferralsols	0.5	300	0.000195	2,580,000	503.1	0
Humic Acrisols / Humic (Ferralic) Cambisols	0.57	300	0.0002223	2,600,000	577.98	0
Humic (Rhodic) Ferralsols	0.44	300	0.0001716	2,660,000	456.456	0
Humic (Ferralic) Cambisols	0.75	300	0.0002925	2,560,000	748.8	0
Humic Alisols / Rhodic (Haplic) Luvisols	0.54	300	0.0002106	2,560,000	539.136	0
Haplic (Humic) Ferralsols / Haplic Lixisols	0.63	300	0.0002457	2,520,000	619.164	0
Humic (Eutric) Cambisols	0.52	300	0.0002028	2,640,000	535.392	0
Haplic Acrisols	0.54	300	0.0002106	2,620,000	551.772	0
Humic Ferralic Cambisols / Ferric Lixisols	0.69	300	0.0002691	2,560,000	688.896	0
Humic Dystric Cambisols	0.72	300	0.0002808	2,500,000	702	0

Source: PEA baseline study, 2020

Appendix table 31: Musanze District

2. 1 Fertilizer recommendation for Maize

through water supply. Maize cropping in the tropics can result into a high biomass yield as well as grain yield ranging from 2 to 12 tons per ha depending on the soil nutrient status as well as fertilizer application coupled with other technologies. The determination of fertilizers shall consider: the soil stock, the expected Nitrogen removal by plant.

Maize fertilizer recommendation computation

Nitrogen required for Soil Units identified Musanze

The nutrients removal through maize grains is estimated to 13.1 Kg, per ton of grains (14% dry matter). Similarly, the nutrients removal in maize residues is estimated to 12.8kg per ton of maize residues (14% dry matter) for Nitrogen. If the yield target is 7 tons of maize grain per Ha, the residues will be estimated to 1.45 as proposed by several authors including (Fleischel *et al*., 2014). Therefore, the target of 7 tons of grain per ha will correspond to a mass of residues equivalent to 10.15 tons. The total removal of N= 7* 13.1+ 10.15*12.8= 120 kg of N. The total N fertilizer to target a yield of 7 tons' grain per ha is than estimated to 120 kg per Ha.

Appendix table 32:Calculation of nitrogen requirement for maize production in Musanze District

Type Soils	Total N %	Mineralized N kg/kg soil at 1.5 %	Target N kg/ha	Average Weight of1 Ha soil	Mineralized N kg /ha	Required N kg/ha
Mollic / Haplic Andosols	0.44	0.000066	120	1,860,000	122.76	0
Mollic Andosols	0.36	0.000054	120	1,920,000	103.68	16.32
Umbric Andosols / Umbric Leptosols	0.41	0.0000615	120	1,900,000	116.85	3.15
Humic Cambisols	0.36	0.000054	120	1,960,000	105.84	14.16
Mollic (Haplic) Andosols	0.33	0.0000495	120	1,980,000	98.01	21.99
Vitric Andosols	0.4	0.00006	120	1,860,000	111.6	8.4
Dystric Regosols / Dystric Leptosols	0.32	0.000048	120	2,300,000	110.4	9.6
Humic (Dystric) Cambisols	0.31	0.0000465	120	2,260,000	105.09	14.91
Humic Acrisols / Humic Ferralsols	0.28	0.000042	120	2,040,000	85.68	34.32
Vertic Luvisols / Luvic Phaeozems	0.26	0.000039	120	2,100,000	81.9	38.1
Terric / Fibric Histosols	0.27	0.0000405	120	2,220,000	89.91	30.09
Humic Acrisols / Humic (Ferralic) Cambisols	0.28	0.000042	120	2,360,000	99.12	20.88
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	0.27	0.0000405	120	2,300,000	93.15	26.85
Haplic Alisols / Dystric Cambisols / Eutric Cambisols	0.26	0.000039	120	2,020,000	78.78	41.22
Humic Alisols / Rhodic (Haplic) Luvisols	0.3	0.000045	120	2,060,000	92.7	27.3
Luvic Phaeozems	0.25	0.0000375	120	2,000,000	75	45
Vertic Luvisols / Vertic Cambisols	0.39	0.0000585	120	1,980,000	115.83	4.17
Humic Ferralsols / Humic Cambisols	0.27	0.0000405	120	2,420,000	98.01	21.99
Andic Gelysols / Gleyic Andosols	0.42	0.000063	120	2,040,000	128.52	0
Umbric Gleysols	0.33	0.0000495	120	2,320,000	114.84	5.16
Umbric Andosols	0.46	0.000069	120	1,960,000	135.24	0

Source: PEA baseline study, 2020

2.2 Phosphorus Recommendation for Maize

The soil tests have shown that phosphorus content is low compared to the optimum rate. Research has shown that a rate of P shall be 51 kg / ha to allow reasonable plant nutrition (Daniel et al., 2011).

Appendix table 33:Calculation of Phosphorus requirement for maize production in Musanze District

FAO_CLASSIFICATION	AP (mg/kg)	Targeted kg/ha	av. P Kg/Ha	Weight kg of soil / Ha	P required kg/ ha
Mollic / Haplic Andosols	12.88	51	23.9568	1,860,000	27.0432
Mollic Andosols	8.89	51	17.0688	1,920,000	33.9312
Umbric Andosols / Umbric Leptosols	14.08	51	26.752	1,900,000	24.248
Humic Cambisols	9.6	51	18.816	1,960,000	32.184
Mollic (Haplic) Andosols	10.4	51	20.592	1,980,000	30.408
Vitric Andosols	11.55	51	21.483	1,860,000	29.517
Dystric Regosols / Dystric Leptosols	6.45	51	14.835	2,300,000	36.165
Humic (Dystric) Cambisols	4.67	51	10.5542	2,260,000	40.4458
Humic Acrisols / Humic Ferralsols	5.15	51	10.506	2,040,000	40.494
Vertic Luvisols / Luvic Phaeozems	3.36	51	7.056	2,100,000	43.944
Terric / Fibric Histosols	3.32	51	7.3704	2,220,000	43.6296
Humic Acrisols / Humic (Ferralic) Cambisols	4.25	51	10.03	2,360,000	40.97
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	3.77	51	8.671	2,300,000	42.329
Haplic Alisols / Dystric Cambisols / Eutric Cambisols	3.11	51	6.2822	2,020,000	44.7178
Humic Alisols / Rhodic (Haplic) Luvisols	7.91	51	16.2946	2,060,000	34.7054
Luvic Phaeozems	3.56	51	7.12	2,000,000	43.88
Vertic Luvisols / Vertic Cambisols	9.18	51	18.1764	1,980,000	32.8236
Humic Ferralsols / Humic Cambisols	3.45	51	8.349	2,420,000	42.651
Andic Gelysols / Gleyic Andosols	7.03	51	14.3412	2,040,000	36.6588
Umbric Gleysols	4.11	51	9.5352	2,320,000	41.4648
Umbric Andosols	18.72	51	36.6912	1,960,000	14.3088

Source: PEA baseline study, 2020

2.3 Potassium requirement for maize production

Potassium is considered as one of the major nutrients needed by crop to grow and produce yield. The soil potassium content considered for general crop production ranges from 150 to 300 mg/ kg depending on the targeted yield per hectare and 150 kg / Ha is considered as optimum for maize production. If one takes an example of the Gleyic / Dystric Cambisols the total available K on 1 Ha is estimated to 386.958 kg. The test has shown that K value of soil unit 1 is 0.8 $cmol_c$ per kg of soil which is equivalent to (0.8*390/1000000) kg per kg of soil=0.000312kg/kg of soil. This value is already much higher than the required amount, so no need of K fertilization

Appendix table 34:Calculation of Potassium Requirement for maize production in Musanze District

	Exch.K+	Targeted K	K present	Weight of	K present	K required
FAO_CLASSIFICATION	CmolC/kg	kg/ ha	kg/kg soil	1 Ha soil	kg /ha	kg /ha
Mollic / Haplic Andosols	0.56	150	0.0002184	1,860,000	406.224	0
Mollic Andosols	0.42	150	0.0001638	1,920,000	314.496	0
Umbric Andosols / Umbric Leptosols	0.35	150	0.0001365	1,900,000	259.35	0
Humic Cambisols	0.35	150	0.0001365	1,960,000	267.54	0
Mollic (Haplic) Andosols	0.41	150	0.0001599	1,980,000	316.602	0
Vitric Andosols	0.77	150	0.0003003	1,860,000	558.558	0
Dystric Regosols / Dystric Leptosols	0.24	150	0.0000936	2,300,000	215.28	0
Humic (Dystric) Cambisols	0.22	150	0.0000858	2,260,000	193.908	0
Humic Acrisols / Humic Ferralsols	0.51	150	0.0001989	2,040,000	405.756	0
Vertic Luvisols / Luvic Phaeozems	0.37	150	0.0001443	2,100,000	303.03	0
Terric / Fibric Histosols	0.42	150	0.0001638	2,220,000	363.636	0
Humic Acrisols / Humic (Ferralic) Cambisols	0.21	150	0.0000819	2,360,000	193.284	0
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	0.26	150	0.0001014	2,300,000	233.22	0
Haplic Alisols / Dystric Cambisols / Eutric Cambisols	0.46	150	0.0001794	2,020,000	362.388	0
Humic Alisols / Rhodic (Haplic) Luvisols	0.39	150	0.0001521	2,060,000	313.326	0
Luvic Phaeozems	0.47	150	0.0001833	2,000,000	366.6	0
Vertic Luvisols / Vertic Cambisols	0.61	150	0.0002379	1,980,000	471.042	0
Humic Ferralsols / Humic Cambisols	0.23	150	0.0000897	2,420,000	217.074	0
Andic Gelysols / Gleyic Andosols	1.03	150	0.0004017	2,040,000	819.468	0
Umbric Gleysols	1.13	150	0.0004407	2,320,000	1022.42	0
Umbric Andosols	1.08	150	0.0004212	1,960,000	825.552	0

Source: PEA baseline study, 2020

2.4 Fertilizer Requirement recommendation for Coffee

2.4.1 Nitrogen requirement for Coffee in Musanze

Coffee Nitrogen requirement varies from year 1 to year 3 where a rate of 220 kg is recommended at third year (Volhoubare Landbou, RSA 1999). Since most of Rwandan coffee plantation are more than 3 years old the amount of nitrogen required in Bugesera is computed here by targeting 220 kg / Ha.

Appendix table 35:Calculation of Nitrogen requirement for coffee production in Musanze District

Type Soils	Total N %	Mineralized N kg/kg soil at 1.5 %	Target N kg/ha	Average Weight of1 Ha soil	Mineralized N kg /ha	Required N kg/ha
Mollic / Haplic Andosols	0.44	0.000066	220	1,860,000	122.76	97.24
Mollic Andosols	0.36	0.000054	220	1,920,000	103.68	116.32
Umbric Andosols / Umbric Leptosols	0.41	0.0000615	220	1,900,000	116.85	103.15
Humic Cambisols	0.36	0.000054	220	1,960,000	105.84	114.16
Mollic (Haplic) Andosols	0.33	0.0000495	220	1,980,000	98.01	121.99
Vitric Andosols	0.4	0.00006	220	1,860,000	111.6	108.4
Dystric Regosols / Dystric Leptosols	0.32	0.000048	220	2,300,000	110.4	109.6
Humic (Dystric) Cambisols	0.31	0.0000465	220	2,260,000	105.09	114.91
Humic Acrisols / Humic Ferralsols	0.28	0.000042	220	2,040,000	85.68	134.32
Vertic Luvisols / Luvic Phaeozems	0.26	0.000039	220	2,100,000	81.9	138.1
Terric / Fibric Histosols	0.27	0.0000405	220	2,220,000	89.91	130.09
Humic Acrisols / Humic (Ferralic) Cambisols	0.28	0.000042	220	2,360,000	99.12	120.88
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	0.27	0.0000405	220	2,300,000	93.15	126.85
Haplic Alisols / Dystric Cambisols / Eutric Cambisols	0.26	0.000039	220	2,020,000	78.78	141.22
Humic Alisols / Rhodic (Haplic) Luvisols	0.3	0.000045	220	2,060,000	92.7	127.3
Luvic Phaeozems	0.25	0.0000375	220	2,000,000	75	145

Source: PEA baseline study, 2020

2.4.2 Phosphorus Requirement for Coffee

Coffee phosphorus requirement varies from year 1 to year 3 where a rate of 50 kg is recommended at third year (Volhoubare Landbou, RSA 1999).

Since most of Rwandan coffee plantation are more than 3 years old the amount of nitrogen required in Bugesera was computed by targeting 50 kg / Ha.

Appendix table 36: Calculation of Phosphorus requirement for coffee production in Musanze District

	AP (mg/kg)	Targeted	av. P	Weight kg of soil	P required
FAO_CLASSIFICATION		kg/ha	Kg/Ha	/ Ha	kg/ ha
Mollic / Haplic Andosols	12.88	50	23.9568	1,860,000	26.0432
Mollic Andosols	8.89	50	17.0688	1,920,000	32.9312
Umbric Andosols / Umbric Leptosols	14.08	50	26.752	1,900,000	23.248
Humic Cambisols	9.6	50	18.816	1,960,000	31.184
Mollic (Haplic) Andosols	10.4	50	20.592	1,980,000	29.408
Vitric Andosols	11.55	50	21.483	1,860,000	28.517
Dystric Regosols / Dystric Leptosols	6.45	50	14.835	2,300,000	35.165
Humic (Dystric) Cambisols	4.67	50	10.5542	2,260,000	39.4458
Humic Acrisols / Humic Ferralsols	5.15	50	10.506	2,040,000	39.494
Vertic Luvisols / Luvic Phaeozems	3.36	50	7.056	2,100,000	42.944
Terric / Fibric Histosols	3.32	50	7.3704	2,220,000	42.6296
Humic Acrisols / Humic (Ferralic) Cambisols	4.25	50	10.03	2,360,000	39.97
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	3.77	50	8.671	2,300,000	41.329
Haplic Alisols / Dystric Cambisols / Eutric Cambisols	3.11	50	6.2822	2,020,000	43.7178
Humic Alisols / Rhodic (Haplic) Luvisols	7.91	50	16.2946	2,060,000	33.7054
Luvic Phaeozems	3.56	50	7.12	2,000,000	42.88
Vertic Luvisols / Vertic Cambisols	9.18	50	18.1764	1,980,000	31.8236
Humic Ferralsols / Humic Cambisols	3.45	50	8.349	2,420,000	41.651
Andic Gelysols / Gleyic Andosols	7.03	50	14.3412	2,040,000	35.6588
Umbric Gleysols	4.11	50	9.5352	2,320,000	40.4648
Umbric Andosols	18.72	50	36.6912	1,960,000	13.3088

Source: PEA baseline study, 2020

2.4.3 Potassium Requirement for Coffee

Coffee Potassium requirement varies from year 1 to year 3 where a rate of 50 kg is recommended at third year (Volhoubare Landbou, RSA 1999). Since most of Rwandan coffee plantations are more than 3 years old the amount of nitrogen required in Bugesera was computed by targeting 250 kg / Ha. The data we have shown that K value of most of the soil units are high compared to the required amount.

2.5 Fertilizer recommendation for Cabbage

2.5.1 Nitrogen Requirement for Cabbage

According to the Fertilizer Society of South Africa, (2000), to produce optimum yields of good quality cabbages, often high amounts of nitrogen fertilizer is applied. It was however, found that yield improvements from 100 to 150 kg·ha^{-1} were not significantly different. Gupta (1987) and Humadi M F, Hadi H. 1988 reported maximum cabbage head mass at 150 kg·ha-1 N. The maximum yields from 150 kg·ha^{-1} N were attributed mainly to increase in head mass. Otherwise, the recommended total amounts of nitrogen fertilizer for cabbage are ranged from 160 to 260 kg·ha^{-1}. Hense, 160 kg/ Ha was used to compute for nitrogen requirement for Cabbage. Using the same computation procedures, the following table of fertilizer requirement was produced.

2.5.2 Fertilizers requirement for Cabbage

Appendix table 37:Calculation of Nitrogen Requirement cabbage production in Musanze District

Type Soils	Total N %	Mineralized N kg/kg soil at 1.5 %	Target N kg/ha	Average Weight of1 Ha soil	Mineralized N kg /ha	Required N kg/ha
Mollic / Haplic Andosols	0.44	0.000066	160	1,860,000	122.76	37.24
Mollic Andosols	0.36	0.000054	160	1,920,000	103.68	56.32
Umbric Andosols / Umbric Leptosols	0.41	0.0000615	160	1,900,000	116.85	43.15
Humic Cambisols	0.36	0.000054	160	1,960,000	105.84	54.16
Mollic (Haplic) Andosols	0.33	0.0000495	160	1,980,000	98.01	61.99
Vitric Andosols	0.4	0.00006	160	1,860,000	111.6	48.4
Dystric Regosols / Dystric Leptosols	0.32	0.000048	160	2,300,000	110.4	49.6
Humic (Dystric) Cambisols	0.31	0.0000465	160	2,260,000	105.09	54.91
Humic Acrisols / Humic Ferralsols	0.28	0.000042	160	2,040,000	85.68	74.32
Vertic Luvisols / Luvic Phaeozems	0.26	0.000039	160	2,100,000	81.9	78.1
Terric / Fibric Histosols	0.27	0.0000405	160	2,220,000	89.91	70.09
Humic Acrisols / Humic (Ferralic) Cambisols	0.28	0.000042	160	2,360,000	99.12	60.88
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	0.27	0.0000405	160	2,300,000	93.15	66.85
Haplic Alisols / Dystric Cambisols / Eutric Cambisols	0.26	0.000039	160	2,020,000	78.78	81.22
Humic Alisols / Rhodic (Haplic) Luvisols	0.3	0.000045	160	2,060,000	92.7	67.3
Luvic Phaeozems	0.25	0.0000375	160	2,000,000	75	85
Vertic Luvisols / Vertic Cambisols	0.39	0.0000585	160	1,980,000	115.83	44.17
Humic Ferralsols / Humic Cambisols	0.27	0.0000405	160	2,420,000	98.01	61.99
Andic Gelysols / Gleyic Andosols	0.42	0.000063	160	2,040,000	128.52	31.48
Umbric Gleysols	0.33	0.0000495	160	2,320,000	114.84	45.16
Umbric Andosols	0.46	0.000069	160	1,960,000	135.24	24.76

Source: PEA baseline study, 2020

2.5.3 Recommended phosphorus for Cabbage

Duarte, L. O. et al. (2019) has shown that application rate of 80 kg/ Ha of phosphorus was optimum for Cabbage production. Thus to calculate the required phosphorus, 80 kg/ Ha was used as target. Following the similar procedure, the table below was produced.

Appendix table 38:Calculation of Phosphorus Requirement for cabbage production in Musanze District

FAO_CLASSIFICATION	AP (mg/kg)	Targeted kg/ha	av. P Kg/Ha	Weight kg of soil / Ha	P required kg/ ha
Mollic / Haplic Andosols	12.88	80	23.9568	1,860,000	56.0432
Mollic Andosols	8.89	80	17.0688	1,920,000	62.9312
Umbric Andosols / Umbric Leptosols	14.08	80	26.752	1,900,000	53.248
Humic Cambisols	9.6	80	18.816	1,960,000	61.184
Mollic (Haplic) Andosols	10.4	80	20.592	1,980,000	59.408
Vitric Andosols	11.55	80	21.483	1,860,000	58.517
Dystric Regosols / Dystric Leptosols	6.45	80	14.835	2,300,000	65.165
Humic (Dystric) Cambisols	4.67	80	10.5542	2,260,000	69.4458
Humic Acrisols / Humic Ferralsols	5.15	80	10.506	2,040,000	69.494
Vertic Luvisols / Luvic Phaeozems	3.36	80	7.056	2,100,000	72.944
Terric / Fibric Histosols	3.32	80	7.3704	2,220,000	72.6296
Humic Acrisols / Humic (Ferralic) Cambisols	4.25	80	10.03	2,360,000	69.97
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	3.77	80	8.671	2,300,000	71.329
Haplic Alisols / Dystric Cambisols / Eutric Cambisols	3.11	80	6.2822	2,020,000	73.7178
Humic Alisols / Rhodic (Haplic) Luvisols	7.91	80	16.2946	2,060,000	63.7054
Luvic Phaeozems	3.56	80	7.12	2,000,000	72.88
Vertic Luvisols / Vertic Cambisols	9.18	80	18.1764	1,980,000	61.8236
Humic Ferralsols / Humic Cambisols	3.45	80	8.349	2,420,000	71.651
Andic Gelysols / Gleyic Andosols	7.03	80	14.3412	2,040,000	65.6588
Umbric Gleysols	4.11	80	9.5352	2,320,000	70.4648
Umbric Andosols	18.72	80	36.6912	1,960,000	43.3088

Source: PEA baseline study, 2020

2.5.4 Potassium Recommendation for Cabbage

Wijevardena. J.D.H, (1993), mention that cabbage removes higher amounts of potassium from soil than other vegetable crops, due especially to the very high amount of biomass it produces. Thus, a rate ranging between 250 to 300 kg/ha was proposed to compute for required potassium for Cabbage. As shown on the table below, all the soil units have more than required K, so no K fertilizer is needed

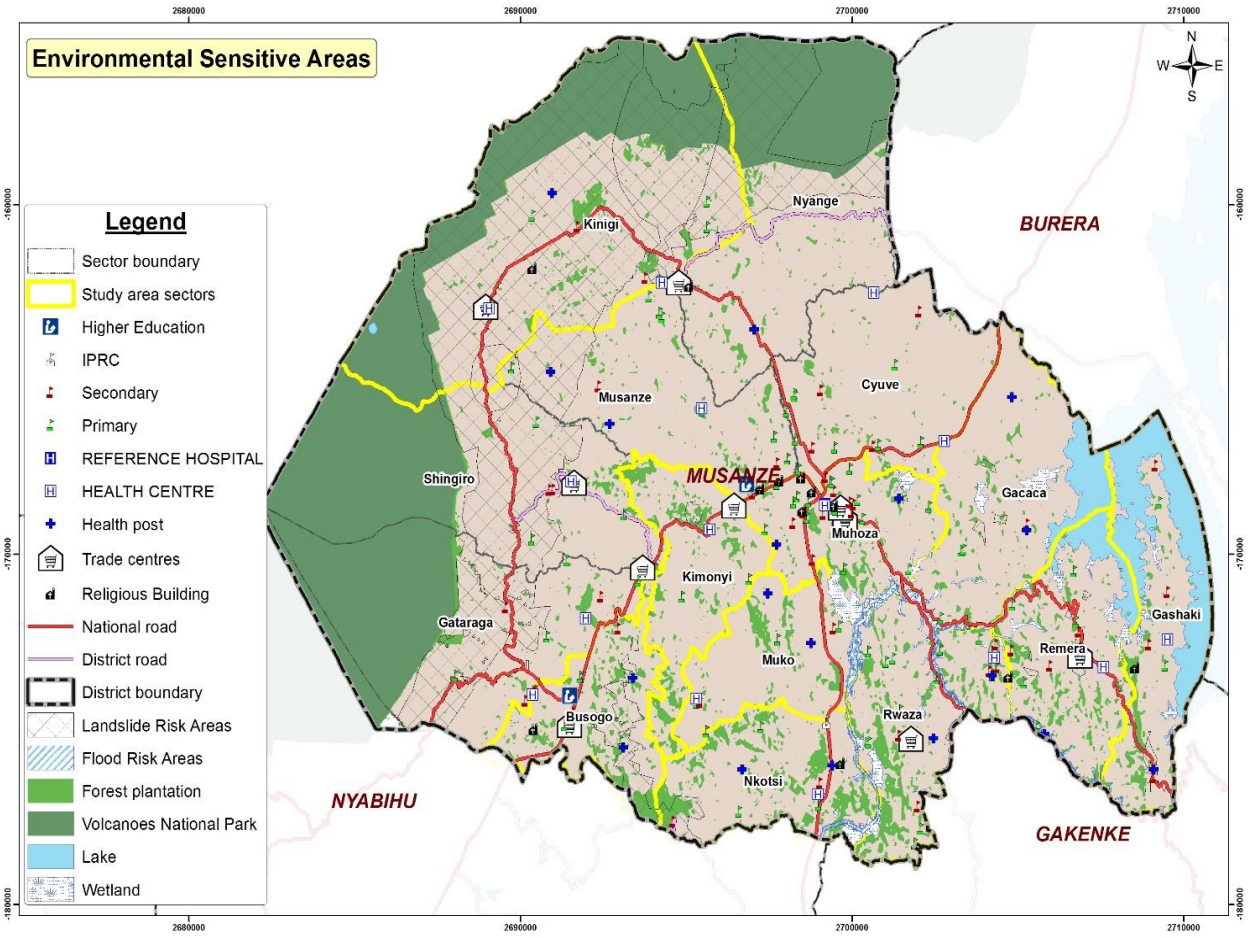
Appendix table 39:Calculation of Potassium Requirement for cabbage production in Musanze District

	Exch.K+	Targeted K	K present	Weight of	K present	K required
FAO_CLASSIFICATION	CmolC/kg	kg/ ha	kg/kg soil	1 Ha soil	kg /ha	kg /ha
Mollic / Haplic Andosols	0.56	300	0.0002184	1,860,000	406.224	0
Mollic Andosols	0.42	300	0.0001638	1,920,000	314.496	0
Umbric Andosols / Umbric Leptosols	0.35	300	0.0001365	1,900,000	259.35	0
Humic Cambisols	0.35	300	0.0001365	1,960,000	267.54	0
Mollic (Haplic) Andosols	0.41	300	0.0001599	1,980,000	316.602	0
Vitric Andosols	0.77	300	0.0003003	1,860,000	558.558	0
Dystric Regosols / Dystric Leptosols	0.24	300	0.0000936	2,300,000	215.28	0
Humic (Dystric) Cambisols	0.22	300	0.0000858	2,260,000	193.908	0
Humic Acrisols / Humic Ferralsols	0.51	300	0.0001989	2,040,000	405.756	0
Vertic Luvisols / Luvic Phaeozems	0.37	300	0.0001443	2,100,000	303.03	0
Terric / Fibric Histosols	0.42	300	0.0001638	2,220,000	363.636	0
Humic Acrisols / Humic (Ferralic) Cambisols	0.21	300	0.0000819	2,360,000	193.284	0
Dystric (Humic) Cambisols / Haplic (Humic) Alisols	0.26	300	0.0001014	2,300,000	233.22	0
Haplic Alisols / Dystric Cambisols / Eutric Cambisols	0.46	300	0.0001794	2,020,000	362.388	0
Humic Alisols / Rhodic (Haplic) Luvisols	0.39	300	0.0001521	2,060,000	313.326	0
Luvic Phaeozems	0.47	300	0.0001833	2,000,000	366.6	0
Vertic Luvisols / Vertic Cambisols	0.61	300	0.0002379	1,980,000	471.042	0
Humic Ferralsols / Humic Cambisols	0.23	300	0.0000897	2,420,000	217.074	0
Andic Gelysols / Gleyic Andosols	1.03	300	0.0004017	2,040,000	819.468	0
Umbric Gleysols	1.13	300	0.0004407	2,320,000	1022.424	0
Umbric Andosols	1.08	300	0.0004212	1,960,000	825.552	0

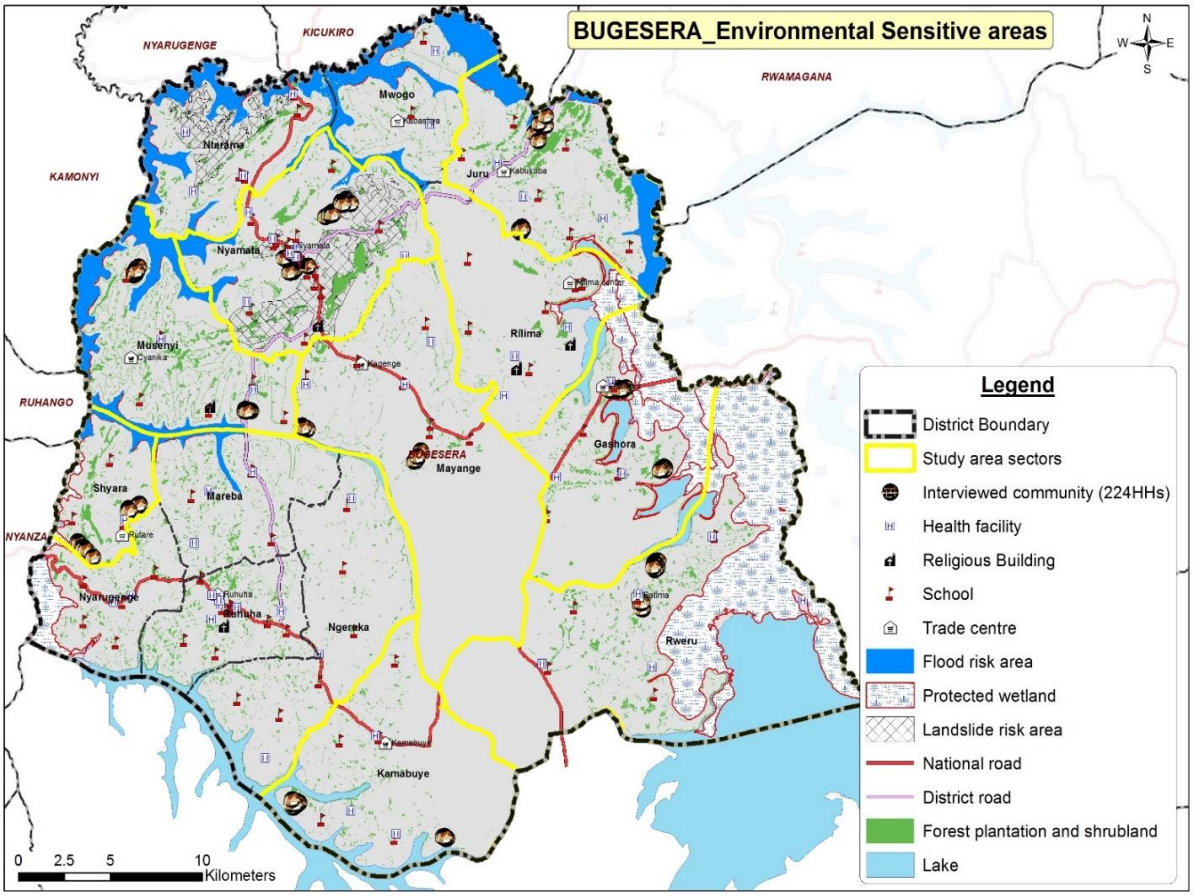
Source: PEA baseline study, 2020

Appendix 7: Maps

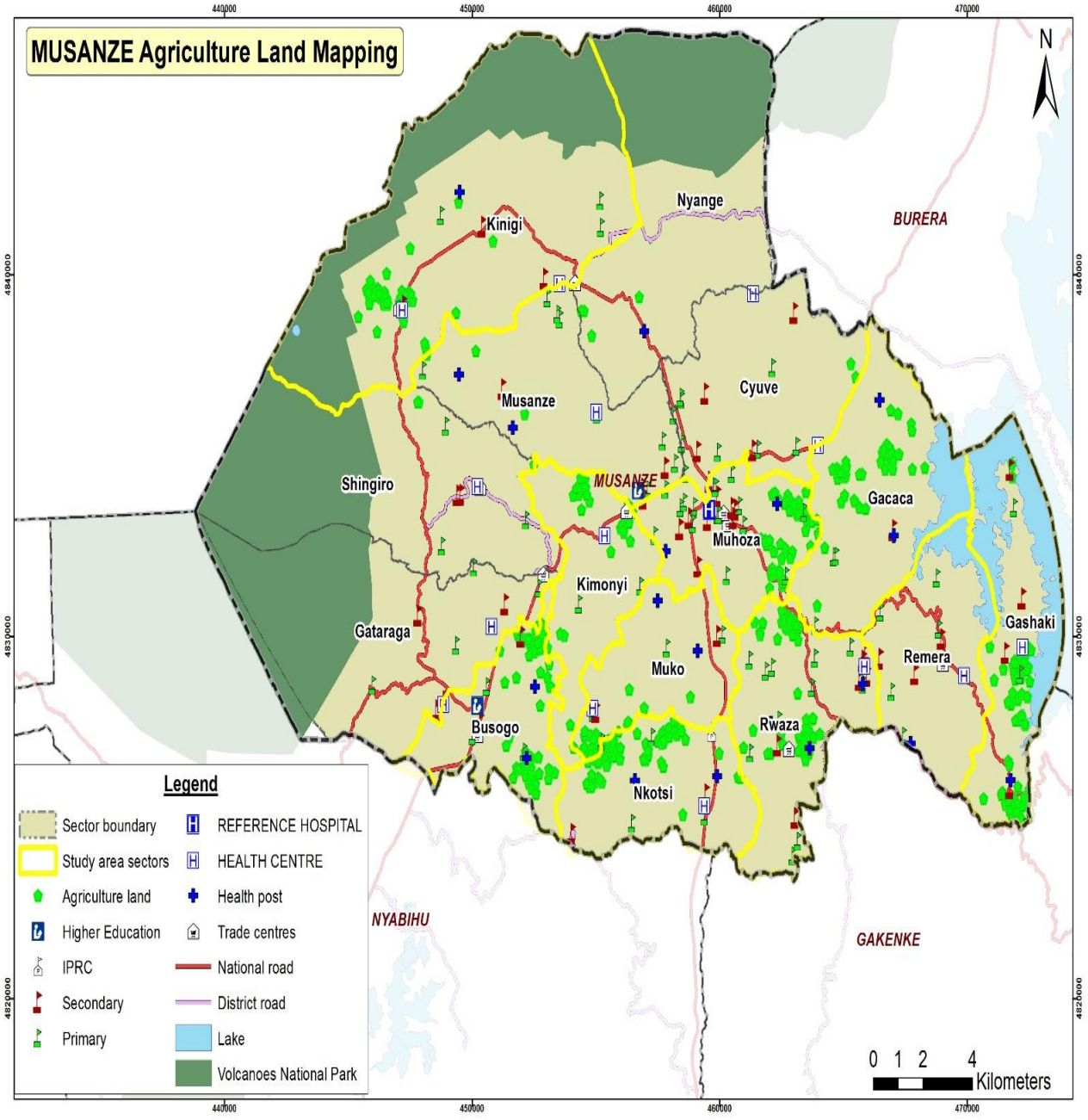
Map 7.1 : Musanze Environmental Sensitive Areas



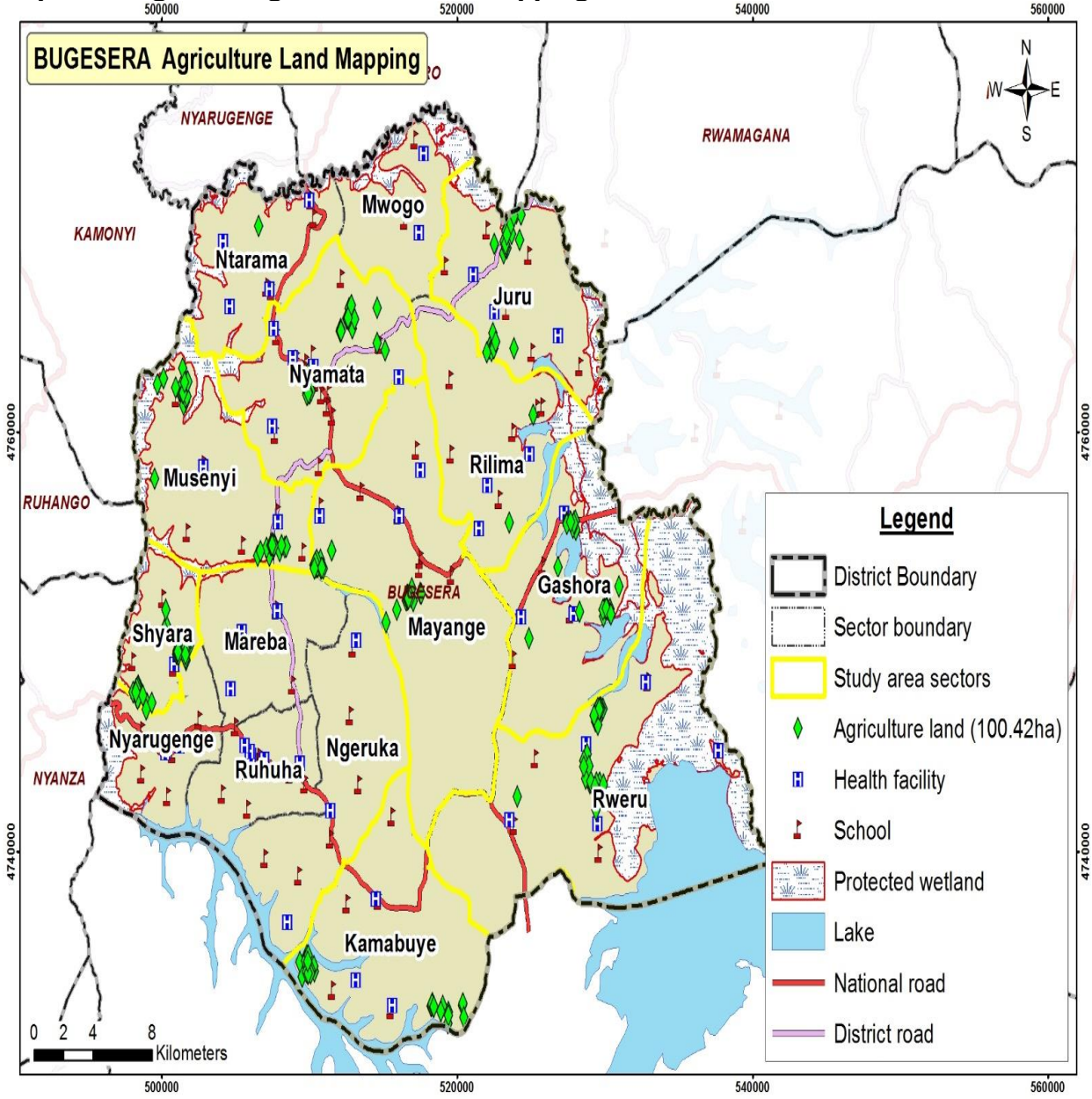
Map7.2 : Bugesera Environmental Sensitive Areas



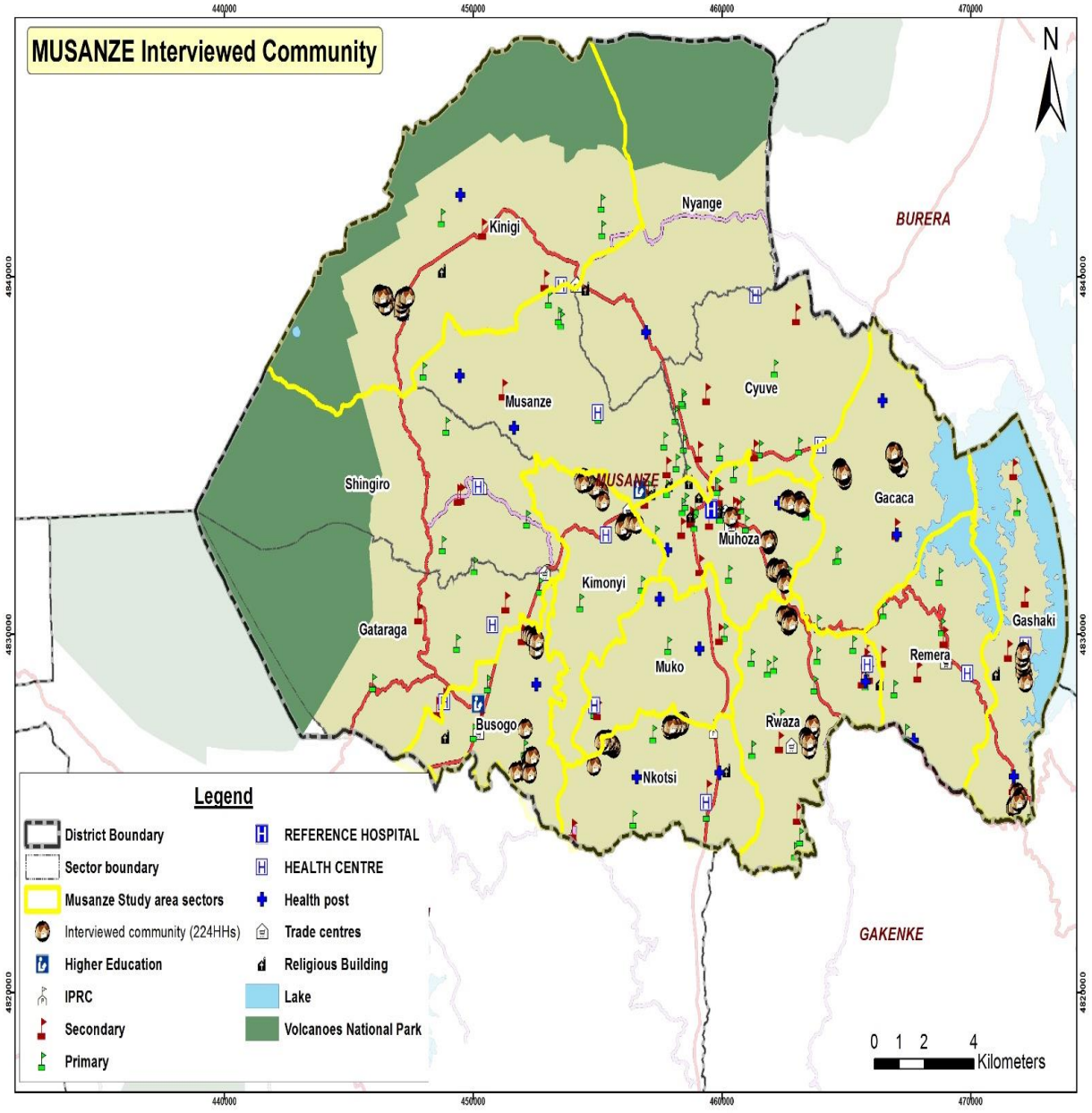
Map 7.3 : Musanze Agriculture Land Mapping



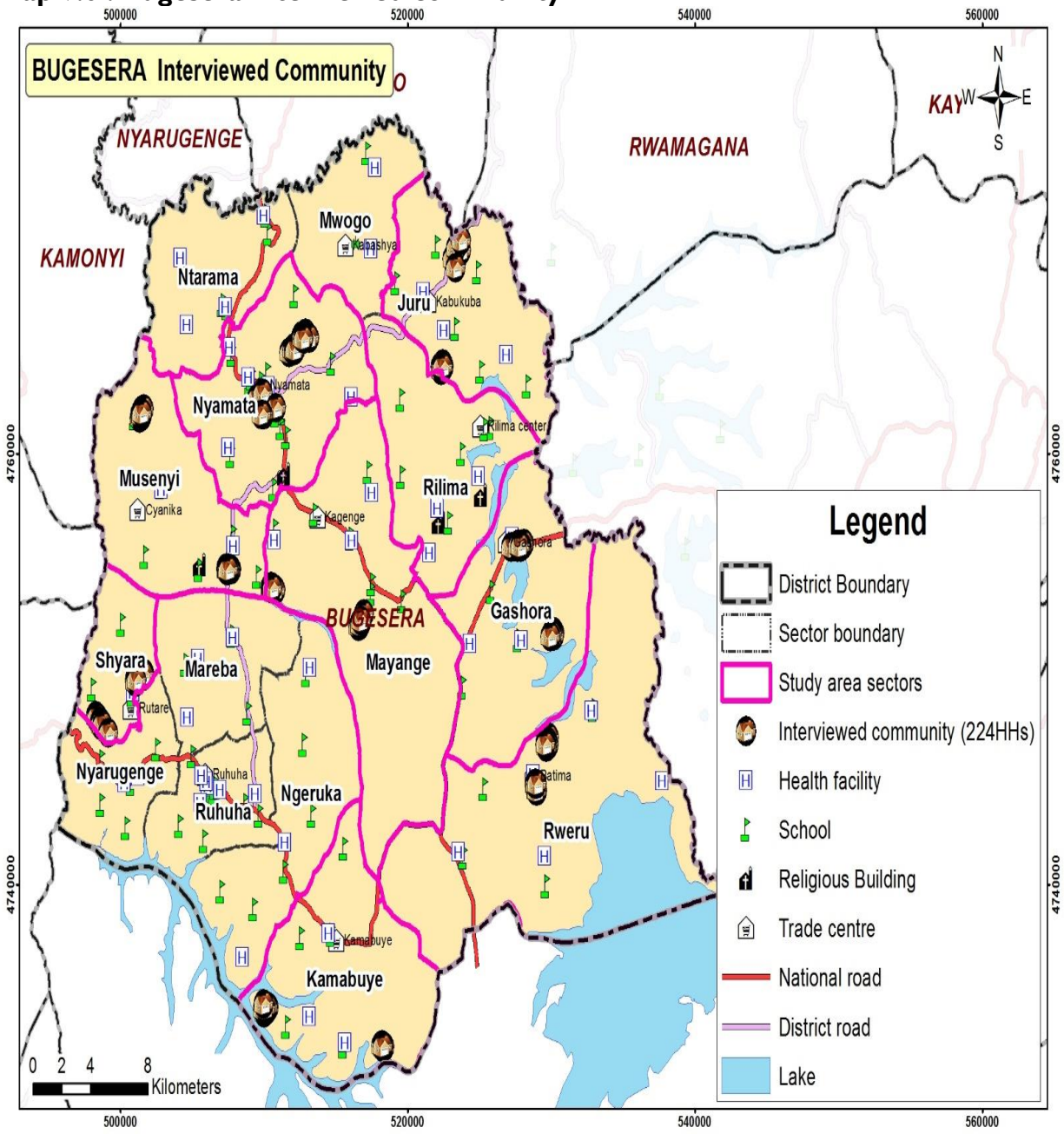
Map7.4 : Bugesera Agriculture Land Mapping



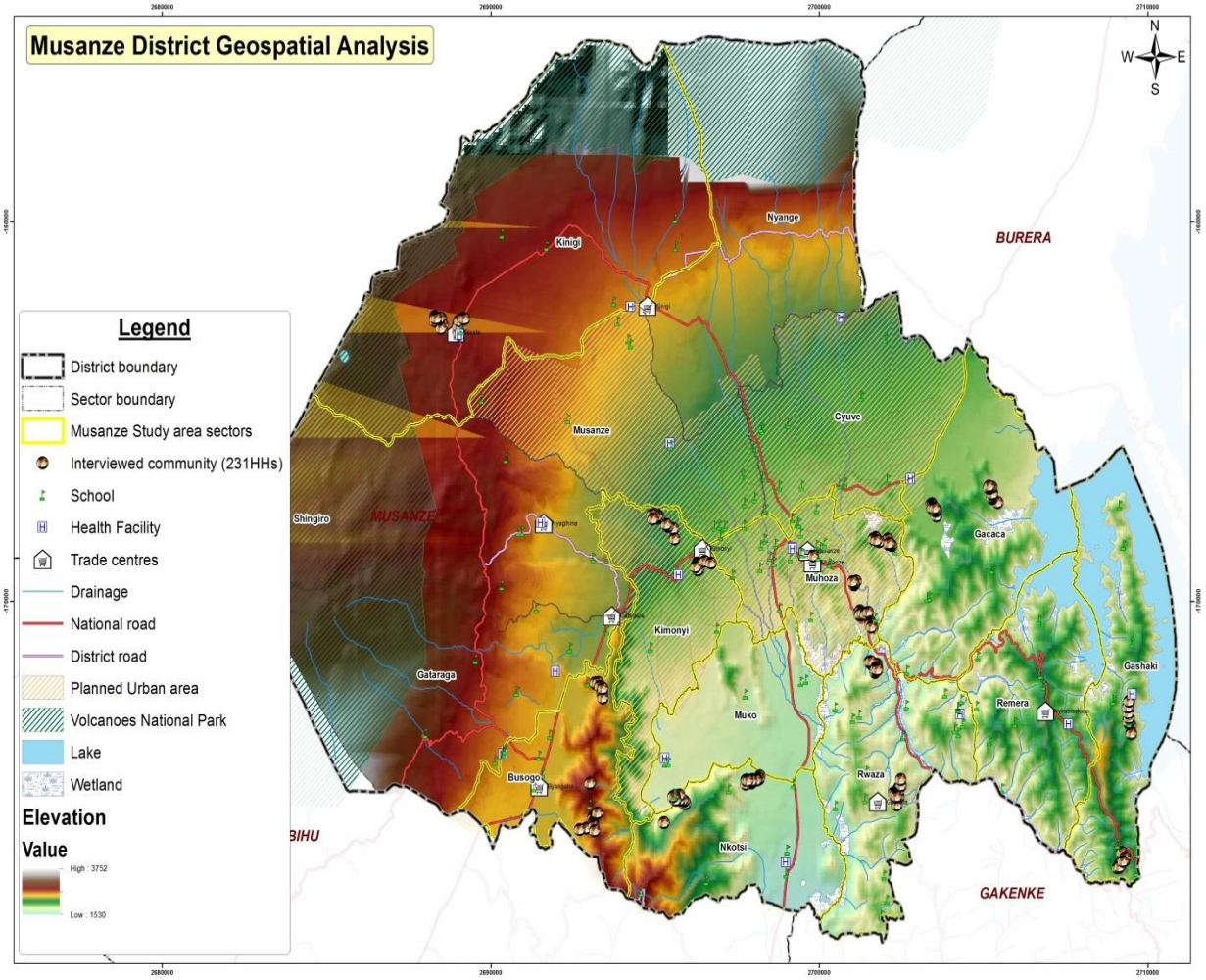
Map 7.5 : Musanze Interviewed community



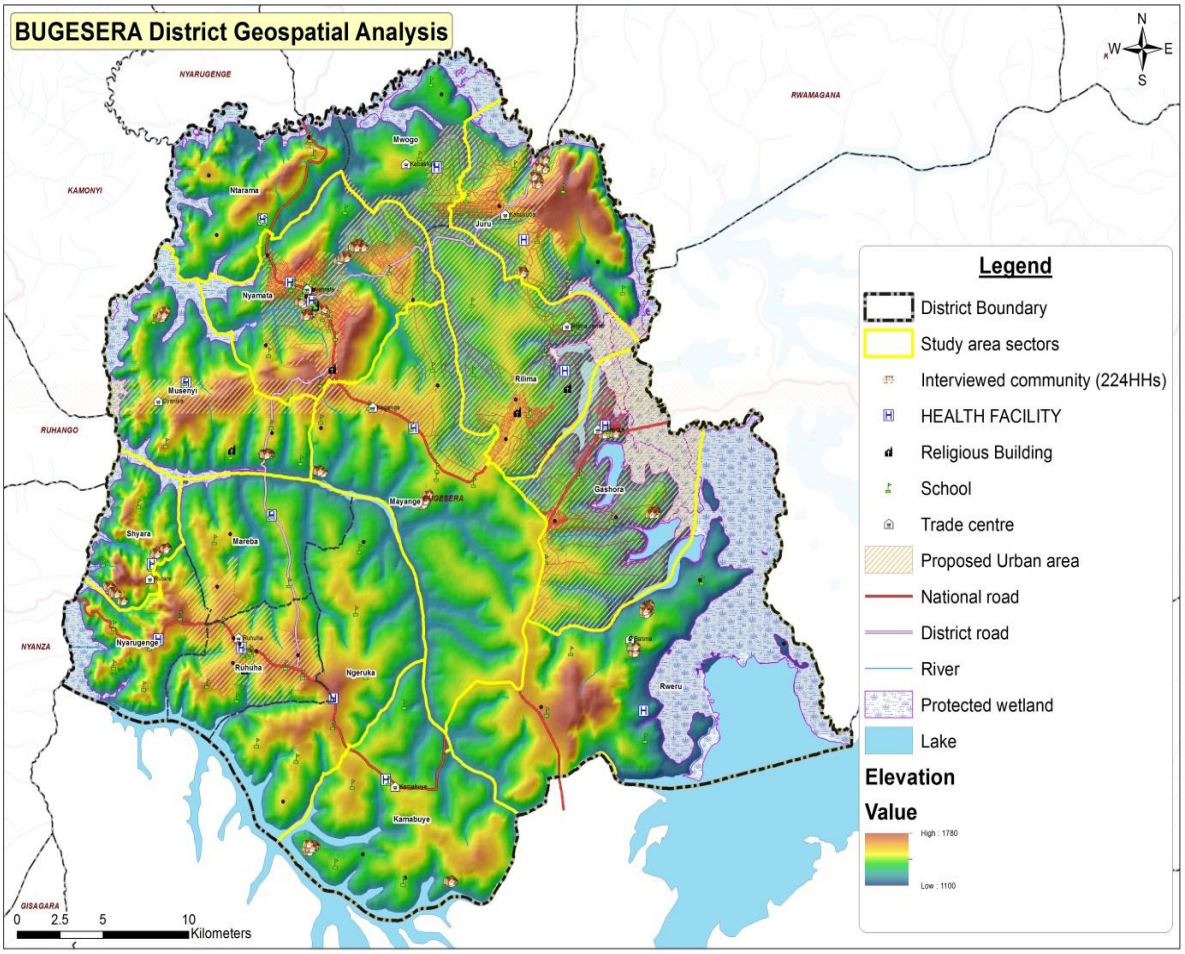
Map 7.6 : Bugesera Interviewed community



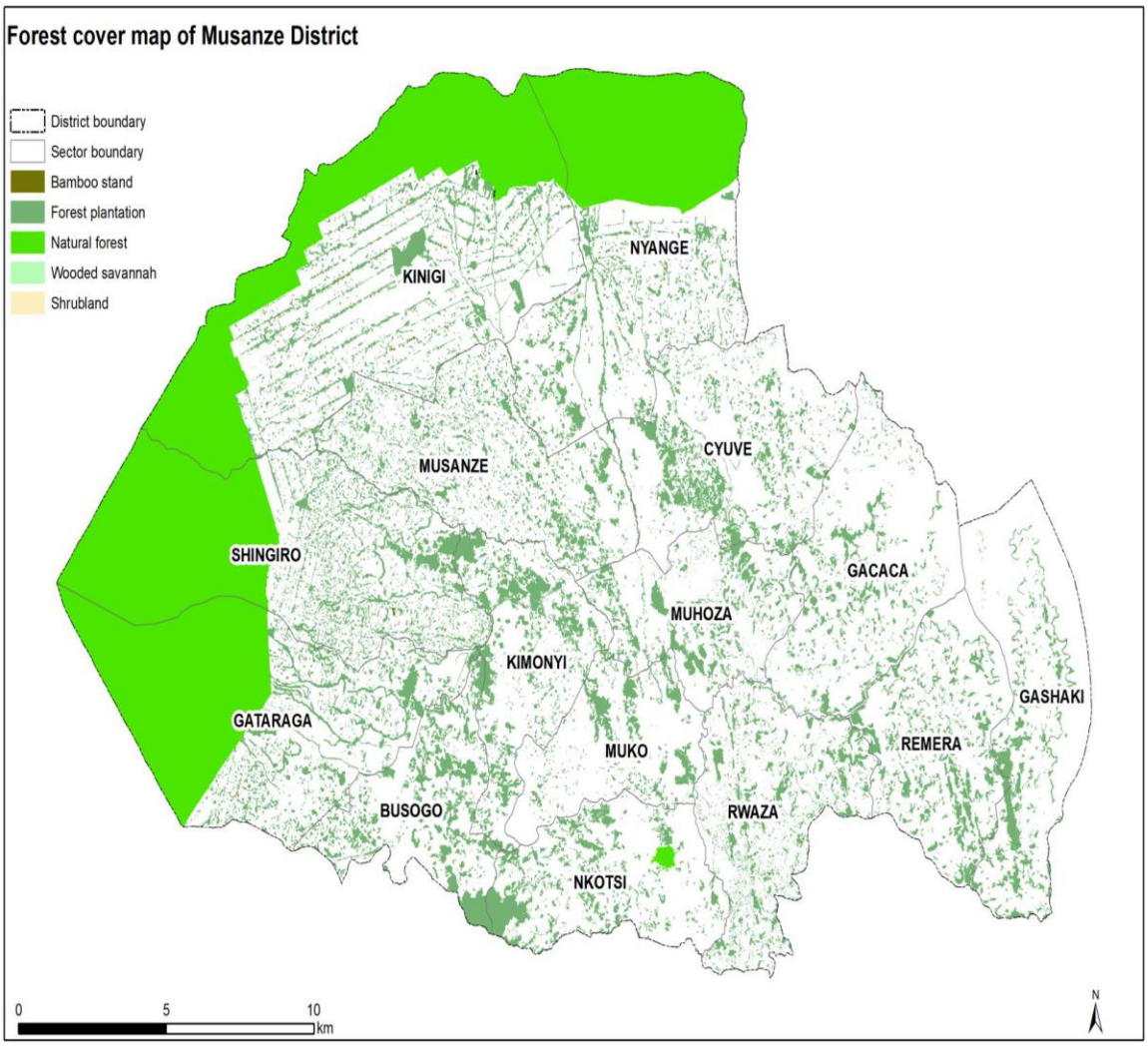
Map 7.7 : Musanze District Geospatial Analysis



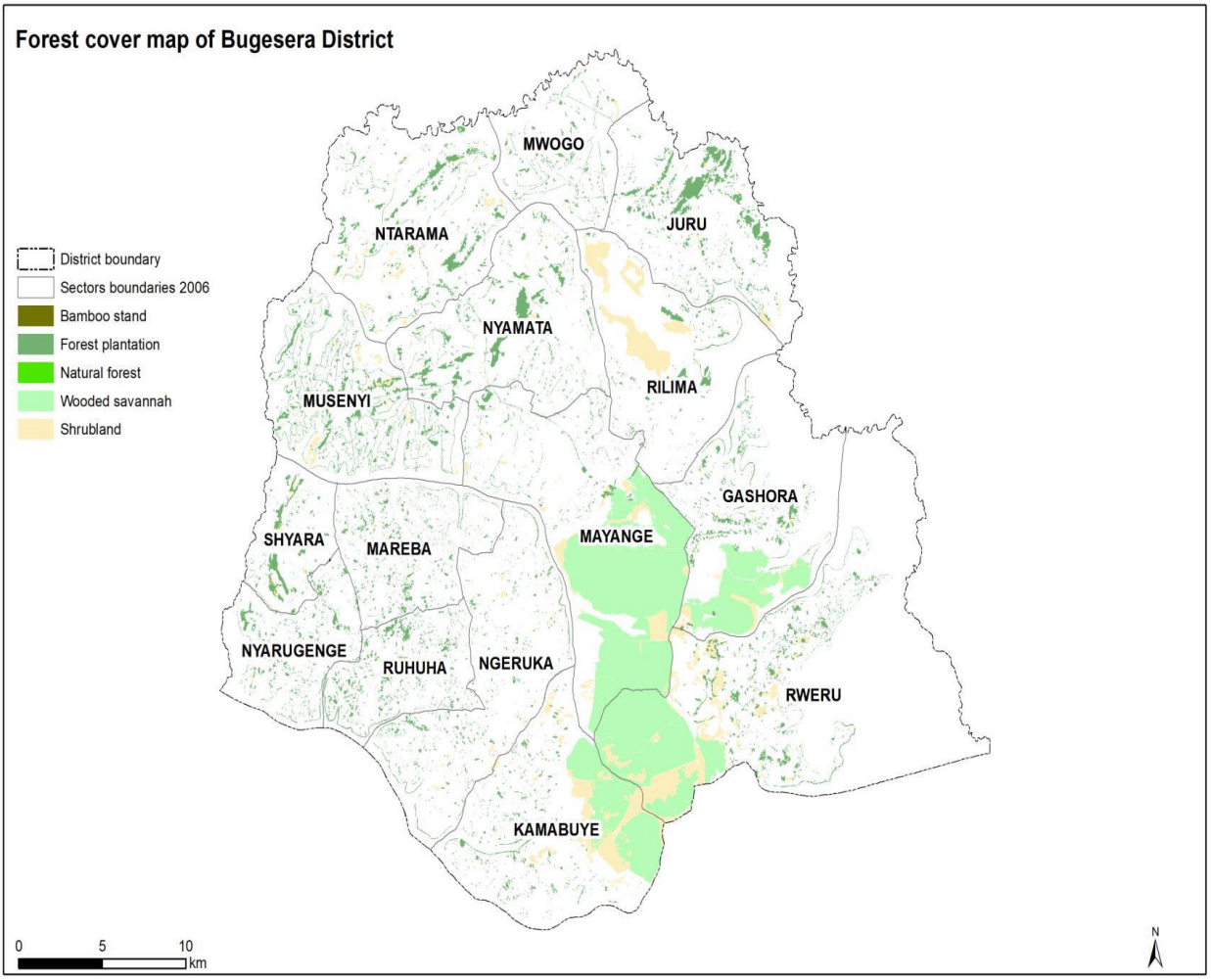
Map7.8 : Bugesera District Geospatial Analysis



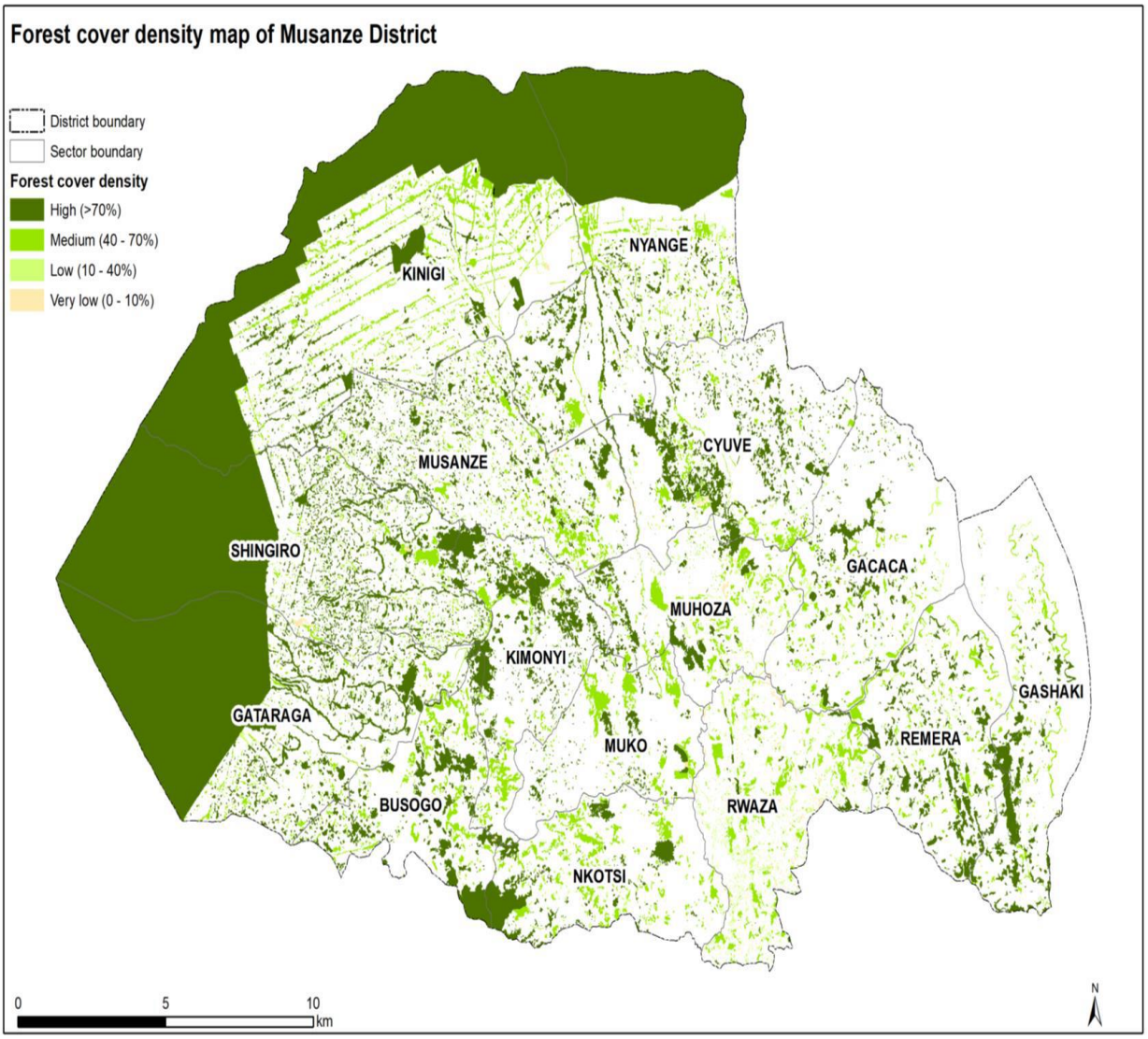
Map 7.9 : Forest Cover of Musanze District



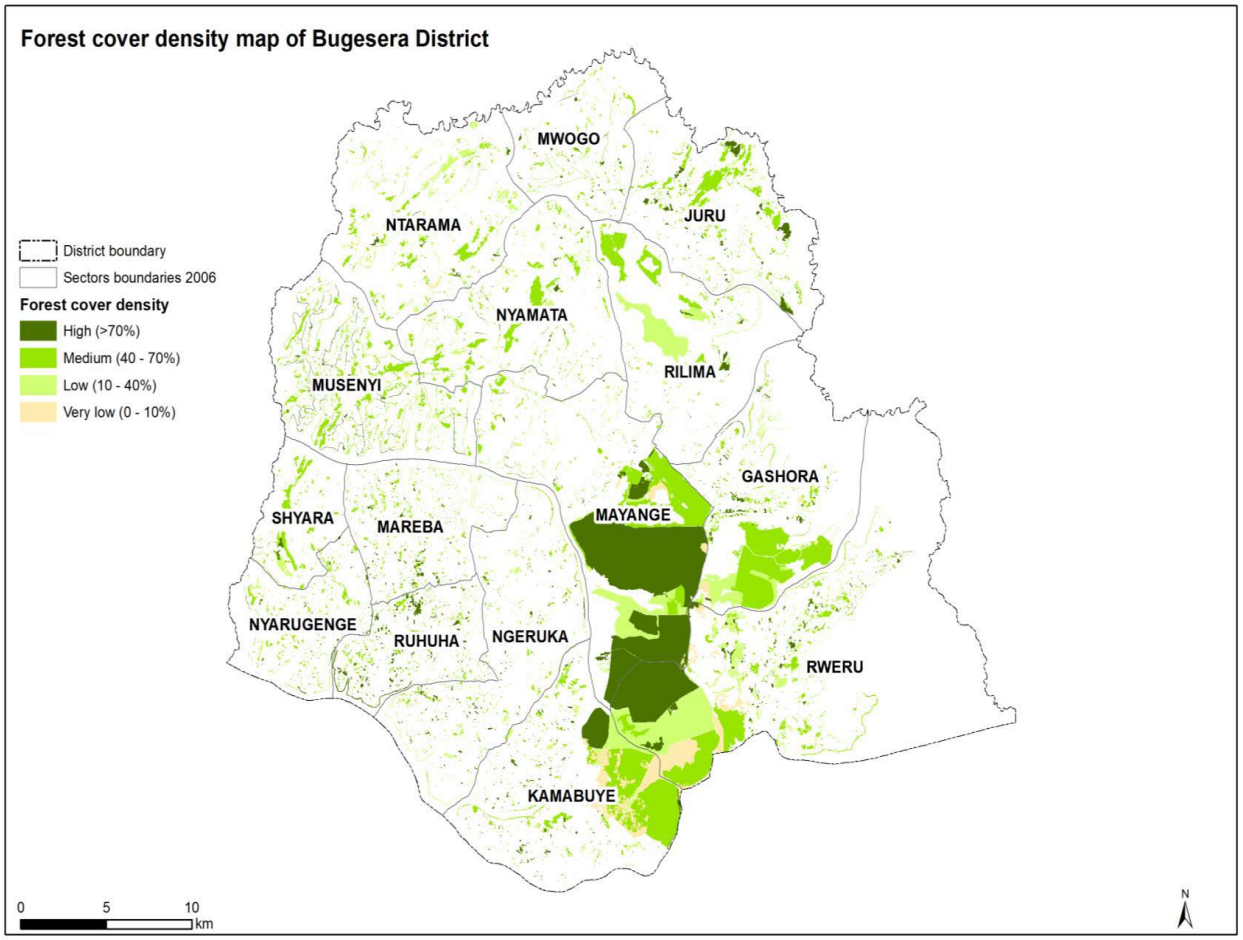
Map 7.10: Forest Cover of Bugesera District



Map7.11: Forest Cover Density Map of Musanze District



Map 7.12 : Forest Cover Density Map of Bugesera District



Appendix 8: Household Questionnaire

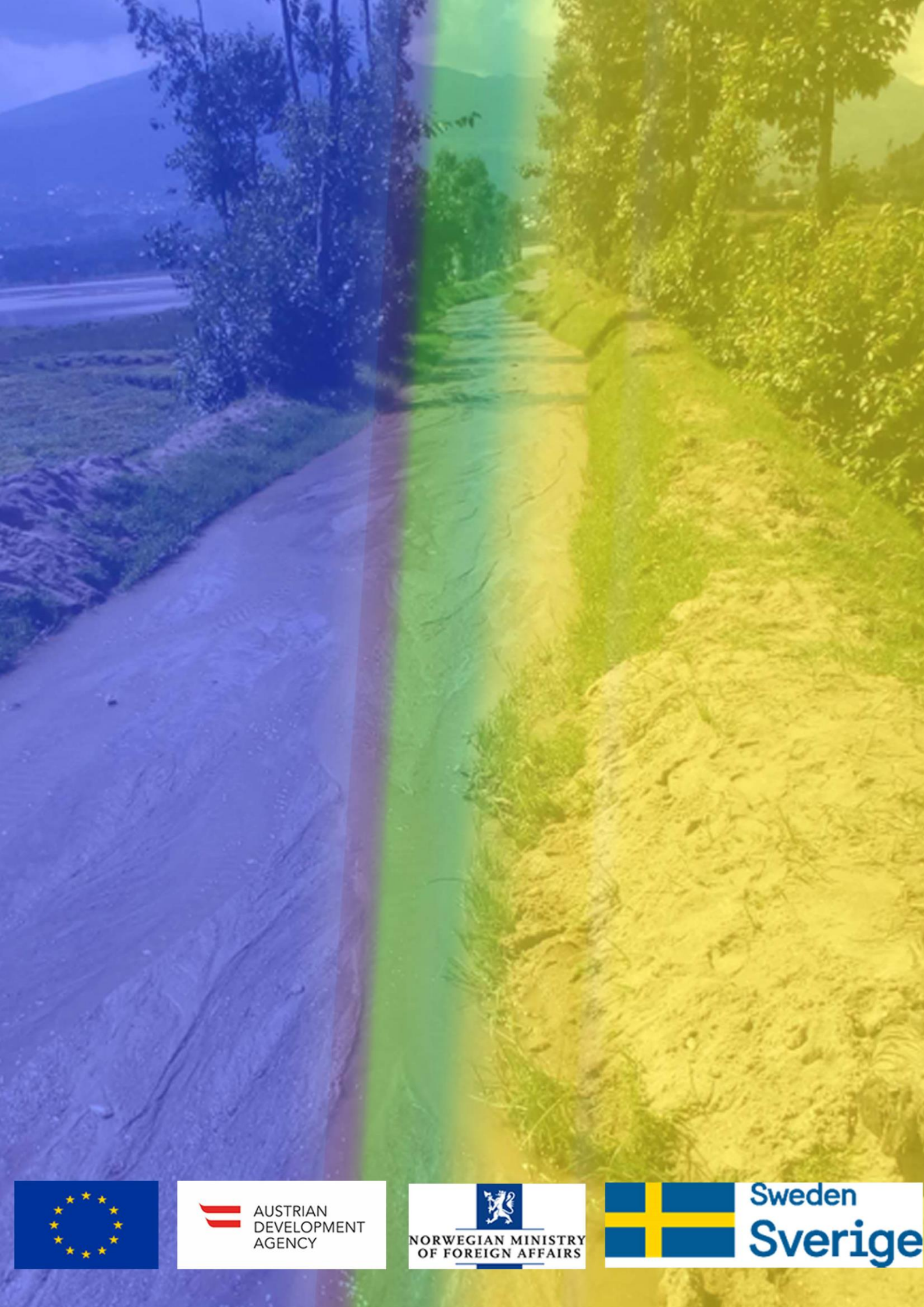
Questionnaire.html

Appendix 9: Qualitative Tools and interviewed KIIs

Qualitative Tools and interviewed KIIs

Appendix 10: Stakeholders analysis

Stakeholders analysis.docx



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