REPUBLIC OF RWANDA

MINISTRY OF ENVIRONMENT

Rwanda Environment Management Authority

THIRD NATIONAL COMMUNICATION UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (U.N.F.C.C.C)

September 2018

REPUBLIC OF RWANDA

Third National Communication

Report to the United Nations Framework Convention on Climate Change

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FOREWORD

On behalf of the Republic of Rwanda, it is with great honor that I present Rwanda's Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC).

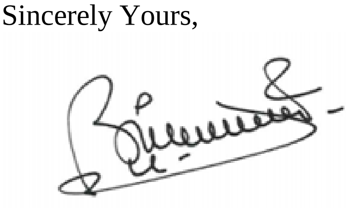
The Government of Rwanda (GoR) is among the countries, which ratified the United Nations Framework Convention on Climate Change (UNFCCC), and its Kyoto Protocol and it is among the first countries to sign and ratify the Paris Agreement. This demonstrates the willingness of being a responsible member of the global community, to seek and achieve global solutions on climate change. In fulfillment of the reporting requirement under Article 12 of the United Nations Framework Convention on Climate Change (UNFCCC), GoR has prepared its Third National Communication Report (TNC).

The process of developing the TNC report was as important as the report itself. It involved all national stakeholders and experts in a two-year effort supported by Global Environment Facility (GEF) and UN Environment (UNEP) and used the best available guidelines. The TNC was produced through the use of national expertise, with the international support in the area of climate projection downscaling. The capacity building components of the TNC have helped to increase national capacity to produce national reports in a suitable manner. The knowledge created and generated within the TNC process will further guide policy decision makers in the preparation and implementation of national development plans, which will take into account both environment sustainability and climate change impacts, especially in the most vulnerable sectors, namely agriculture, livestock, water resources, infrastructure, energy and health.

The findings of this TNC reveal the main drivers of vulnerability and sectoral priority areas in need of specific adaptation measures as well as the current gaps in terms of training and capacity, data acquisition and storage. In this context, this report represents the most recent comprehensive outlook of climate change in the country. It embodies an important milestone in our commitments under the UNFCCC and our efforts in raising climate change awareness to influence domestic policies and strategies.

As we submit this Third National Communication, Rwanda has adopted its "National Climate Change and Low Carbon Development Strategy", of which the content and the perspectives are also reflected in this TNC.

Sincerely Yours,



Vincent BIRUTA
Minister of Environment

ACKNOWLEDGEMENT

We are pleased to express our gratitude to those who, in one way or another, have contributed in the preparation and publication of this Third National Communication report. Our appreciation goes particularly to the UNFCCC Secretariat, Global Environmental Facility (GEF) and UN Environment, in its quality as GEF Implementing Agency, for their financial and technical support and training in different methodological tools.

We would like to take this opportunity to thank all the sectoral ministries, government departments, local government authorities, research and academic institutions, private sector, non-governmental organisations, civil society and other key institutions for participating in the development of this TNC.

We are thankful to all international and national experts who have conducted sectors studies; and all those who took part in different validation workshops, which considered the thematic reports and the final report of the Rwanda Third National Communication under the UNFCCC.

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- Rwanda Water and Forestry Authority (RWFA);
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ABBREVIATIONS AND ACRONYMS

AD	Activity Data
AfDB	African Development Bank
AFOLU	Agriculture, Forestry and Other Land Use
AREU	Agricultural Research and Extension Unit
ASL	Above Sea Level
BAU	Business as Usual
BIG	Biomass Integrated Gasification
BNR	Banque Nationale du Rwanda (National Bank of Rwanda)
BOD	Biological Oxygen Demand
CBA	Cost Benefit Analysis
CCAP	Climate Change Action Plan
CNG	Compressed Natural Gas
CNRM	Centre National de Recherches Météorologiques
CoK	City of Kigali
COMESA	Common Market for Eastern and Southern Africa
COP	Conference of Parties
CRS	Climate Reference Station
CSIRO	Commonwealth Scientific and Industrial Research Organization
DPCs	Districts Performance Contracts
EDCL	Energy Development Corporation Limited
EDPRS	Economic Development and Poverty Reduction Strategy
EESD	Environmental Education for Sustainable Development
EF	Emission Factors
EIA	Environmental Impact Assessment
EPA	Environment Protection Act
EST	Environmental Sound Technologies
ETPA	Education, Training and Public Awareness
EUCL	Energy Utility Corporation Limited
FONERWA	Rwanda Green Fund for Environment
Frw	Rwandan franc
GCF	Green Climate Fund
GCMs	Global Climate Models
GDP	Gross Domestic Product
GEF	Global Environment Facility
GGCRS	Green Growth and Climate Resilience Strategy
GHGs	Greenhouse Gases
GIS	Geographical Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GNI	Gross National Income
GoR	Government of Rwanda
HFC	Hydrofluorocarbon
HFO	Heavy Fuels Oil

ICE	Internal Combustion Engine
ICT	Information and Communication Technology
ICZM	Integrated Coastal Zone Management
IEA	International Energy Agency
IFC	International Finance Corporation
IMAGE	Integrated Model to Assess the Greenhouse Effect
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IWRM	Integrated Water Resource Management
JAF	Districts' Joint Action Forums
JICA	Japan International Cooperation Agency
KCC	Kigali City Council
LDCF	Least Developed Country Fund
LFO	Light Fuels Oil
LSF	Large-Scale Famers
MIDIMAR	Ministry of Disaster Management and Refugee Affairs
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government
MINEACOM	Ministry of Trade, Industry and East African Community Affairs
MINECOFIN	Ministry of Finance and Economic Planning
MINEDUC	Ministry of Education
MINICOM	Ministry of Trade and Industry
MINILAF	Ministry of Lands and Forestry
MININFRA	Ministry of Infrastructure
MINIRENA	Ministry of Natural Resources
MINISANTE	Ministère de la Santé (Ministry of Health)
MINITERE	Ministère des Terres, de l'Environnement, des Forêts, de l'Eau et des Mines
MoE	Ministry of Environment
MSW	Municipal Solid Waste
NA	Not available or Not Applicable
NAEB	National Agriculture Export Board
NAMA	Nationally Appropriate Mitigation Action(s)
NAP	National Adaptation Plan
NATCOMs	National Communication Reports
NBI	Nile Basin Initiative
NC	National Communication
NCC	National Climate Committee
NDBP	National Domestic Biogas Programme
NDC	Nationally Determined Contributions
NE	Not Estimated
NGO	Non-Governmental Organization
NISR	National Institute of Statistics of Rwanda
NMVOC	Non-Methane Volatile Organic Compounds
NO	Not Occurring

NOAA	National Oceanic and Atmospheric Administration
NOx	Oxides of Nitrogen
NREL	National Renewable Energy Laboratory
ODS	Ozone Depleting Substance
OECD	Organization for Economic Cooperation and Development
PDF	Probability Density Function
PPM	Parts per million
PSF	Private Sector Federation
QA/QC	Quality Assurance/Quality Control
RAB	Rwanda Agriculture and Animal Resources Board
RCP	Representative Concentration Pathways
RDB	Rwanda Development Board
RDF	Rwanda Defense Force
REG	Rwanda Energy Group
REMA	Rwanda Environment Management Authority
RHA	Rwanda Housing Authority
RLMUA	Rwanda Land Management and Use Authority
RNP	Rwanda National Police
RSB	Rwanda Standards Board
RTDA	Rwanda Transport Development Agency
RURA	Rwanda Utilities Regulatory Authority
RWFA	Rwanda Water and Forestry Authority
SNC	Second National Communication
SSPs	Shared Socioeconomic Pathways
SWDS	Solid Waste Disposal Sites
SYB	Statistical Year Book
TAP	Technology Needs Assessment
TGICA	Task Group & Scenario Support for Impact & Climate Analysis
TNA	Technology Needs Assessment
TNC	Third National Communication to the UNFCCC
TWG	Thematic Working Groups
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UR/CAVM	University of Rwanda / College of Agriculture, Animal Sciences and Veterinary Medicine
VAA	Vulnerability and Adaptation Assessment
WASAC	Water and Sanitation Corporation Ltd
WMO	World Meteorological Organisation
WWF	World Water Forum

EXECUTIVE SUMMARY

ES. EXECUTIVE SUMMARY

The Government of Rwanda (GoR) is among the countries, which have ratified the United Nations Framework Convention on Climate Change (UNFCCC), and one among the first countries to sign and ratify the Paris Agreement COP21. This demonstrates its willingness, being a responsible member of the global community, to seek and achieve global solutions on climate change. In fulfillment to the reporting requirement under Article 12 of the United Nations Framework Convention on Climate Change (UNFCCC), GoR has prepared its Third National Communication Report.

One of the current major concerns of mankind is climate change. These are attributed directly or indirectly to human activities which lead to the increased emission of greenhouse gases (CO_2, N_2O, CH_4, CO, NOx, NMVOC). It should be noted that these activities are directly related to economic development of different countries including Rwanda.

ES.1: NATIONAL CIRCUMUSTANCES AND INSTITUTIONAL ARRANGEMENT

Rwanda is a landlocked country located in the east of central Africa. It lies between 1°4´ and 2°51´south latitude, and 28°53´ and 30°53´ east longitude and it covers an area of 26,338 km^2. It lies approximately at 120 kilometres south of the Equator, at 1,100 kilometres from the Indian Ocean, at 1,920 kilometres from the Atlantic Ocean, at 3,750 kilometres from the Mediterranean Sea, and at 3,980 km from South Africa Cape. It is bordered by Uganda at the North, Tanzania at the East, Burundi at the South and the Democratic Republic of Congo at the West.

Rwanda's administrative structure comprises 4 provinces (Eastern, Western, Northern and Southern Provinces) and City of Kigali all subdivided into 30 districts, 416 sectors, 2, 148 cells and 14, 816 villages. The altitude varies between 900 m and 4507 m from east to west where eastern plains are lying on 1,000 m to 1,500 m and the central plateau region is located between 1,500 m and 2,000 m. The Congo-Nile Ridge and volcanic chains of Birunga have height varying between 1,800 m and 4,507 m (on the top of Kalisimbi Volcano) while the regions around Kivu Lake and Bugarama plains are sitting on 900 m to 1800 m (Sirven and Gotanegre, 1974; MINIRENA, 2010).

The mean annual temperature oscillating between 20 °C and 22 °C. The central plateau region enjoys rainfall of between 1,100 mm and 1,300 mm, received in 90 to 150 days, with an annual mean temperature of between 18 °C and 20 °C. The highlands, including the Congo-Nile Ridge and volcanic chains of Birunga, benefit from an annual rainfall of between 1,300 mm and 1,600 mm, received in 140 to 210 days, with annual mean temperature ranging between 10 °C and 18 °C. Regions around Lake Kivu and Bugarama plains get annual rainfall of between 1,200 mm and 1,500 mm, received in 150 to 210 days, and annual mean temperature oscillating between 18 °C and 22 °C (Ilunga *et al.*, 2004; MINIRENA, 2010; Muhire and Ahmed, 2015 and 2016).

The Ministry of Environment (MoE) is the key institution in charge of making policies and programmes related to the environment and climate change and the Rwanda Environment Management Authority (REMA) is the regulatory agency tasked to coordinate the implementation of those policies and programmes.

ES.2: NATIONAL GREENHOUSE GAS INVENTORY

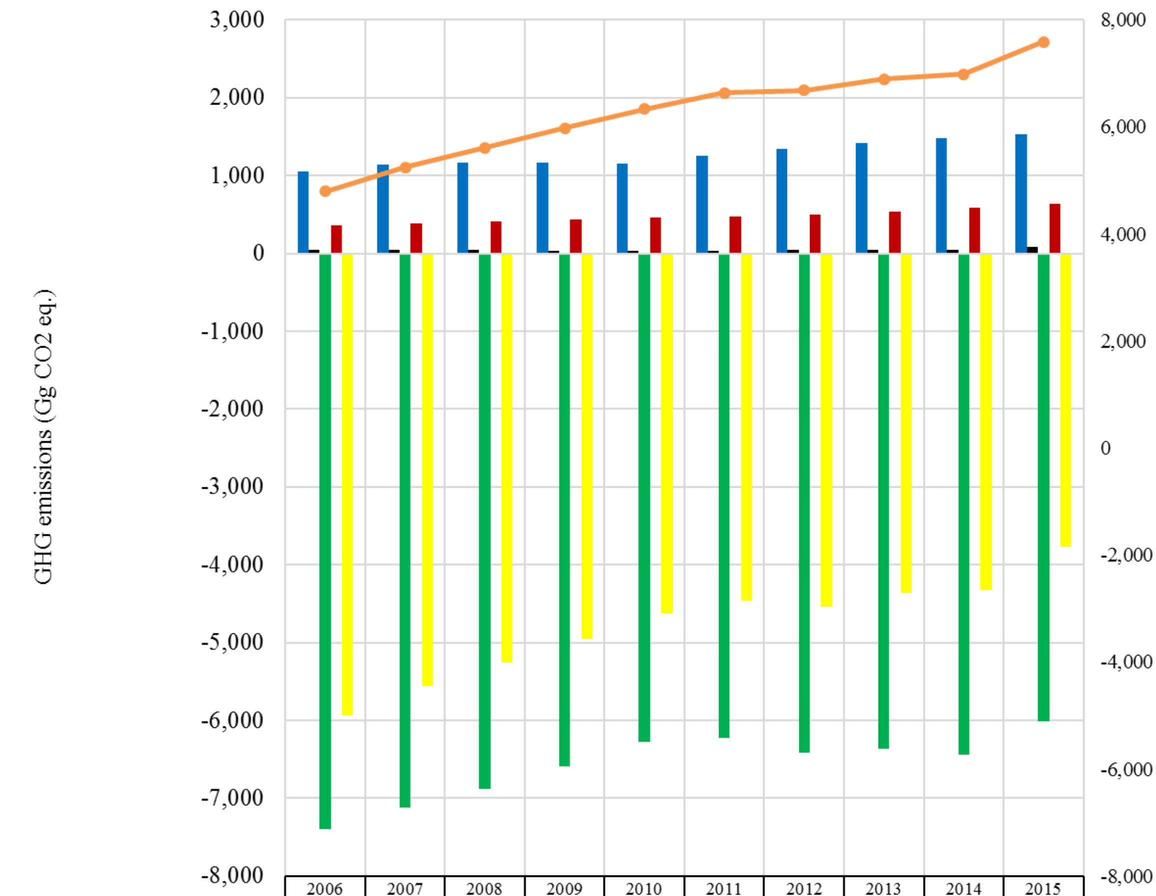
The Rwanda's GHG inventory report was developed and structured according to the UNFCCC convention and in compliance with the 2006 IPCC guidelines. The GHG emissions and their uncertainties were estimated for a period between 2006 and 2015 for energy, IPPU, AFOLU and waste sectors and their respective categories. In general, Tier 1 methodology was applied to estimate emissions of direct greenhouse gases (CO_2, CH_4, N_2O, HFCs) for all sectors and country specific data were considered where available.

During the period between 2006 and 2015, the dynamic of Rwanda's GHG emissions with and without FOLU showed an increasing trend with average annual increases 4.54 % and 4.8%, respectively, while net GHG removals showed a nearly constant trend with an annual increase of 0.63%. During the whole period, GHG emissions from FOLU had a dominant contribution to net emissions, resulting in a net carbon sequestration. The increase in GHG emissions could be attributed to the growing Rwandan economy, the change in lifestyle, and the modernization of the agricultural sector. Rwanda recorded a rapid increase in GHG emissions during the period between 2014 and 2015.

The GHG intensity (i.e., the amount of GHG emitted per GDP) decreased from 14.4 Gg/USD in 2006 to 10.54 Gg/USD. This decrease could be explained by the rapid increase in Rwandan economy. During the same period the GDP increased from USD 333 to USD 720. The increase in GDP was estimated at 53.75 % between 2006 and 2015, while that of GHG emissions was only 36.83 %. In addition, the GHG emissions per capita have increased from 532.39 to 676.23 kg per capita with an annual increase of 2.46%.

ES.2.1 Emission trend by sector

The GHG emissions from various sectors and their trends during the period between 2006 and 2015 are presented in Figure ES.2.1 where the energy and waste sectors were the dominant contributors to total GHG emissions, while the IPPU sector had the least contribution.

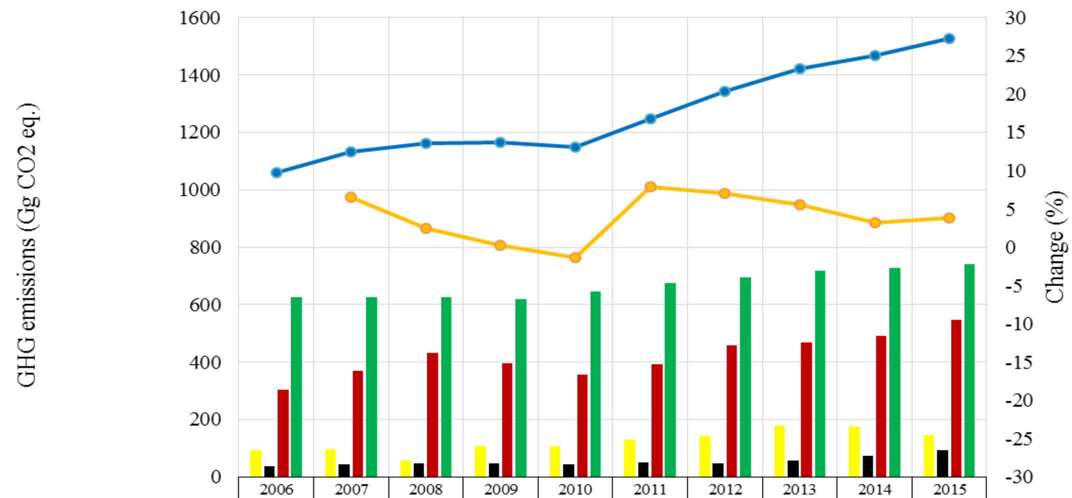


	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Energy	1,058.79	1,139.11	1,164.18	1,164.65	1,150.14	1,248.41	1,343.16	1,421.46	1,475.12	1,526.37
IPPU	40.26	39.60	39.76	34.94	36.54	38.29	39.47	43.32	49.15	81.68
AFOLU	-7,394.51	-7,125.08	-6,879.36	-6,594.30	-6,276.83	-6,224.55	-6,416.59	-6,364.98	-6,443.97	-6,014.41
Waste	362.26	390.14	415.38	437.22	457.89	477.22	497.26	542.33	589.17	637.27
Total emissions with FOLU	-5,933.19	-5,556.22	-5,260.04	-4,957.49	-4,632.26	-4,460.63	-4,536.70	-4,357.87	-4,330.53	-3,769.09
Total emissions without FOLU	4,795.45	5,242.10	5,608.45	5,981.33	6,337.19	6,640.50	6,682.44	6,897.63	6,987.43	7,590.76

Figure ES.2.1: Contribution of various sectors to total GHG emissions in 2006, 2012 and 2015

ES2.2 Energy sector

Estimated GHG emissions from energy sector between 2006 and 2015 showed an increasing trend with an annual increase of 4.2% (Figure ES.2.2). Obviously, the increase in GHG emissions followed the trends in both, fuel consumption and GDP.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Energy industries	91.73	95.94	58.03	104.99	105.67	130.36	143.78	179.54	176.84	144.99
Manufacturing industries and construction	38.34	42.48	46.05	46.55	43.08	48.85	47.33	56.29	73.25	92.59
Transport	301.94	369.4	432.87	394.17	355.5	393.54	458.29	468.53	489.56	547.35
Other sectors	626.77	624.92	624.62	618.94	645.43	675.68	693.78	717.1	728.56	741.44
Total	1,058.78	1,132.74	1,161.57	1,164.65	1,149.68	1,248.43	1,343.18	1,421.46	1,468.21	1,526.37
Change		6.53	2.48	0.26	-1.30	7.91	7.05	5.51	3.18	3.81

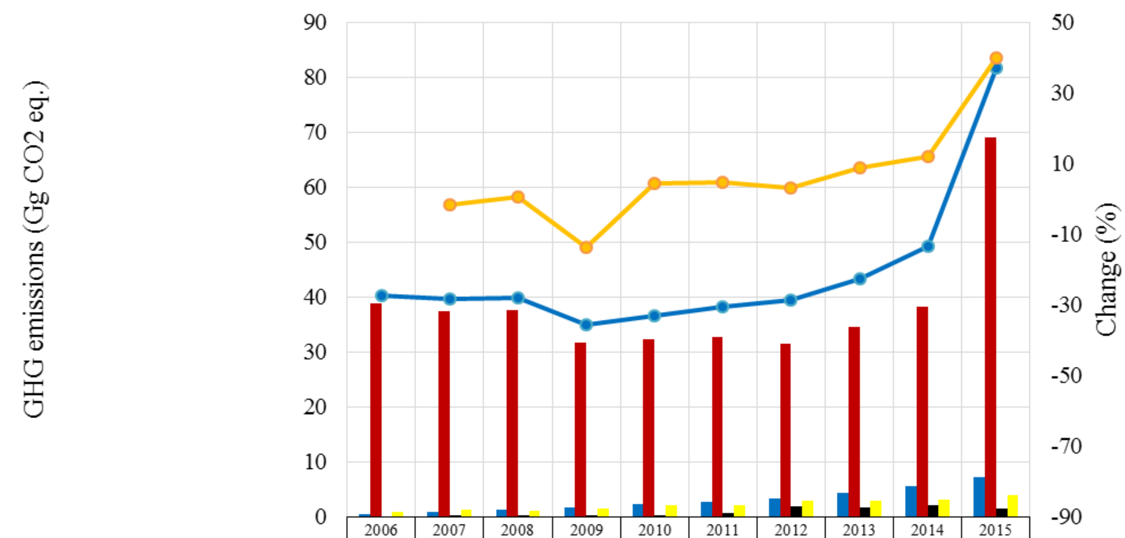
Figure ES.2.2: GHG emissions from energy sector in Rwanda between 2006 and 2015

The analysis of key gases revealed that the sectors – Biomass (CH_4), Road Transportation (CO_2), Energy Industries - Liquid Fuels (CO_2), Manufacturing industries and construction-liquid fuel (CO_2), Other Sectors – Biomass (N_2O), Sectors - Liquid Fuels (CO_2) are the top contributors to total GHG emissions from the energy sector. In addition, a consistent time series was observed in the estimated GHG emissions and in the comparison with the results of the second national communication.

ES.2.2.1 IPPU sector

During the period between 2006 and 2015, the IPPU sector had the least contribution to total GHG emissions in Rwanda. Estimated GHG emissions were mainly generated from (i) 2A mineral industry, (ii) 2.C metal industry, (iii) 2D Non-Energy Products from Fuels and Solvent Use and, (iv) 2F product use as substitutes of ozone depleting substances. Nevertheless, the sub-sectors that are applicable considering Rwanda circumstances are: (i) 2A mineral industry: 2A1: cement production and 2A2: lime production; (ii) 2.C metal industry: 2C.1 iron and steel production and 2C.2 ferroalloys production; (iii) 2D Non-Energy Products from Fuels and Solvent Use: 2.D.1 Lubricant use and 2.D.2 Paraffin Wax use; and (iv) 2F product use as substitutes of ozone depleting substances: refrigeration and air conditioning.

Overall greenhouse gas emissions in the IPPU sector have gradually increased during the ten-year period at an annual growth rate of 8 %. The gas-per-gas analysis showed that the main gas emissions were from carbon dioxide, which contributed 94% of the total emissions in ten years average. Whereas HFCs were only generated from the product use as substitute for ozone depleting substances, the CO_2 emissions were generated by mineral industries, metal industries, and non-energy products from fuel and solvent use.

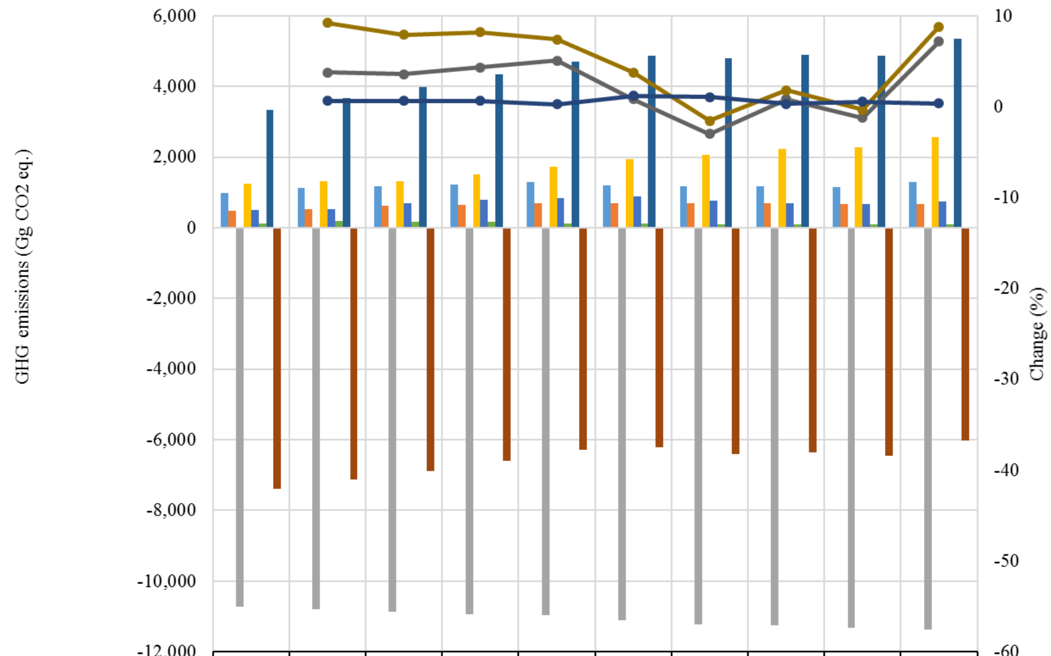


	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Product Usesas Substitutes for ODS	0.42	0.84	1.27	1.72	2.20	2.71	3.26	4.29	5.63	7.18
Mineral Industry	38.88	37.44	37.49	31.70	32.21	32.79	31.51	34.63	38.13	69.11
Metal Industry	0.00	0.00	0.01	0.05	0.07	0.70	1.88	1.59	2.20	1.52
Non-Energy Products from Fuels and Solvent Use	0.96	1.32	0.99	1.47	2.06	2.09	2.81	2.81	3.20	3.88
Total	40.26	39.60	39.76	34.94	36.54	38.29	39.47	43.32	49.15	81.68
Change		-1.67	0.40	-13.81	4.39	4.58	2.97	8.90	11.85	39.83

Figure ES.2.3: GHG emissions from IPPU sector in Rwanda between 2006 and 2015

ES.2.2.2 AFOLU sector

The GHG emissions in agriculture and livestock were estimated for enteric fermentation of livestock, manure management, and agricultural practices consisting of rice cultivation and mineral nitrogen fertilizer applications to soil, manure, compost and crop residues applications to soil, nitrogen mineralization in freshly cultivated soil following land use change, organic soils, urine and dung deposited on pastures and paddock, atmospheric volatilization of nitrogen from managed soils and manure management, leaching and runoff. Agriculture burning was excluded from the report as this practice is banned in Rwanda. Figure ES 2.4 shows that the AFOLU sector has more carbon sequestered than emitted and forests are the most important carbon sinks. During the period between 2006 and 2015, the dynamic of GHG emissions/removals from AFOLU sector showed fluctuating trend with an annual average increase of 2.37%.



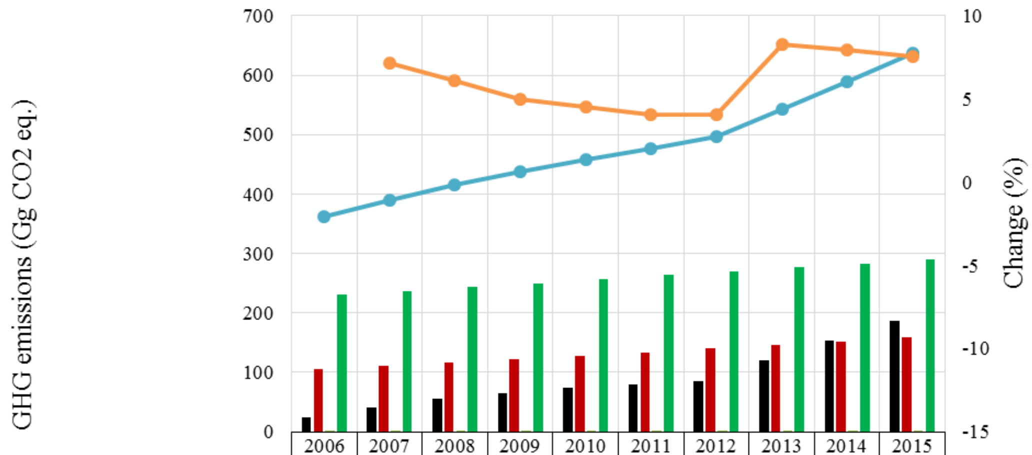
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Enteric Fermentation	979.55	1,116.74	1,181.37	1,213.23	1,303.64	1,207.01	1,173.80	1,174.16	1,147.18	1,283.75
Manure management	488.53	524.05	613.31	653.29	690.66	692.42	702.49	698.53	676.56	672.99
Total Removals	-10,728.64	-10,798.32	-10,868.49	-10,938.82	-10,969.46	-11,101.13	-11,219.13	-11,255.49	-11,317.96	-11,359.85
Urea application	1,246.42	1,317.63	1,326.42	1,514.03	1,731.23	1,948.44	2,065.98	2,224.42	2,283.19	2,559.04
Soil	501.10	533.42	701.33	786.32	849.89	897.82	757.17	693.24	676.08	731.34
Rice cultivations	118.54	181.40	166.69	177.66	117.20	130.89	103.11	100.17	90.98	98.33
Total from Agriculture	3,334.14	3,673.24	3,989.13	4,344.52	4,692.63	4,876.58	4,802.54	4,890.52	4,873.99	5,345.44
Total with FOLU	-7,394.51	-7,125.08	-6,879.36	-6,594.30	-6,276.83	-6,224.55	-6,416.59	-6,364.98	-6,443.97	-6,014.41
Change in total with FOLU		3.78	3.57	4.32	5.06	0.84	-2.99	0.81	-1.23	7.14
Change in total from agriculture		9.23	7.92	8.18	7.42	3.77	-1.54	1.80	-0.34	8.82
Change in total removals		0.65	0.65	0.64	0.28	1.19	1.05	0.32	0.55	0.37

Figure E.S2.4: GHG emissions/removals from AFOLU sector in Rwanda between 2006 and 2015

While FOLU had a modest increase of 0.63%, agriculture subsector showed a fluctuating trend with an annual average in emissions of 5.03 %. The annual average increase of 2.37 % was observed for the total GHG emission with FOLU.

ES.2.2.3 Waste sector

To compute emissions from wastewater sector, two subcategories have been considered, viz., domestic wastewater (4D.1) and industrial wastewater (4D.2) with domestic wastewater emissions being the main contributor to emissions from wastewater source category. Considering the period 2006-2015, the total annual emissions from waste sector have respectively increased from 362.26 Gg CO_2-eq to 637.27 Gg CO_2-eq. (Figure ES.2.5). Comparing emissions source per subcategory, it has been evidenced that emissions from wastewater treatment and discharge subcategory are the highest with the contribution of 54.29 % to the total GHG emissions from waste sector followed by emissions from biological treatment of solid waste (28.23 %), solid waste disposal (17.23%) and incineration with negligible contribution of 0.25% in 2012. Furthermore, GHG emissions from the wastewater treatment and biological treatment of solid waste subcategories recorded a slow increase: for the period 2006-2015 with the increase rate of 3% and 6%, respectively, while solid waste disposal recorded an increase rate of 75%. The high shift for solid waste disposal is mainly shaped by the involvement of private sector associated with poor waste source separation, which has more than doubled the fraction of solid waste to SWDS from 141,380 tonnes/year to 495,760 tonnes/year from 2006 to 2015, respectively.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Solid Waste Disposal	24.04	41.51	54.68	64.93	73.04	79.82	85.7	119.22	152.82	186.99
Biological Treatment of Solid Waste	105.5	110.44	115.62	121.04	126.71	132.65	140.36	145.38	152.19	159.33
Incineration and Open Burning of Waste	1.06	1.08	1.12	1.14	1.17	1.2	1.23	1.26	1.29	1.32
Wastewater Treatment and Discharge	231.67	237.11	243.97	250.11	256.97	263.54	269.98	276.47	282.88	289.63
Total	362.27	390.14	415.39	437.22	457.89	477.21	497.27	542.33	589.18	637.27
Change		7.14	6.08	4.99	4.51	4.05	4.03	8.31	7.95	7.55

Figure ES.2.5: GHG emissions from waste sector in Rwanda between 2006 and 2015

ES.3: NATIONAL CLIMATE CHANGE MITIGATION ASSESSMENT

This chapter provides details about mitigation assessment and abatement measures (mitigation scenarios) for Rwanda in energy sector (electric power generation, industries, buildings and transport) and non-energy sector (waste, industrial processes and product use (IPPU), agriculture, and forestry and other land use). Mitigation scenarios have been informed and aligned to existing Government sectorial policies, strategies and programmes. In order to ensure consistency, the level of emission reductions has been also aligned with the national targets outlined in the NDCs.

Mitigation assessments were based on a combination of three alternative approaches namely (i) activity-based approach, (ii) an outcome-based approach, or (iii) a combination of the two approaches (WRI&UNDP, 2015). The total GHG emission reductions or removals have been calculated by developing business-as-usual sectoral baseline scenarios and alternatives scenarios based on various policy implementation assumptions. The transformation module of LEAP software was used to model baseline and mitigation scenarios in the energy sectors. Relevant data for developing baseline and alternative scenarios were collected from different public and private data custodian as well as through literature review from different scientific sources.

Baseline scenarios

The development of baseline scenarios or business as usual scenarios was founded in a number of assumptions guided by the NAMA report (REMA, 2015) and the detailed implementation plan for the NDCs (REMA, 2017). In addition to key assumptions specific to different sectors, general assumptions include:

- *Population growth*: from 10.5 million in 2012 to 23.2 million in 2050;
- *GDP growth*: from USD 756 in 2017 to USD 1,493 in 2024 and USD 12,476 in 2050;
- *Urbanisation*: the rate of urbanization of up to 30% in the Provinces and 100% in Kigali;
- *Electricity*: achieve universal access to electricity from the current household access of 34.5%;
- *Industries*: manufacturing industry will steadily grow at an annual rate of 7%.
- *Agriculture*: steady increase in the use of mineral fertilizers (5% annually);
- *Forest cover*: increase and maintain forest cover to 30% of the country land area
- *GHG emissions*: trend of GHG emissions historical data in different energy and non-energy sectors as estimated in the GHG inventory report for the period 2006 to 2015.

(1) Energy sectors

(i) Electric power generation

The evolution of major fuels simulated in the transformation module of LEAP software shows that the electric generation will be dominated by peat and hydropower plants with 43.48% and 42.01%, respectively in 2050. The biomass will be the least contributor to total generation with only 0.24%. The baseline electricity generation (business as usual) modelled through LEAP is projected to grow substantially from 1,089,800 GJ in 2012 to 21,394,800 GJ in 2050. GHG emissions in the BAU scenario will increase from 106.12 Gg CO_2-eq. to 3,346.27 Gg CO_2-eq. (Table ES.3.1).

(ii) Industries

The modelled baseline GHG emissions from industrial sector are expected to increase from 50.19 Gg CO_2-eq. to 1,170.82 Gg CO_2-eq. in 2050 (Table ES.3.1). The non-metallic mineral industries will remain the main contributor to GHG emissions through the year 2050 and the food industries will be the least contributor.

(iii)Buildings

The energy in buildings encompasses the energy consumption for cooking, heating (room heating, water heating), cooling (air-conditioning), lighting and operating electrical appliances. The baseline GHG emissions from buildings are expected to increase from 2,183.00 GgCO_2-eq. in 2012 to 6,145.40 Gg CO_2-eq. in 2050 (Table ES.3.1). The projected baseline GHG emissions will be generated by combustion activities of various fuel including wood and wood wastes, kerosene, LPG, diesel, and biogas.

(iv)Transportation

The GHG emissions from the transportation sector are mainly generated from fuel combustion activities in various categories of vehicles. The baseline scenario developed in the LEAP software shows that GHG emissions will increase from 447.57GgCO_2-eq. in 2012 to 1,678.25 Gg CO_2-eq. in 2050 (Table ES.3.1). GHG emissions from motorcycles are expected to be the dominant contributor to total GHG emissions from transport.

(2) Waste sector

(a) Solid waste

The business-as-usual scenario for the GHG emissions from solid waste sector considered the emission from (i) solid waste disposal site; (ii) biological treatment of solid waste; and (iii) waste incineration. The BAU scenario for the solid waste sector shows an increase from 347.64 Gg CO_2-eq. in 2015 to 2,269.17 Gg CO_2-eq. in 2050 (Table ES.3.1). This high increase of more than 6 times will be dominated by the increase of urban population from 2.6 to 12.1 million in 2015 and 2050, respectively.

(b) Wastewater

The wastewater sub-sector in Rwanda is still developing in terms of practices and technology use and is not currently serviced by centralized systems and utilities in either urban or rural areas. Today the sanitation infrastructures in Rwanda mainly include the following: (i) individual small wastewater treatment unit specific to a building or a semi collective sewer network, which release uncontrolled treated effluent, (ii) septic tanks for individual houses and small building which are emptied regularly with the faecal sludge disposed in dumping sites, (iii) individual latrines, which are emptied regularly with the faecal sludge disposed in dumping sites. The BAU emissions from wastewater were modelled using the 5 year trend of emissions prior to 2015, they will increase from 289.63 Gg CO_2-eq. in 2015 to 641.94 Gg CO_2-eq. in 2050 (Table ES.3.1).

(3) Industrial Processes and Product Use sector

The Industrial Processes and Product Use (IPPU) sector comprises GHG emissions generated directly from the non-energy-related industrial activities. The GHG emissions from fuel combustion are considered in the energy sector. In Rwanda, the GHG emissions from the IPPU sector represent the emission generated from the following categories: (i) 2A mineral industry, (ii) 2C metal industry, (iii) 2D Non-Energy Products from Fuels and Solvent Use and, (iv) 2F product use as substitutes of ozone depleting substances. The baseline scenario of IPPU emissions shows a gradual increase from 81.68 Gg CO_2-eq in 2015 and 259.10 Gg CO_2-eq. in 2030 to 1207.66 Gg CO_2-eq. in 2050 (Table ES.3.1).

(4) Agriculture

(a) Crop sub-sector

The crop sub-sector, accounting for more than 67% of GHG emissions in 2015, is projected to grow at the rate of 5% for business as usual. The major source of GHG emissions in the crop sub-sector is mineral fertilizer use through urea application. Under the BAU scenario, the GHG emissions from crop sub-sector will increase from 2,066.00 Gg CO_2-eq. in 2012 to 8,354.00 Gg CO_2-eq. in 2050 (Table ES.3.1).

(b) Livestock sub-sector

Livestock, which was contributing less than 36% of the total Agriculture emissions in 2015, will most probably grow slowly due to limited resources for its further expansion, especially, large stock. The BAU scenario assumes implementation of current policies and GHG emissions trend prior to 2015, which is 3.3% annual increase. Under the BAU scenario, the GHG emissions from livestock will increase from 1,876.00 Gg CO_2-eq. in 2012 to 3,780.00 Gg CO_2-eq. in 2050 (Table ES.3.1).

(5) Forestry and other land use

The business as usual (BAU) scenario for Forestry and Other Land Use assumes implementation of current policies and GHG emission removals trend prior to 2015, which is 0.6% annual increment, and increase of forest cover until 30% of country land area is reached. Under the BAU scenario, the GHG emission removals from Forestry and Other Land Use will increase from -11,219.10 Gg CO_2eq. in 2012 to -13,594.80 Gg CO_2eq. in 2050 (Table ES.3.1). The summary of emission simulation for the BAU scenario from 2012 to 2050 in all sectors is provided in TableES.3.1,while Figure ES.3.1 illustrates the simulation trend of BAU emissions from all sectors between 2012 and 2050.

Table ES.3.1: Summarized emission simulation (Gg CO_2 eq.) in business as usual scenarios

BUSINESS AS USUAL										
Sector	**Subsector**	2012	2015	2020	2025	2030	2035	2040	2045	2050
Energy	Electric power generation	106.1	82.0	234.2	407.2	692.8	1204.4	2093.5	3231.8	3346.3
	Energy Industries	50.2	91.2	129.8	185.4	265.8	382.7	553.1	803.0	1170.8
	Buildings	912.5	955.2	1133.3	1386.9	1718.5	2183.0	2995.8	4215.4	6145.4
	Transportation	447.6	510.4	601.5	706.5	833.1	986.5	1172.8	1400.1	1678.3
	Total energy	1516.4	1638.7	2098.7	2686.0	3510.3	4756.5	6815.3	9650.3	12340.8
Waste Sector	Solid waste	227.3	347.6	500.7	640.0	809.8	1025.3	1313.8	1709.2	2269.2
	Wastewater	270.0	289.6	324.5	363.6	407.4	456.4	511.4	573.0	641.9
	Total Waste	497.3	637.3	825.3	1003.6	1217.2	1481.8	1825.1	2282.2	2911.1
IPPU	Total IPPU	39.5	81.7	120.0	176.3	259.1	380.7	559.4	821.9	1207.7
AFOLU	Crop	2066.0	2559.0	3387.0	4215.0	5042.0	5870.0	6698.0	7526.0	8354.0
	Livestock	1876.0	1957.0	2217.0	2477.0	2738.0	2999.0	3259.0	3520.0	3780.0
	Forestry and other land use	-11219.1	-11359.9	-11704.8	-12060.2	-12426.4	-12803.7	-13192.4	-13593.0	-13594.8
National total		**-5224.0**	**-4486.2**	**-3056.8**	**-1502.3**	**340.2**	**2684.3**	**5964.4**	**10207.4**	**14998.7**

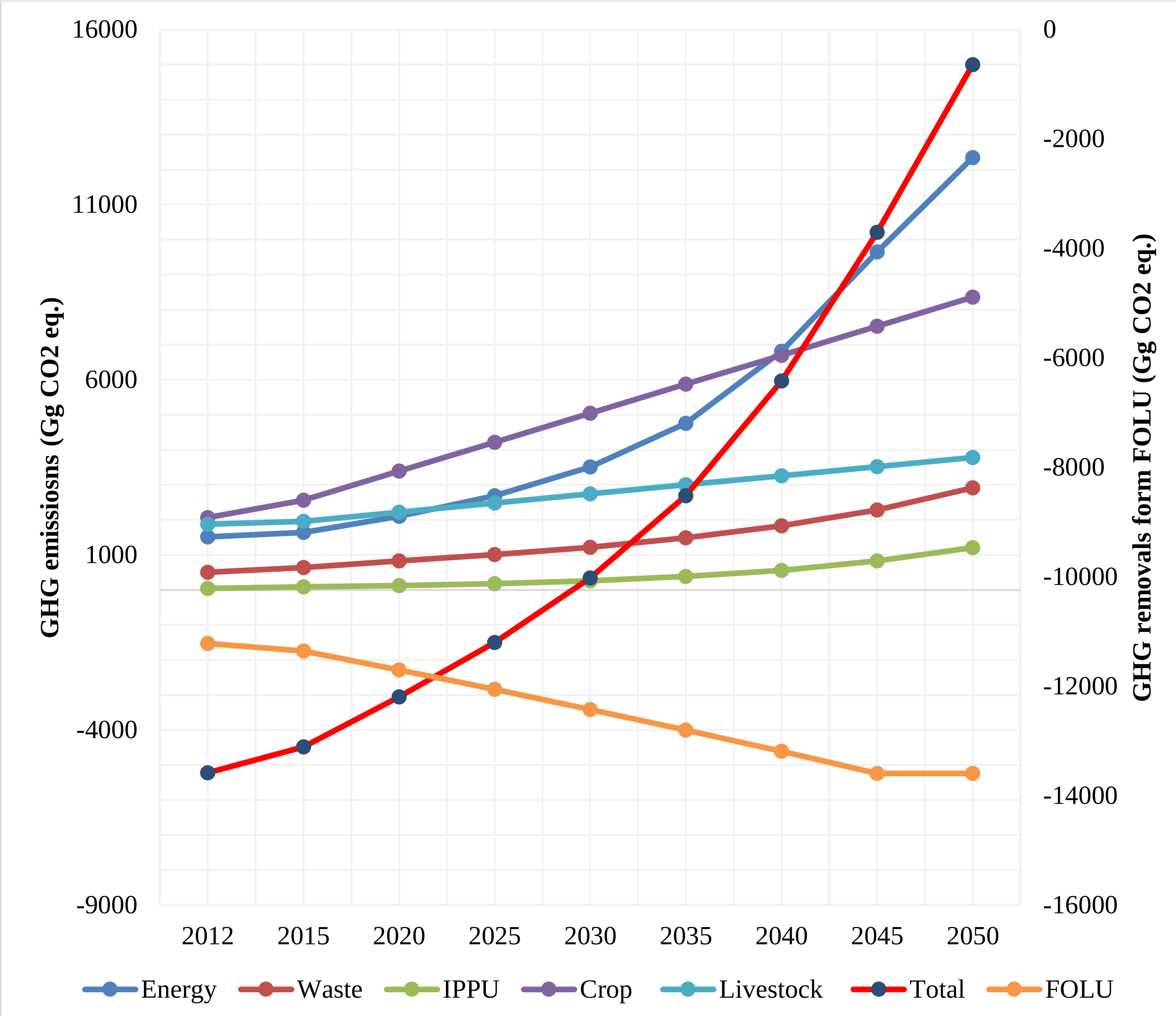


Figure ES.3.1: Emission simulation trends for BAUscenarios in different sectors

Mitigation scenarios and reduced emissions

(1) Energy sectors

(i) Electric power generation

The mitigation scenario for electricity generation was found on Government targets to increase the renewable energy power generation while reducing the liquid fuels for power generation. Under the mitigation scenario, the GHG emissions for electricity supply will increase 106.100 Gg CO_2-eq. to 1,300.90 Gg CO_2-eq. (Table ES.3.2). The main mitigation scenario is the use of large renewable energies (Large hydro and solar PV plants) scenario. Compared to the BAU (business as usual) scenario, the electricity supply mitigation scenario is projected to generate a cumulative emissions reduction of 20,377.80 Gg CO_2-eq. by 2050 (Table ES.3.3).

(ii) Energy use in industries

The mitigation scenario essentially consists in increasing efficiency in manufacturing processes in different industries. The implementation of mitigation measures will decrease the GHG emissions from various industries from 1,170.82 GgCO_2-eq. in 2012 to 1,087.56 Gg CO_2-eq. in 2050 (Table ES.3.2). This will result in a cumulative reduction of 884.75 Gg CO_2-eq. by 2050 (Table ES.3.3).

(iii) Buildings

The proposed mitigation scenario also referred to as efficient building consists of the efficient and sustainable use in residential and commercial buildings, the use of the efficient lighting and the use of solar heaters for hot water in buildings. By the year 2050, the GHG emissions are projected to reduce from 6,145.42 GgCO_2-eq. to 3,463.04 Gg CO_2-eq. (Table ES.3.2). That is a cumulative GHG emissions reduction of 38,993.79 Gg CO_2-eq. (Table ES.3.3).

(iv) Transportation

The proposed mitigation options consist of an integration of various options including the adoption of electric cars combined with the fuel efficiency and the implementation of the recently signed agreement to construct an electric rail between Isaka and Kigali. The simulated GHG emissions under mitigation scenario are expected to increase from 447.60 GgCO_2-eq. in 2012 to 1,169.40 Gg CO_2-eq. in 2050 (Table ES.3.2), which means a cumulative GHG emission reduction of 8,690.40 Gg CO_2-eq. between 2012 and 2050 (Table ES.3.3).

(2) Waste sector

(a) Solid waste

Two mitigation scenarios were considered for GHG mitigation in solid waste: (a) Utilisation of Landfill Gases (LFG) for power generation and (b) Use of solid waste for energy generation. Under the LFG mitigation scenario, the GHG emissions will increase from 347.6 Gg CO_2-eq. in 2015 to 1238.8 Gg CO_2-eq in 2050 (Table ES.3.2). The reduced emissions from utilization of Landfill Gases for power generation will increase from 94.52 Gg CO_2-eq. in 2020 to 1030.41 Gg CO_2-eq. in 2050 (Table ES.3.3).

The alternative mitigation scenario for solid waste sector is the development and implementation of Waste-to-Energy (WtE) plants servicing the Kigali and other urban area (REMA, 2015). Under the WtE mitigation scenario, the GHG emissions could go from 347.6 Gg CO_2-eq. in 2015 to 1631.5 Gg CO_2-eq. in 2050 (Table ES.3.2). The reduced emissions from WtE plants would increase from 153.11 Gg CO_2-eq. in 2021 to 637.6 Gg CO_2-eq. in 2050 (Table ES.3.3).

(b) Wastewater

The mitigation scenario for wastewater treatment assumes the introduction of centralised wastewater treatment plants and the reuse of wastewater in particular for irrigation purposes. Under this mitigation scenario the GHG emissions are projected to increase from 296.30 Gg CO_2eq. in 2016 to reach 421.33 Gg CO_2-eq in 2050 (Table ES.3.2). The avoided emission for wastewater treatment and reuse measures without considering other several co-benefits is around 220 Gg CO_2-eq. by 2050 (Table ES.3.3).

(3) Industrial Processes and Product Use sector

Two mitigation options were considered in the IPPU sector. The first option is "*increased proportions of Pozzolana in cement*". In addition to improving energy combustion efficiency methods, a progressive increase of Pozzolana in cement by substituting clinker with pozzolana is proposed as mitigation option. The implementation of this mitigation scenarios will result in a reduction of total baseline IPPU emissions from 2.86 Gg CO_2-eq. in 2025 to 48.97 Gg CO_2-eq. in 2050 (Table ES.3.2). The second option is "*Gradual substitution of F-gases by less polluting substitutes".* This mitigation option consists in substituting gradually F-gases by less polluting substitutes (ODS). Under this mitigation scenario, the total baseline IPPU emissions will increase from 0.51 Gg CO_2-eq. in 2020 to 86.46 Gg CO_2-eq. in 2050 (Table ES.3.3).

(4) Agriculture

(a) Crop sub-sector

Major mitigation options in the crop sub-sector include replacement of urea by less volatile N fertilizers, more judicious use of fertilizers based on soil maps and specific crop requirements, and development of large quantity and high quality compost production, farmer training and compost quality control system to largely reduce N losses. Under the medium mitigation option A, the GHG emissions from the crop sub-sector will increase from 2,066.0 Gg CO_2-eq in 2012 to 7,194.0 Gg CO_2-eq in 2050 (Table ES.3.2)

(b) Livestock sub-sector

Major mitigation options in the livestock sub-sector include replacement of local cows with the improved ones and reducing their number while maintaining milk production level, promotion of biogas and collective farm holdings, as well as building manure storage facilities and training in improved cow and manure management. Two mitigation scenarios were considered: (a) Option A with Girinka scheme to medium levels (improved cow, better feed and biogas plants) and (b) Option B with Girinka scheme to maximum levels with higher adoption and outscaling of the technologies (more improved cow, better feed and biogas plants). Under the medium mitigation option A, the GHG emissions from livestock will increase from 1876 Gg CO_2-eq in 2012 to 2466 Gg CO_2-eq in 2050 (Table ES.3.2).

(5) Forestry and other land use

Based on strategies outlined in the government policy and program documents, major mitigation measures in Forestry and Other Land Use will include (i) Development of agroforestry for sustainable agriculture which will enable increasing the number of trees (multi-purpose trees) on farm per hectare; (ii)Promotion of afforestation and reforestation of designated areas through improved germplasm and technical practices in planting and effective post-planting operations (maintenance/tending activities), (iii) Rehabilitation and improved forest management of degraded forest resources, (iv) Efficient wood conversion and sustainable biomass energy. Under the mitigation option A, the GHG emission removals from Forestry and Other Land Use will increase from -11,219.1 Gg CO_2-eq in 2012 to -26,150.3 Gg CO_2-eq in 2050 (Table ES.3.2).

The summary of emission simulation for mitigation scenarios from 2012 to 2050 is provided in Table ES.3.2 and Figure ES.3.2, while Table ES.3.3 and Figure ES.3.3provides the summary of emission simulation for reduced emissions in mitigation scenarios from 2012 to 2050.

Table ES.3.2: Summarized emission simulation (Gg CO_2-eq.) in mitigation scenarios

MITIGATION SCENARIOS										
Sector	**Subsector**	2012	2015	2020	2025	2030	2035	2040	2045	2050
Energy	Electric power generation	106.1	82.0	191.5	306.4	412.1	716.3	1109.3	1817.4	1954.6
	Energy Industries	50.2	91.2	127.6	179.1	253.5	361.6	519.0	749.3	1087.6
	Buildings	912.5	955.2	960.2	910.4	919.9	1064.5	1422.3	2136.2	3463.0
	Transportation	447.6	510.4	474.0	548.4	635.8	738.6	859.4	1001.7	1169.4
	Total energy	1516.4	1638.7	1753.2	1944.3	2221.3	2880.9	3910.0	5704.6	7674.6
	Solid waste	227.3	347.6	406.2	349.4	407.7	375.3	115.5	317.2	601.1

Waste Sector	Wastewater	270.0	289.6	324.5	350.9	384.9	416.6	440.9	448.3	421.3
	Total Waste	497.3	637.3	730.7	700.3	792.6	791.9	556.4	765.5	1022.5
IPPU	Total IPPU	39.5	81.7	119.5	168.3	233.3	339.6	496.7	729.8	1072.3
AFOLU	Crop	2066.0	2559.0	3139.0	3718.0	4298.0	4877.0	5457.0	6532.0	7194.0
	Livestock	1876.0	1957.0	2029.0	2102.0	2175.0	2247.0	2320.0	2393.0	2466.0
	Forestry and other land use	-11219.1	-11359.9	-12796.9	-14415.6	-16239.1	-18293.2	-20607.2	-23213.9	-26150.3
National total		-5224.0	-4486.2	-5025.4	-5782.8	-6518.9	-7156.8	-7867.1	-7089.0	-6720.9

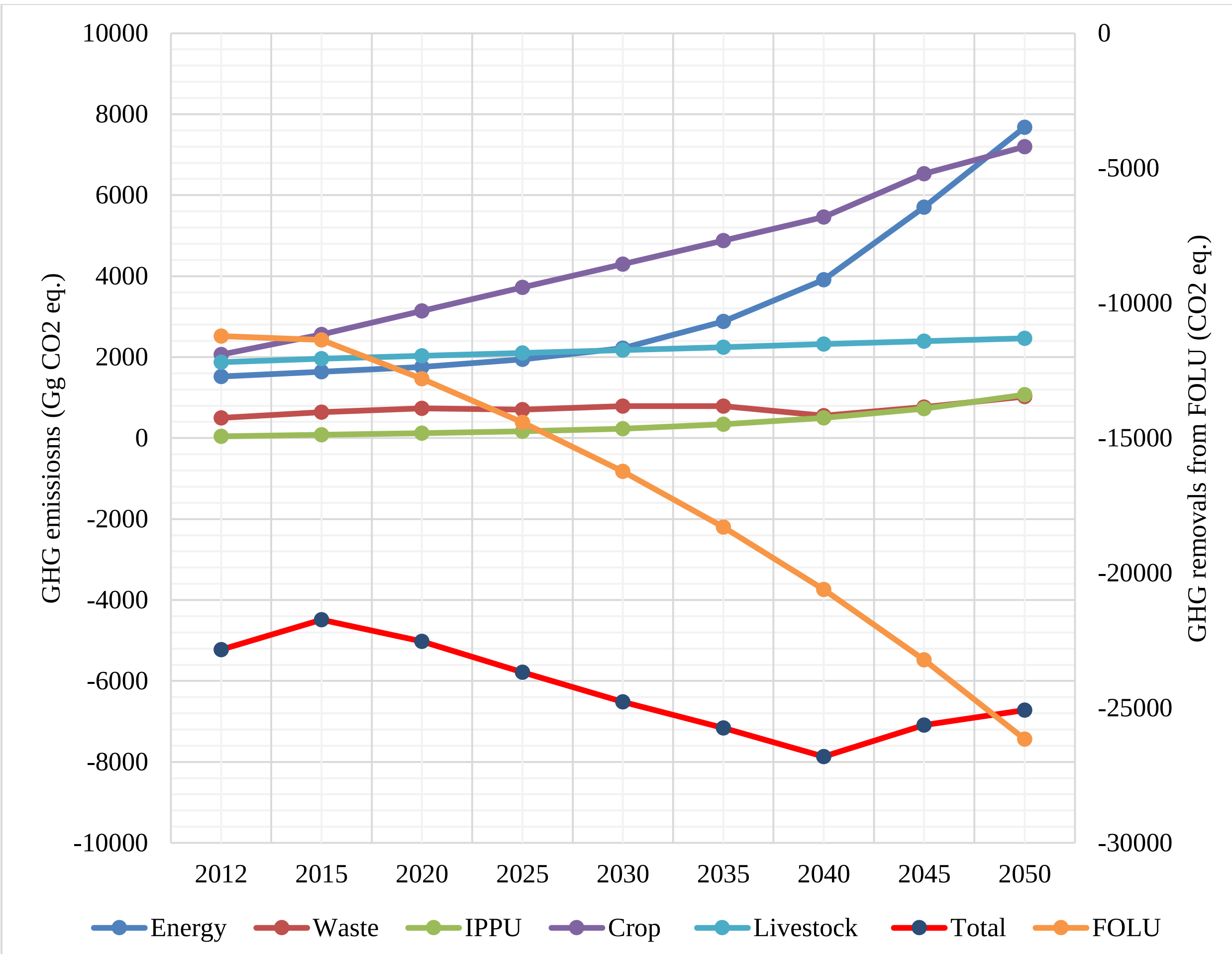


Figure ES.3.2: Emission simulation trends for mitigation scenarios in different sectors

Table ES.3.3: Summarized emission simulation (Gg CO_2-eq.) reduced in mitigation scenarios

EMISSION REDUCED/REMOVED										
Sector	**Subsector**	2012	2015	2020	2025	2030	2035	2040	2045	2050
Energy	Electric power generation	0	0	42.7	100.8	280.8	488.1	984.2	1414.4	1391.7
	Energy Industries	0	0	2.2	6.3	12.3	21.1	34.1	53.7	83.3
	Buildings	0	0	173.1	476.6	798.6	1118.5	1573.6	2079.2	2682.4
	Transportation	0	0	127.5	158.1	197.3	247.9	313.4	398.3	508.8

	Total energy	0	0	345.5	741.7	1289.0	1875.6	2905.2	3945.7	4666.1
Waste Sector	Solid waste	0	0	94.5	290.6	402.1	650.1	1198.2	1392.0	1668.0
	Wastewater	0	0	0.0	12.7	22.5	39.8	70.5	124.7	220.6
	Total Waste	0	0	94.5	303.3	424.6	689.9	1268.7	1516.7	1888.7
IPPU	Total IPPU	0	0	0.5	8.1	25.8	41.1	62.7	92.2	135.4
AFOLU	Crop	0	0	248.0	497.0	744.0	993.0	1242.0	994.0	1160.0
	Livestock	0	0	188.0	375.0	563.0	752.0	939.0	1127.0	1314.0
	Forestry and other land use	0	0	1092.1	2355.4	3812.7	5489.5	7414.8	9620.9	12555.5
National total		0	0	1968.6	4280.5	6859.1	9841.1	13832.4	17296.5	21719.7

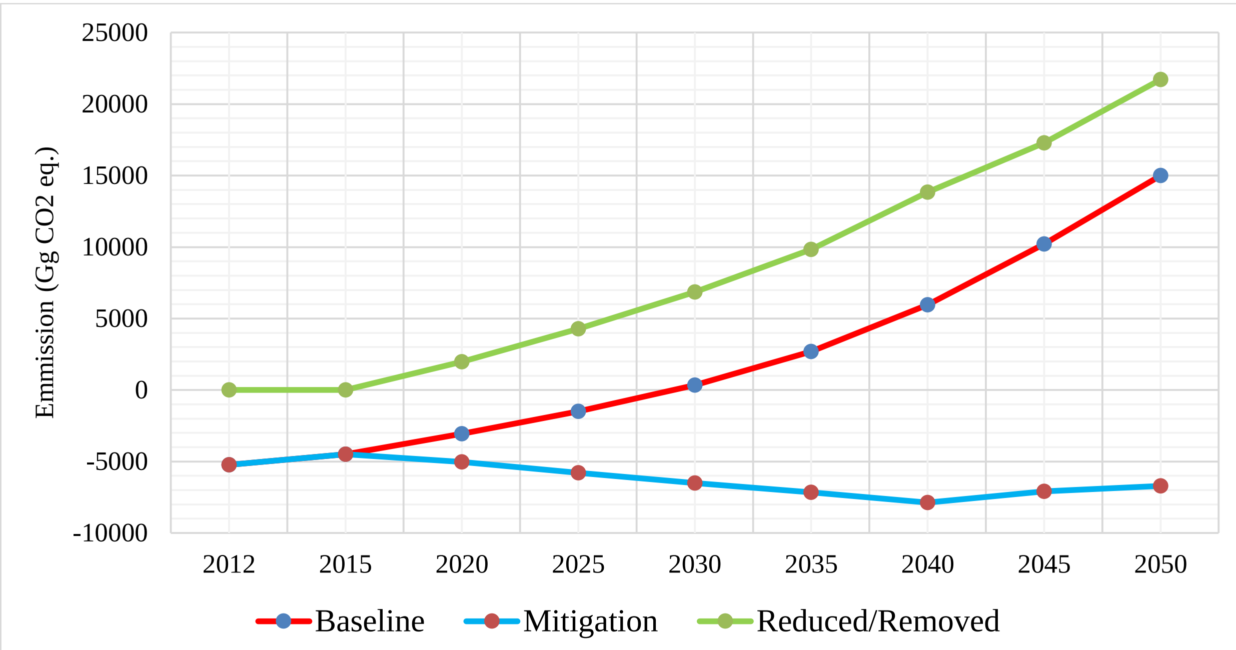


Figure ES.3.3: Total emissions reduced or removed through mitigation scenarios

ES.4.VULNERABILITY ASSESSMENT AND ADAPTATION TO CLIMATE CHANGE

OBSERVED CLIMATE TRENDS

Climate change and variability have rapidly emerged as one of the most serious threats to sustainable development especially for developing African countries such as Rwanda.Therefore, there should be continuous and regular preparedness to climate variability. Thus, the section on climate change analysis and future climatic scenarios was included in the Third National Communication report.

The raw climatic data (temperatures and precipitations) used in this study were obtained from the Meteo Rwanda and the Rwanda Environment Management Authority (REMA). Length and completeness of records were the basic criteria used to select weather stations in order to have the most complete dataset. This study used a number of statistical techniques in an attempt to quantify the magnitude and significance in rainfall, number of rainy days, temperature and aridity index changes taking place in Rwanda. A geographical information system (GIS) was used to present spatially the results on maps.

Though spatial-temporal variations were observed in mean temperature, rainfall, number of rainy days and aridity index, the study revealed a dominant increased trend in mean temperatures for the period 1961-2016. The highest increase varying between 1.4 °C and 2. 56°C was added on annual mean temperature over the south-west and eastern regions of Rwanda for the period of 46 years since 1971 to 2016. The northern highlands were warmed at the lowest rate of between 0.11°C and 1.7°C by 2016.

A decline of between 1.15 and 2.54 days is expected in number of rainy days by 2016 at most parts of country apart from in the western region represented by Kamembe weather station where a rise of 2.01 days is observed. This reveals that more dry spells are expected in Rwanda, especially in the eastern region represented by Kigali.

The expected decreasing trends in mean rainfall and number of rainy days during the rainy seasons in regions like the south-eastern lowlands and central plateau which already have a limited water supply are likely to cause a decline in water storage. This scenario may result in shortening the crop growing period. This will affect negatively the agricultural sector, especially coming at a time crops are in the fields and need an ample supply of water for growth and maturity. Therefore, Rwanda may expected the reduced crop production if the adaptation measures are not taken in due time.

On the other hand, the expected general increase in mean rainfall and number of rainy days in the north-west highlands and south-western regions will make them to have a constant supply of water (Muhire *et al.*, 2016). However, more occurrence of flooding episodes, soil erosion and landslides in these regions might lead to greater destruction not only of the physical environment but also human activities and existing infrastructures. Therefore, the more solid adaptation and mitigation measures were recommended to deal with the on-going events of climate change and variability in Rwanda.

WATER RESOURCES

Rwanda has a dense hydrographic network with ± 2 km/km^2, generally well endowed with sources from discontinuous aquifers of Precambrian terrains.

The hydrological system of Rwanda is subdivided into two main basins: the Nile basin and Congo basin. The Nile basin covers around 67% of the country’s territory, and it drains 90 of national water bodies, whereas the Congo Basin covers 33% of Rwanda’s territory and drains 10% of the national water bodies (MINITERE, 2005). In terms of water resources availability, Rwanda receives a total rainfall of 27.5 billion m^3 per year with total evapo-transpiration losses of 20.7 billion m^3 and the total renewable water resources stand at 6.8 billion m^3 per year (MINIRENA, 2015).

To understand the vulnerability of the water resources sector, an analysis and prediction for 2050 of the country’s main river flow fluctuations, the Nyabarongo river, was conducted and the results indicated that the entire hydrograph of the Nyabarongo River, including the baseflow, is directly related to the rainfall more than anthropogenic water abstractions and such conditions indicate that the Nyabarongo catchment's hydrology is vulnerable to any change in climate. This trend is almost the same for the entire hydrological system of Rwanda, and it is characterised by very high peak flows during rainy days causing destructive flooding and immediately followed by prolonged drought periods in some parts of the country. However, the number of rainy days was observed to decrease between 52% and 64% considering some stations in Rwanda over the period of 1961-1990 (Muhire, 2017).

In the recent past years, the Government of Rwanda has put in place various instruments to ensure a sustainable and integrated management of water resources, among which the 2011 National Policy for Water Resources Management (WRM), the 2011 Green growth strategy, which includes a program dedicated to IWRM and the 2015 National water resources master plan. All these instruments are expected to contribute in strengthening the resiliency to climate change of the Rwanda's water resources sector.

Building on the existing instruments, a number of adaptation measures are proposed under this NTC report and they include both soft and hard measures. The soft measures include mainly elements related to strengthening the water resources information system like floods forecasting and water allocation models but also catchments management plans and floods/drought control plans while the hard measures include aspects like catchments protection, development of water storage systems as well as the relocation of people living in flood prone areas.

AGRICULTURE, LIVESTOCK AND FOREST

Since the 80s, the Rwanda country's agricultural sector faces a series of unique constraints. Because of a high population density and limited land resources, where most farmers mostly practice rain-fed agriculture (the use of organic and non-organic fertilizers is insufficient for nutrient replenishment).

A synthesis of vulnerability assessment and proposed adaptation strategies in Agriculture, Livestock and Forestry is provided in the table ES.3.4 below. The performance indicators are grouped in seven categories namely food security (yield), access to water for the sector, employment in the sector, health of people in the sector, rural infrastructure to access the production, economic growth and export from the sector.

Table ES.3.4: Synthesis of vulnerability assessment and adaptation strategies in Agriculture, Livestock and Forestry sector

Performance indicators	Climate indicators	Climate impacts (vulnerability)	Adaptation strategies		
			Adaptation options		
Food security	Rainfall and humidity	- Reduced water availability for irrigation. - Increased runoff, nutrient leaching and water loss due to rain variability - Reduced yield and production of crops, animal feed and livestock. - Reduced rainy days will reduce total water quantity absorbed/ retained by soil. - Greater rainfall quantity in one rain will likely destroy/damage the existing soil conservation structures, increase erosion, landslide risks and flooding, and reduce quantity of water for rain harvesting structures	-Incentivise mechanisation -Strengthen soil protection on slopes, in villages and roads; -Promote IFSM, irrigation and rain water harvesting; -Breed and disseminate varieties more resistant to pests and diseases; -Promote multipurpose trees; higher nutritive crops and fodder; -Broadcasting of weather forecasts and sowing dates; -Develop precise fertiliser recommendations; -Use IT for extension requests and feedback from farmers; -Promote drip irrigation and closed greenhouse systems; -Use private sector for input and training delivery	Food security	Rainfall and humidity
	Temperature	- Increased populations of crop and livestock pests; - Increased diseases; - Lower productivity of crops adapted to cool climate; ➢ Increased water evaporation from crop foliage and soil	-Develop multi-cropping, rotation and system approach; -Zero tillage and mulch use; -Crop-Tree-Livestock integration -Resource allocation from large to small stock; -Develop new feed formulations and alternative feeds -Expand aquaculture & poultry; -Reduce cattle and use more productive crossbreeds; -Promote cooperative cattle farms; -Strengthen disease diagnostic, prevention and surveillance.		Temperature
	Wind storms	- Increased destruction of taller crops (e.g. banana, maize) and sometimes trees	-Develop adapted crop varieties; creation of windbreaks using agroforestry		Wind storms
	Hailstones	a) Crop damage/destruction; yield reduction	-Mapping where this happens; -Promote thicker leaves crops		Hailstones
Access to water in the sector	Rainfall and humidity	- Reduced water supply, - competition for use of water	-Incentivize rainwater harvesting; -Expand investment in water harvesting at settlement and community levels	Access to water in the sector	Rainfall and humidity
	Extreme events	• Disruption of infrastructure (e.g. water pollution)	-Plan for higher cost of infrastructure maintenance		Extreme events
Employment in the sector	Rainfall and humidity	1. With higher risks for agricultural production under climate impact, some labor will be attracted to other sectors such as forestry and mining. - Anthropogenic stress and increased deforestation and forest degradation due to	-Promote technologies to offset the risks of agricultural production and other challenges; -Create rural non-agricultural employment and small businesses (e.g. in food processing); -Expand loans in agriculture sector as well as weather related crop insurance	Employment in the sector	Rainfall and humidity

Performance indicators	Climate indicators	Climate impacts (vulnerability)	Adaptation strategies		
			Adaptation options		
		climate hardships (e.g. crop failure due to drought)			
	Temperature	- With higher risks for agricultural production under climate impact, some labor will be attracted to other sectors.	- Promote technologies to offset the risks of agricultural production and other challenges		Temperature
Health of people in the sector	Rainfall and humidity	- Along with climate change/ increase of pests and disease vectors for crops, there may be increase of population of disease vectors (e.g. malaria), and more people employed in agriculture may be sick	-Develop new strategies for disease vector control and prevention	Health of people in the sector	Rainfall and humidity
	Temperature	- Along with climate change/ increase of diseases for crops, human disease vector increase (e.g. malaria) may affect human health	- Develop new strategies for disease vector control and prevention		Temperature
Rural infrastructure	Rainfall and humidity	- The existing infrastructure was built without consideration for increased rainfall intensity and may now be destroyed/ damaged with heavy rainfall	-Plan for higher maintenance cost for infrastructure and its renewal and expansion	Rural infrastructure	Rainfall and humidity
	Temperature	- Temperature increase will result in higher heating of tarmac roads and their shorter life	-Plan for more frequent road repair/ maintenance		Temperature
Environmental degradation	Rainfall and humidity	- Reduced forest productivity due to drought and extreme climate events (e.g. wind throws, floods and fires) will lead to clearing of more forests to meet demand of forest products	-Capacity building of forest product users; -Efficient use of forest products; -Improve forest productivity	Environmental degradation	Rainfall and humidity
	Temperature	- The risk of forest fire is expected to increase with increased temperatures and erratic precipitations due to climate change. - Although increased CO_2 will lead to increased productivity in some regions, increased temperature will likely increase tree stress particularly in arid or semi-arid areas, reducing their productivity and leading to dieback. - Water catchments will be affected by rainfall decline	- Planting more fire resistant tree species in fire prone areas -Taking precaution to prevent bush fires through creating and maintaining firebreaks in forests -Water harvesting technologies should be promoted		Temperature
Economic growth	Rainfall and humidity	- Higher rainfall intensity will increase soil loss and nutrient leaching from soil, thus challenging agricultural productivity growth	- Promote IFSM and precise fertilizer application; -Develop nutrient efficient varieties - Develop IPM strategies in forests	Economic growth	Rainfall and humidity

Performance indicators	Climate indicators	Climate impacts (vulnerability)	Adaptation strategies		
			Adaptation options		
		- Water stress and long droughts will likely favour some pests and diseases in forests	- Carry out research and promote plantation of drought and pests resistant tree species - Plant the right tree species to the right place		
	Temperature	- Higher temperature will lead to switch to crops with higher optimum temperature - Some forest species may not cope with increased temperatures. ➢ Increased temperature and drought conditions may lead to increased susceptibility of some tree species to pests and diseases	- Plan for crop change and make a roadmap for where this change has to happen - Use tree species adapted to local conditions during reforestation - Carry out silvicultural/ maintenance activities as per schedule - Plant the right tree species to the right place		Temperature
Export from the sector	Rainfall and humidity	- Increased rainfall will positively impact coffee, tea and banana production. - Some forest and horticultural crops will benefit too.	- Prepare quality control and new market niches for increased coffee, tea, horticultural production, poles and lumber - Develop food processing industries	Export from the sector	Rainfall and humidity
	Temperature	- Temperature increase will negatively affect tea and coffee production, but banana will produce in shorter cycle	- Develop value chain for increased banana production - Promote agroforestry in coffee and tea plantations		Temperature

ENERGY

Various energy resources used in Rwanda, their respective infrastructure and energy outputs, the electricity generation and distribution networks as well as the electricity end use vulnerabilities were analyzed and possible adaptation options were suggested. Both current and potential vulnerability under future scenarios were identified and analyzed. In addition, the socio-economic impact on energy sector was analyzed.

The proposed adaptation measures were ranked based on the multi-criteria analysis. The results revealed that the hydropower and biomass are currently vulnerable to climate change. The energy sector is expected to be vulnerable to projected changes in climate variables including temperatures and rainfall. In addition, the frequency and intensity of extreme weather events such as floods, landslides, hailstorm etc., and possible rise in inland level are expected to result in numerous consequences. The projected increase socio-economic variable such as population and economic growth are expected to increase the stresses on biomass and electricity generation. Existing policies and strategies will play a key role in the adaptation to the latter consequences supplemented by the proposed adaptation measures.

INFRASTRUCTURE

The infrastructure sector is fundamental for the operation of the economy and society of Rwanda, now and in the future. In the recent years, the infrastructure sector was given a key priority for the economic transformation of Rwanda through improved transport and building infrastructures, planting the seeds of a green economy and better managing the process of urbanization.

The projected climate changes indicate that a rise in temperature is anticipated across Rwanda in the coming years up to 2050, especially during the dry seasons. Between 0.10 °C and 0.30 °C are expected to be added on annual mean temperature across the country apart from the northern region where a decrease of 0.06 °C is expected. In addition, a decreasing trend in mean rainfall and number of rainy days is expected. This reveals that more dry spells are expected over Rwanda, especially, in the eastern region. Climate change will also affect the north-west highlands and south-western regions of Rwanda with an increase in rainfall intensities. There is also high probability that the number of days with extreme temperature will continue to increase by 2050 while the days with extreme rainfall will be relatively stable.

Therefore, climate change will affect the infrastructure assets as well as the environment and social system in general. The vulnerability will depend on various factors such as the technology used for construction and operation, the population density and subsequent settlement. In addition, geographic characteristics observed in Rwanda such as steep slopes, soil instability and socio-economic drivers such as building in flood prone areas and poor management of soil erosion also contribute to the vulnerability. Consequently, weak infrastructure can turn natural events into disasters depending on their degree of exposure, sensitivity and adaptive capacity.

Potential impact of climate change to infrastructure sector will vary and also depend on build-up areas and type of infrastructure. For example, higher temperatures may cause asphalt pavement to soften and expand, thermal cracks formation in concrete, increased use of air conditioning in buildings, increased dust emission from non-asphalted roads. With these changes, it might become more costly to maintain and build roads and to maintain housing infrastructures, especially, in western and eastern regions of Rwanda.

In addition, a decrease in mean annual rainfall may lead to reduced efficiency of hydro-power plants, reduction in water supply for domestic use especially in the south, central and south-eastern regions of the country. The days with extreme rainfall intensities may also result in flooding, soil erosion and landslides leading to the destruction or damage of buildings and road infrastructure. Particularly relevant for the eastern region, storms may cause many impacts including damage to buildings and roads as well as house destruction.

The results from a non-exhaustive estimate of possible cost of losses due to climate change impacts shows that over 68.0 billion Frw or 80.0million USD, which represent 22.8% of the 2015/16 national budget allocated to infrastructure development, could be lost due to the infrastructure vulnerability to landslides and windstorms. Therefore, considering only this vulnerability to landslides and windstorms, it would be worth for Rwanda to invest in the proposed climate change adaptation measured for the infrastructure sector.

For better planning and to establish climate resilient infrastructure, the following adaptation measures were given high priority with the aim to set up resilient transport systems and to promote safe, suitable and well-kept building infrastructures up to 2050.

In transport sector, the subsequent adaptation measures were considered as high priority interventions in descending order:

1. Integration of climate information in transport infrastructure planning and design
2. Catchment management / IWRM
3. Institutional capacity development on adaptation mechanisms
4. Application of climate adapted material and technologies
5. Regular maintenance and upgrading of road and drainage infrastructures (Improved transport infrastructure)
6. Real time awareness and intervention during transport failure

Regarding the housing sector, the following climate change adaptation measures were given high priority in descending order:

1. Mapping of vulnerability areas before construction
2. Preventing construction on unsuitable sites, such as flood plains and steep slopes
3. Developing green city models
4. Establish climate-resilient infrastructure
5. Establishment of early warning system for disaster response plans
6. Relocate households from high risk zones
7. The foundation of buildings used for housing need to be erected

BIODIVERSITY, TOURISM AND HEALTH

The existing information confirms that climate change in Rwanda affects the sectors of biodiversity, tourism as well as health, but each sector has its own specific risk factors. Detailed information for Biodiversity, Tourism and Health sectors has been provided in this document (see Chapter 4).The areas of vulnerability have been highlighted throughout the chapter.

The status of biodiversity in Rwanda at ecosystem and species levels is linked to climate change. The number of species is threatened due to climate change. Seven plant species, 8 bird species, 16 mammal species (of which *Gorilla beringei* is the most vulnerable), and one amphibian species were found as being the most vulnerable due to climate change in Rwanda. The biodiversity policies, strategies and law were reviewed in order to propose the adaptation strategies for the conservation of biodiversity in a changing climate change, including: (i) effective conservation of the existing biodiversity, especially, in the protected areas; (ii) reduce the source of harm not directly linked to climate change, (iii) effective conservation of natural and planted forest ecosystems, and (iv) mainstreaming climate change into biodiversity policies. Biodiversity sector is considered among the most vulnerable to climate change because the ecosystems and biodiversity are exposed directly to natural conditions and have less adaptive capacity. Therefore, conservation efforts need to address particularly the effects of climate change on Rwandan biodiversity.

The status of tourism in Rwanda first illustrated by the statistics of tourism arrivals from 2007 to 2014,which are dominated by arrivals for business and conferences (38.7%) and visiting friends and relatives (30.8%). The tourism destinations and attractions were documented, and statistics of national park visits were provided from 2005 to 2015.They indicated that volcanoes national park was the most visited (43.6%). The statistics of accommodation availability were also increased as it was documented from 2009 to 2014, while significant efforts have been made to construct high-standard hotels to better serve tourists and to boost the national economy from tourism industry. The analysis of vulnerability of tourism sector due to climate change indicated that this sector will be mainly affected through indirect effect of climate change on biodiversity, which is the greatest contributor to tourism revenue in Rwanda. In 2014, the Rwanda tourism sector has introduced a new strategy to attract more tourists for meetings, incentives, conferences and events (MICE tourism strategy) as an alternative to nature-visiting tourism. It is expected to make Rwanda the first destination in Africa. Because the major data on tourism sector were those linked to its economic contribution, it is recommended to collect more data on potential impacts of climate change on tourism sector.

For health sector, the vulnerability to climate change was assessed using the existing statistics, which included child mortality, total number of outpatients, their mortality, identification of the climate-sensitive diseases (f. ex., respiratory infections, malaria, food and water-borne diseases, and malnutrition) for each of the 30 districts in Rwanda. Malaria and respiratory infections outpatients were the highest in Eastern and South-eastern parts of the country. Health sector was well powered for implementation of adaptation measures to make the sector healthier. The adaptation strategies for minimizing impacts of climate change on health sector were proposed such as continued basic health care services, improving the accessibility of health care services, and integrated monitoring of food and water-borne diseases. Considering that climate-sensitive diseases were driven by many factors, it was recommended to conduct a deeper study to quantify the impacts of climate change for particular diseases.

ES5: OTHER INFORMATION CONSIDERED RELEVANT TO THE ACHIEVEMENT OF THE OBJECTIVES OF THE CONVENTION

ES5.1. Integration of Climate changes issues into relevant social economic policies and strategies

Integration of climate change issues implies its mainstreaming into relevant policies, plans, programs and projects at national, sub-national, and local scale. This means to include climate change issues into the ongoing sector planning and management to ensure that the adaptation measures are considered and supported financially. Major sectors are integrating climate change in their policies, strategies and plans; awareness raising and policy direction have triggered climate change integration in development projects and activities.

ES.5.2. Activities related to environmental technologies transfer

Climate-smart technologies are known as the technologies that are used to address climate change and to reduce greenhouse gas emissions. These technologies include renewable energies such as wind energy, solar power and hydropower. In this context, climate-smart technologies are also used to adapt to the adverse effects of climate change such as development of drought-resistant crops, early warning systems; “soft” climate technologies such as energy-efficient practices or training for using equipment falls also in this framework (UNFCC).

ES.5.3. Climate change research and systematic observation

The International Research Institute for Climate and Society (IRI) and partners have been leading an effort to simultaneously improve the availability, access and use of climate information at national level in African countries. This effort, named “Enhancing National Climate Services

(ENACTS)”, has already been implemented in a number of countries in Africa. The foundation of ENACTS is the creation of quality-controlled, spatially and temporally complete climate data set. This involves organisation and quality control of station data, and generating historical time series by combining station observations with satellite and other proxies. This approach has been implemented by Meteo Rwanda to generate over 30 years (1981 to present) of rainfall and over 50 years (1961-2014) temperature time series at decadal (10-daily) time scale and for every 5km grid point across Rwanda.

ES.5.4. Education, Training and public awareness

This section covers detailed information on education, training and public awareness activities conducted by government institutions and stakeholders to promote climate change resilience in Rwanda. Education, training, and public awareness are under the responsibilities of REMA through Environmental Education and Mainstreaming Department (DEEM).

Public awareness and broad national sensitization on environment and climate change has been successfully conducted across the country at central and decentralized levels, and within the private sector, civil society, NGOs, environment clubs and public schools. Key activities include: developing a strategy to implement environment education for sustainable development; competitions; creating awareness materials and training modules; integration of national environment/climate priorities and commitments into sector planning, budgeting and implementation supported by mainstreaming checklists and guidelines targeting staff in charge of planning, EDPRS facilitators, and District environment officers, and training the Rwandan police to support law enforcement.

Government institutions and private sector have participated in informal education to raise environment and climate change awareness through school competitions, debate public lectures events commemoration, field visit, field tours and training workshops. A set of trainings on EESD have been delivered to decentralized institutions (District environment and education officers), media and civil society organisations. In collaboration with other institutions and NGOs, REMA has provided technical support (trainers and training manual) to the training and workshops organized in line with environment and climate change. Different social media, TV and radio have disseminated information related to climate change and environment.

ES.5.5. Capacity building

To implement the crosscutting issues planned in EDPRSII and Vision 2020, REMA has contributed to build capacity of planners from different sectors through providing trainings on use of tools and checklists for mainstreaming environment and climate change into sector strategic plans. Also, District planners and Environment District officers were trained on mainstreaming environment and climate change into District Performance Contracts and District Development plans (DDPs). Local environmental NGOs were equipped with skills to reorient their activities towards the implementation of environment and climate change issues planned in the Vision 2020 and EDPRS II. REMA in collaboration with LVCEEP have trained youth in Bugesera and Kirehe on their role in policy advocacy and also empowered them to start up small income generating projects. They were equipped with skills on agriculture in green house. Station Technical Experts have been trained by MINEDUC in collaboration with climate observatory project needed to run sensitive scientific instrumentation, perform data analysis and data quality control, and become experts in the field of atmospheric chemistry instrumentation.

ES.5.6. Information sharing

Rwanda Environment Management Authority (REMA) established an online climate change portal. The portal aims to serve as information hub on climate change in Rwanda and it provides a platform for all climate change practitioners and stakeholders to discuss, network and share climate change knowledge and information.

The Portal also aims to encourage more climate change adaptation and mitigation initiatives and innovation by empowering and supporting individuals, institutions, and communities to undertake action. It was established with an objective to raise awareness and promote action on climate change in Rwanda.

In this regard, to keep the portal effective and alive all stakeholders in climate change are invited to contribute to its update by sharing their initiatives, reports and cooperate on studies and events.

The website of Rwanda climate change portal is http://www.rema.gov.rw/climateportal/

ES.6: CONSTRAINTS, GAPS, AND RELATED FINANCIAL, TECHNICAL AND CAPACITY NEEDS

The main constraints and gaps were the availability of data for GHG emission inventory in different sectors, limited financial capacity to mitigate the impacts of climate change and lack of skills and knowledge for local communities to adapt to the climate change impacts. Financial, technical and capacity needs were also discussed and are very important for enabling the country to better respond to climate change issues to increase the resilience and promote green growth.

Table ES.6.1: Technical and capacity constraints, gaps and needs

Sector	Technical and capacity constraints and gaps	Technical and capacity needs
GHG Emission Inventory	• Lack of skills and understanding of using IPCC software 2006 • Limited country specific data such as emission factors, etc	• To assist in training of experts on national inventory process, climate change mitigation and adaptation technologies as well as raising awareness of the communities on how to mitigate and adapt to climate change • Provide continuous data collection for GHG Emission Inventory by all sectors according to IPCC 2016 software • Researches and related funds are needed to provide the missing data for instance national emission factors which will advance the used methodology at tier 2 level.
Energy	• Lack of physical characteristics of various fuels (Peat, liquid fuels and biomass, methane gas, LPG, etc.)	• Mobilize research funds for determination of emission factors and physical characteristics of the fuels used in the energy sector.

Sector	Technical and capacity constraints and gaps	Technical and capacity needs
	• Lack of country specific emission factors for the latter fuels and related technologies • Lack of information on travelled km for vehicles • Lack of methane gas specific emission factor to be considered in the GHG inventory • Limited studies related to energy generation vulnerability assessment • Lack of studies on the impact of climate change on the energy end use in the household and institutions	• Conduct surveys for energy consumption and use in the households and institution to fill gaps in data. • To conduct surveys to collect data on fuels consumption in transportation sector • To conduct surveys on the biomass use in the charcoal production chain. • To support various researches on the climate change impact on the energy generation and use.
IPPU	• The main gaps relate to the limited use of cleaner production measures, the lack of green buildings as well as the lack of technology that use the improved material efficiency in cement production	• There is a need to use the best available technology and the use of improved material efficiency in cement-to-clinker fractions. This will require further national and international researches to evaluate appropriate substitution materials and to assess their regional availability.
AFOLU	• Lack of specific country data (e.g. emission factors and expansion factors) for estimating GHG emissions • Local agricultural and forestry and other land use models are lacking. • Inadequate monitoring of farmers inputs and outputs. The early warning systems for climate conditions are still not usable by the farmers.	• To support research and monitoring of activity data in order to establish specific country data and develop local or national agricultural, forestry and other land use models so as to improve estimation of GHG emissions from AFOLU. • To ensure regular collection of activity data for GHG Emission inventory according to IPCC 2006 software. • Support and improve early warning systems for agricultural seasons' onsets so as to help farmers to minimize crop failure and other weather hazards.
WASTE	• Unsuitable waste management methods such as collection, disposal and treatment approaches	• To improve waste management practices by considering the waste prevention techniques and other sustainable approaches for waste collection and treatment such as waste source separation, sanitary landfills and energy recovery from waste. This will require large scale capacity building and awareness raising for sustainable waste management.

Financial needs

Apart from Government budget for financing Climate change response activities are needed to be supported financially. The support should come from Government and Bilateral and Multilateral donors. The foundation FONERWA could act as a Public Private Partnership Vehicle and employ public financing mechanisms such as grants, lines of credit, loan guarantees, public venture capital and equity capital. These mechanisms would enable green businesses and they will help consumers to overcome the initial investment costs of low carbon technologies, and would attract private sector financing of low carbon investments.

The FONERWA funds can be accessed by line ministries, government agencies, districts, civil society organisations (including academic institutions) and the private sector. At least 20% of total FONERWA resources will be earmarked for the private sector for use across core financing windows (excluding Window 4), and at least 10% of Fund resources will be earmarked for Districts (REMA: 2015).

Key strengths of the FONERWA Fund from a GoR perspective include the national orientation and ownership of the fund. Strengths from a donor perspective include national ownership and an opportunity to pool resources with other donors towards an extra-budgetary climate/environment fund. The primary source of FONERWA seed financing is bilateral Development Partners who can capitalize the Fund in the short-term (and long-term). DFID Rwanda provided initial seed capital of GBP 22.5 million (REMA: 2015). A secondary source is domestic capitalization from the Government of Rwanda. As of January 2014, the GoR has committed counterpart funding of approximately USD$ 3.7 million. The FONERWA also seeks to facilitate access to multilateral financing sources, as well as internal and external private sector sources. Towards this, FONERWA has successfully supported the GoR in accessing approximately USD 15 million in external finance, including USD 10 million from the Adaptation Fund, with approximately USD 15 million pending approval from other sources as stated in the lessons from national climate compatible development planning in Rwanda(REMA, 2015).

INTRODUCTION

One of the current major concerns of mankind is climate change. These are attributed directly or indirectly to human activities which lead to the increased emission of greenhouse gases (CO_2, N_2O, CH_4, CO, NOx, NMVOC). It should be noted that these activities are directly related to the economic development of different countries.

These emissions affect the composition of the world atmosphere along the natural vulnerability of the climate. They are often accompanied with significant harmful effects (vulnerability) on the composition, resistance, productivity of natural and manmade ecosystems, functioning of the socio-economic systems, man's health and welfare.

It is therefore the responsibility of UNFCCC Parties, Kyoto Protocol and Paris Agreement to take precautionary measures to predict, prevent or reduce the causes of climate change and limit their harmful effects in order to achieve sustainable development.

To date, parties to the UNFCCC, Kyoto Protocol and Paris Agreement are required to apply and disseminate practical technologies and processes, which can enable to control, reduce or prevent anthropogenic GHG emissions (which are not regulated by the Montreal Protocol) in all relevant sectors, especially, those of energy, water resources, transport, industry, agriculture, health, forestry and waste management.

This implies that on top of reducing the greenhouse gas emissions at the minimum level and strengthening of their sinks, the following actions need to be implemented:

- Systematic observation and the constitution of archive data on climate system, which would facilitate, to better understand the causes, effects, magnitude and the sequences of climate change, and to reduce and get rid of any uncertainties that may subsist in this regard;
- Exchange of scientific, technological, technical, socio-economic and regulation data on the climate system and climate change, as well as the socio-economic consequences, which might arise from anthropogenic reactions;
- Education, training and sensitization of the public in the field of climate change, as well as massive involvement of NGOs.

In accordance with the above concerns, this report constitutes the Third National Communication under the UNFCCC.

However, we recall that Rwanda developed its initial communication, which considers 2002 as a year of reference instead of 1994. Rwanda has also developed the second national communication, which considers 2005 as a year of reference. The 2012 was chosen as reference year for the third national communication, and its GHG inventory covers the period of 2006-2015.

Rwanda doesn't have its own methodology for estimation of national GHG emissions and sinks. However, the directives for establishment of national communications of non-annex I parties of convention according to the decision 17/CP.8 and GIEC method were used.

Thus, this report is structured as follows:

- The first chapter presents the national circumstances and institutional arrangement. It focuses on the political, institutional, legal, physiographic (relief, climate, and natural resources) framework, and on the socio-economic indicators;
- The second chapter deals with national inventory of emissions and absorptions of GHG (CO_2, N_2O, CH_4, CO, NO_x, COVNM), sector per sector (energy, transport, industry, waste, agriculture and animal husbandry);
- The third chapter deals with the mitigation of GHG emissions and the strengthening of sinks, in relation to the data on energy demand, energy transformation, agriculture and animal husbandry, land use, land use change and forestry;
- The fourth chapter is concerned with the vulnerability and adaptation to climate change in relation to climate change scenarios, water resources, agriculture, forest, energy, infrastructure, biodiversity, tourism and health;
- The fifth chapter is related to additional information deemed useful to achieve the convention goal, which is climate change integration, transfer of technologies, research and systematic observations, information on the research projects, education, development and capacity building in relation to climate change, information and information network for researchers, training and sensitization of the public; and
- The sixth and final chapter deals with difficulties, identified gaps, financial resources, technical means and capacity necessary for remediation; it focuses on obstacles and gaps, barriers identification, and the impact of the selected options at the macro-economic level.

CHAPTER 1

NATIONAL CIRCUMUSTANCES AND INSTITUTIONAL ARRANGEMENT




CHAPTER I: NATIONAL CIRCUMUSTANCES AND INSTITUTIONAL ARRANGEMENT

1.1 Introduction

1.1.1 Climate Change institutional arrangements

The Ministry of Environment (MoE) is the key institution in charge of making policies and programmes related to the environment and climate change and the Rwanda Environment

Management Authority (REMA) is the regulatory agency tasked to coordinate the implementation of those policies and programmes. Under REMA, a specific department of climate change and international obligations (DCCIO) was established in 2011 with a purpose to address the issues of climate change and to coordinate the implementation of multilateral environmental agreements. DCCIO comprises 4 desks in charge of: climate change mitigation, climate change adaptation, climate data and the international environmental agreements. The Table 1.1 below summarizes key local stakeholder institutions having attributions related to climate change.

Table 1.1 Institutions and activities relating to climate change in their mandate

No.	Institutions	Activities rerating to climate change in their mandate
1	MoE	Overall formulation and oversight of Policies and strategies on the environment and climate change
2	MINILAF	Coordination of forest management and agro-forestry development; land use planning
	REMA	Activities related to climate change in their mandate
4	Meteo Rwanda	Provision of accurate and timely weather and climate information
5	MINAGRI	Development and management of suitable programmes of transformation and modernization of agriculture and livestock to ensure food security and to contribute to the national economy
	MININFRA	Energy and urban planning management policy development
7	RTDA	Implement activities related to transport
8	RHA	Implementation of the national housing, urbanization, construction and Government assets management policies
9	MINEDUC	Overall formulation and oversight of Policies and strategies related to education, including environment education, in curriculum and research institutions
10	MoH	Development of environmental health policies and strategies
11	MINECOFIN	Financing of climate change programs and projects
12	RSB	Examining compliance with quality standards responding to sound environment and climate change requirements
13	REG	Implementation of projects providing environmental and climate friendly energy (renewable energy); energy supply that supports the development of green industry and services
14	WASAC	Management of water and sanitation services in Rwanda, through continuous innovation.
15	MINALOC	Facilitation of policy implementation at local level
16	MIDIMAR	Development of policies and strategies for adaptation to disasters due to climate change

The National Climate Change Committee at national level was established to develop TNC and various relevant institutions have nominated their representatives to be members of the Committee and those already having representatives in Third National Communication (TNC) Working Groups were automatically Members of NCCC.

1.1.2 Institutional arrangements for preparation of Third National Communication

Under the former Ministry of Natural Resources and, currently, the Ministry of Environment, the TNC project was implemented by REMA through the Single Project Implementation Unit (SPIU). The project was implemented under supervision of the National Climate Change Committee (NCCC) and four Thematic Working Groups of technical experts from REMA and other institutions were assigned the tasks in line with the TNC report structure, quality assurance and the UNFCCC guidelines. The figure below summarizes the Institutional Arrangement for preparation of TNC.

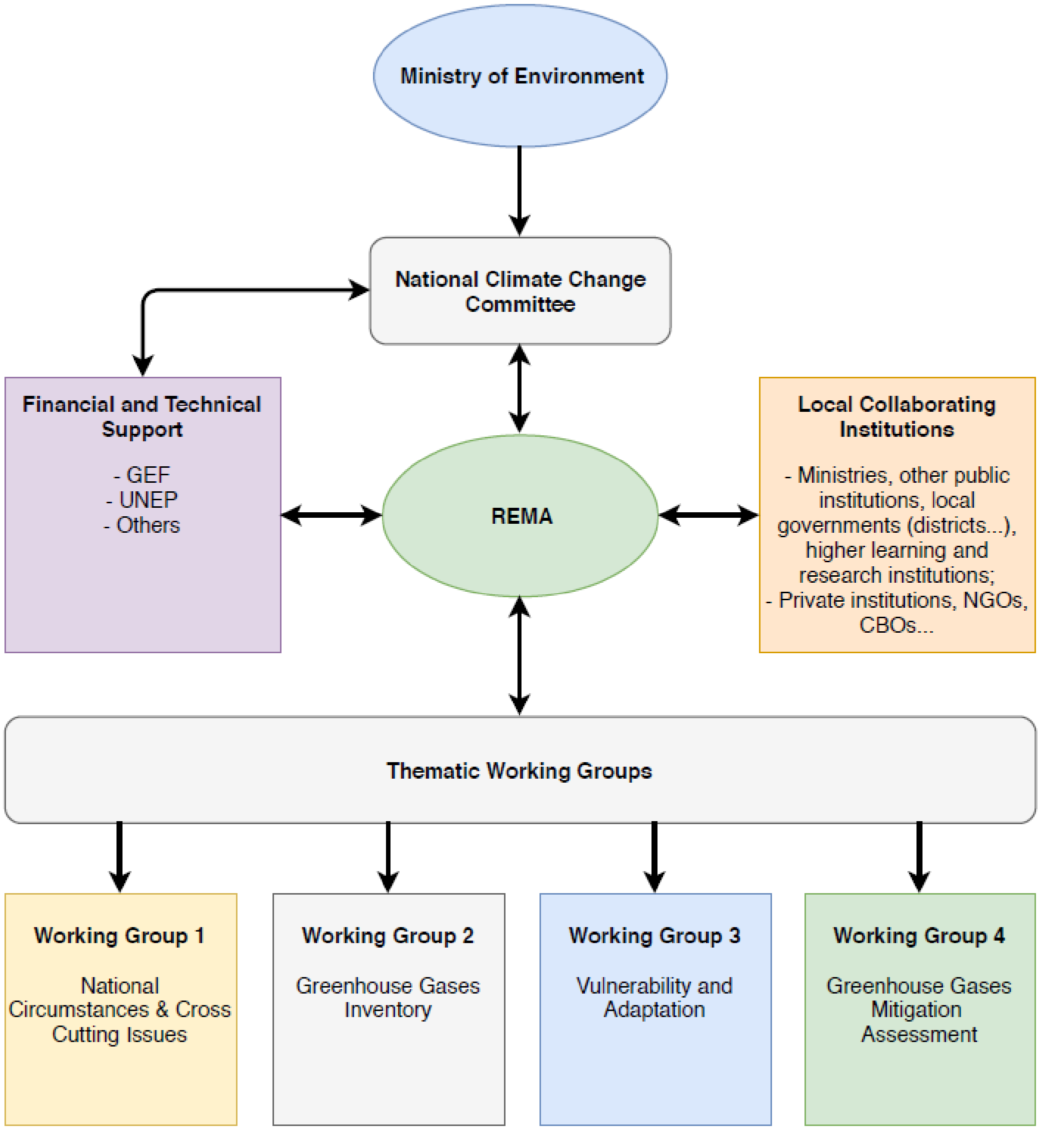


Figure 1.1 Institutional Arrangement for preparation of Third National Communication

1.1.3 Legislations, policies and strategies related to climate change in Rwanda

Rwanda has put in place a legal, policy and strategic framework dealing with climate change, limiting the losses linked to climate variability and to increasing climate change adaptive capacity. At the international and regional levels, it has ratified the United Nations Framework Convention on Climate Change (UNFCCC) as a Non-Annex 1 Party in 1995 and later the Kyoto Protocol. Rwanda has also ratified the Paris Agreement, which deals primarily with greenhouse emissions mitigation, adaptation and financing and is also Party to other Rio and Chemical Conventions. Rwanda submitted its Initial National Communication in September 2005 and the Second National Communication in June 2012.

At domestic level, the National Constitution, which is the highest legal instrument, constitutes the basis for the legal framework for the protection and safeguarding of environment and climate change in Rwanda. In the same perspective, the legal framework for the management of environment and climate change was put in place by the Organic Law determining the modalities of protection, conservation and promotion of environment in Rwanda as well as other various laws and regulations. In addition, the environmental law and the environment policy are currently being revised to better integrate climate change considerations. Also, the Green Growth and Climate Change Resilience Strategy was developed to ensure sustainable development and low carbon economy.

1.1.4 Financial and technical support partners

Various financial and technical support partners involved in climate change activities in Rwanda include: Global Environment Facility (GEF); United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP); the United Nations Economic Commission for Africa (UNECA); the Adaptation Fund (AF), the Green Climate Fund (GCF), World Bank (WB), DFID, the Rwanda's Green Fund (FONERWA), etc.

1.2. Geographical Profile

Rwanda is a landlocked country located in the east of central Africa. It lies between 1°4´ and 2°51´south latitude, and 28°53´ and 30°53´ east longitude, and it covers an area of 26,338 km^2. It lies approximately at 120 kilometres south of the Equator, at 1,100 kilometres from the Indian Ocean, at 1,920 kilometres from the Atlantic Ocean, at 3,750 kilometres from the Mediterranean Sea, and at 3,980 km from South Africa Cape. It is bordered by Uganda at the North, Tanzania at the East, Burundi at the South and the Democratic Republic of Congo at the West.

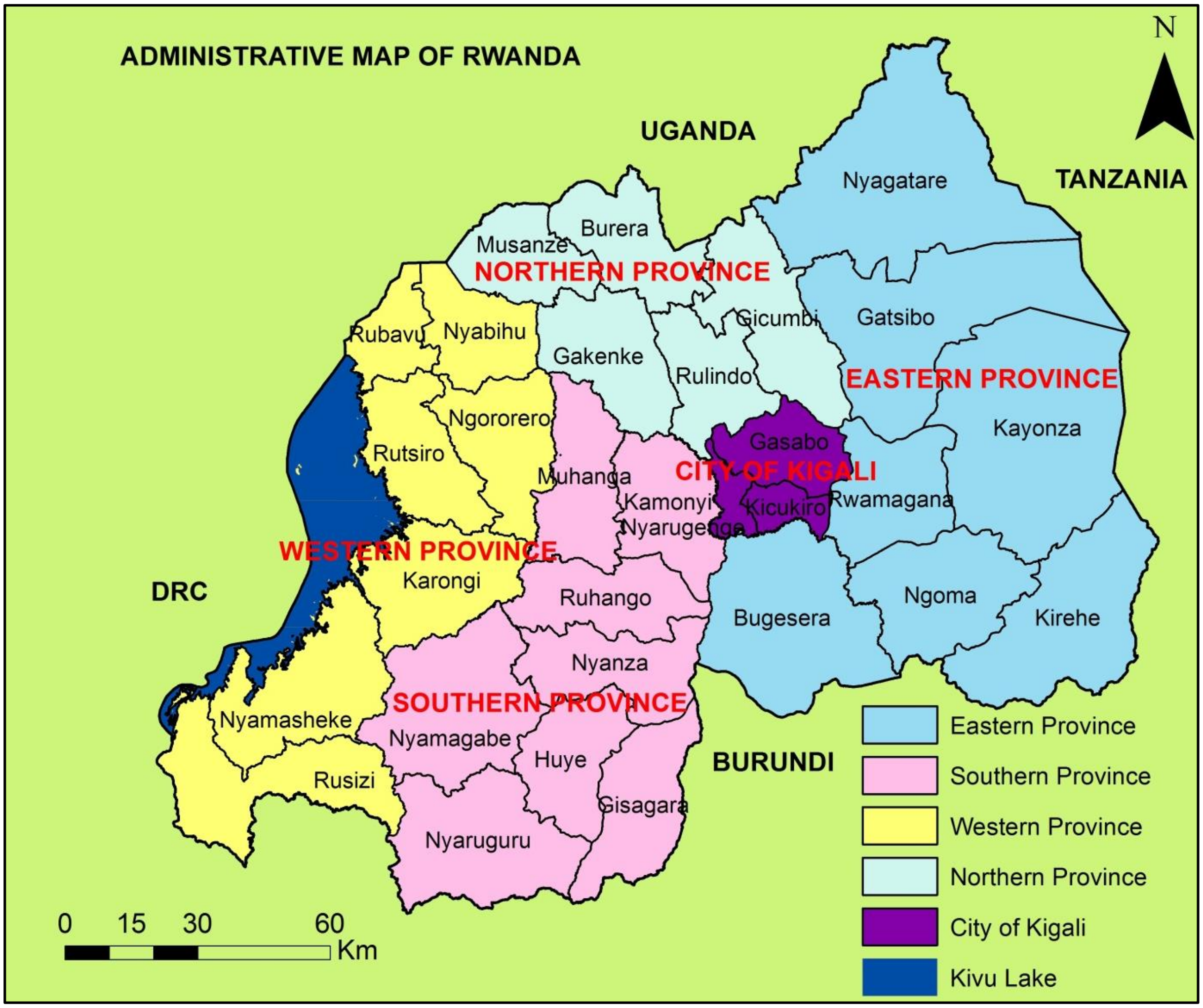


Figure 1. 2 Administrative Map of Rwanda

Rwanda's administrative structure comprises 4 provinces (Eastern, Western, Northern and Southern Provinces) and City of Kigali, all subdivided into 30 districts, 416 sectors, 2, 148 cells and 14, 816 villages. The altitude varies between 900 m and 4507 m from east to west where eastern plains are lying on 1,000 m to 1,500 m and the central plateau region is located between 1,500 m and 2,000 m. The Congo-Nile Ridge and volcanic chains of Birunga have height varying between 1,800 m and 4,507 m (on the top of Kalisimbi Volcano) while the regions around Kivu Lake and Bugarama plains are sitting on 900 m to 1800 m (Sirven and Gotanegre, 1974; MINIRENA, 2010).

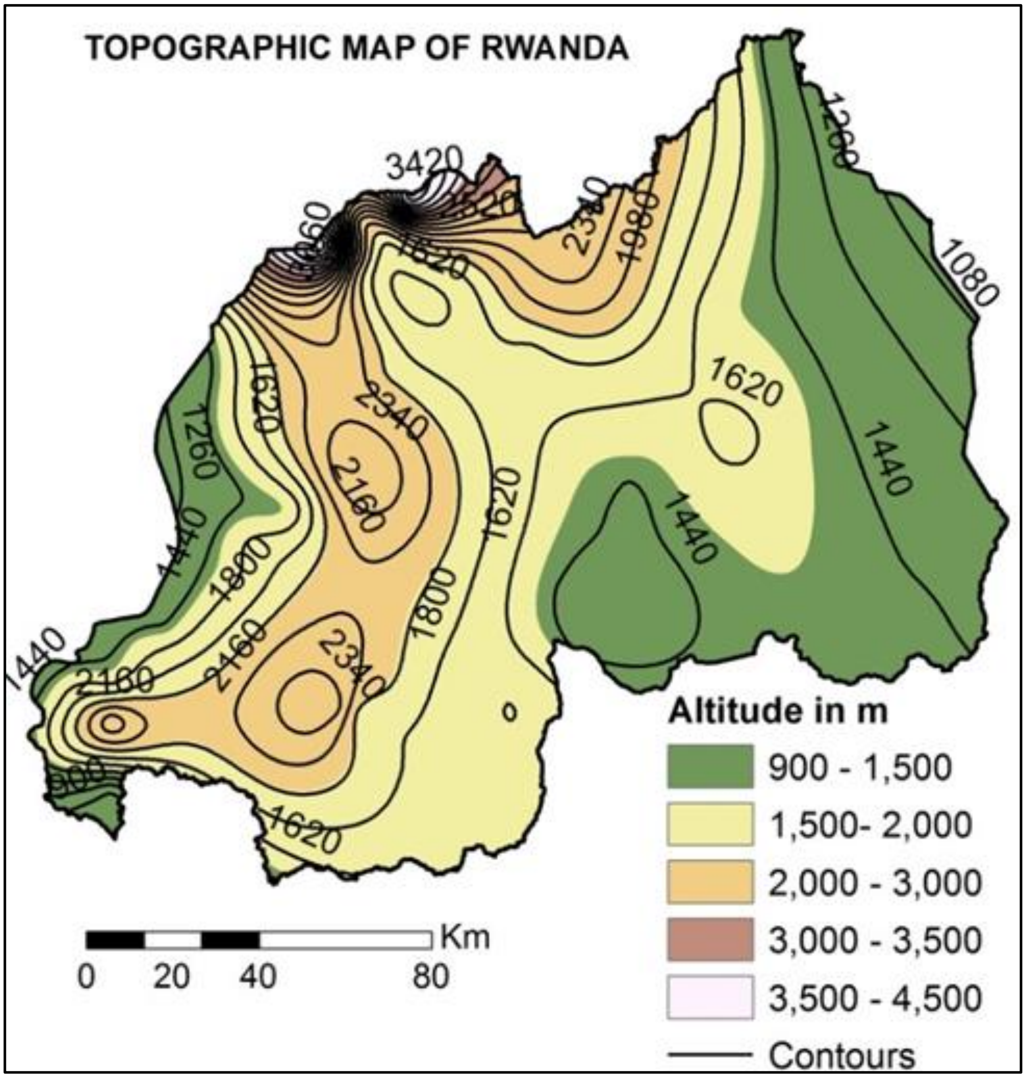


Figure 1.3 Relief of Rwanda
Source: REMA, 2015

1.2.1 Climate and climate variability

1.2.1.1. Climate

Despite its proximity to the Equator, Rwanda enjoys a tropical climate moderated by hilly topography stretching from east to west. The country is divided into four main climatic regions, namely, eastern plains, central plateau, highlands, and regions around Lake Kivu. The eastern plains receive an annual rainfall of between 700 mm and 1,100 mm (which falls in 57 to 100 days), with mean annual temperature oscillating between 20 °C and 22 °C. The central plateau region enjoys rainfall of between 1,100 mm and 1,300 mm, received in 90 to 150 days, with an annual mean temperature of between 18 °C and 20 °C. The highlands, including the Congo-Nile Ridge and volcanic chains of Birunga, benefit from an annual rainfall of between 1,300 mm and 1,600 mm, received in 140 to 210 days, with annual mean temperature ranging between 10 °C and 18 °C. Regions around Lake Kivu and Bugarama plains get annual rainfall of between 1,200 mm and

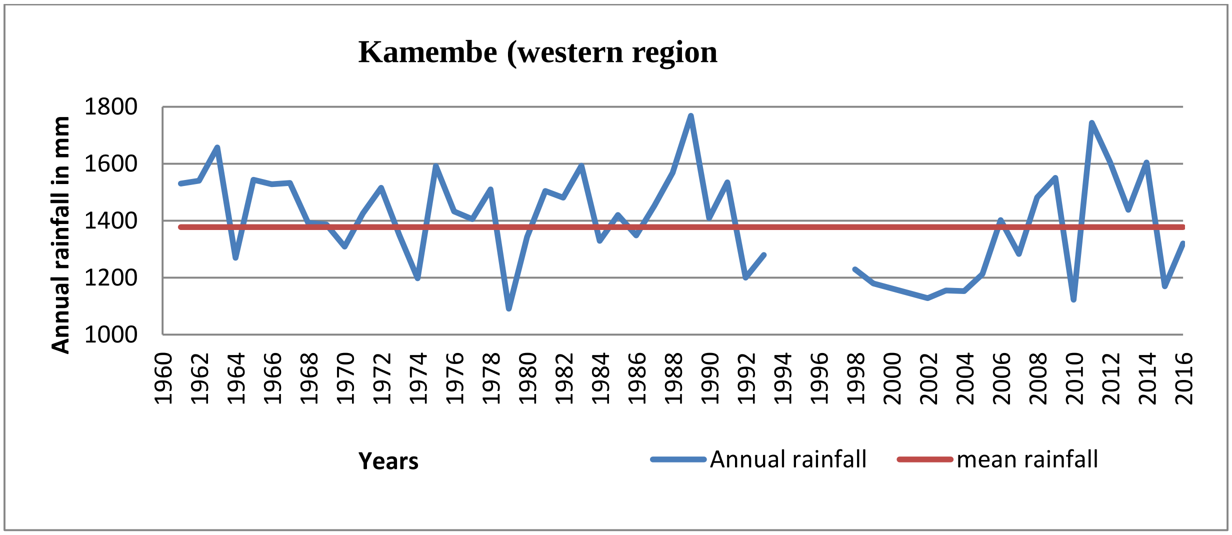
1,500 mm, received in 150 to 210 days, and annual mean temperature between 18°C and 22°C (Ilunga *et al.*, 2004; MINIRENA, 2010; Muhire and Ahmed, 2015; 2016).

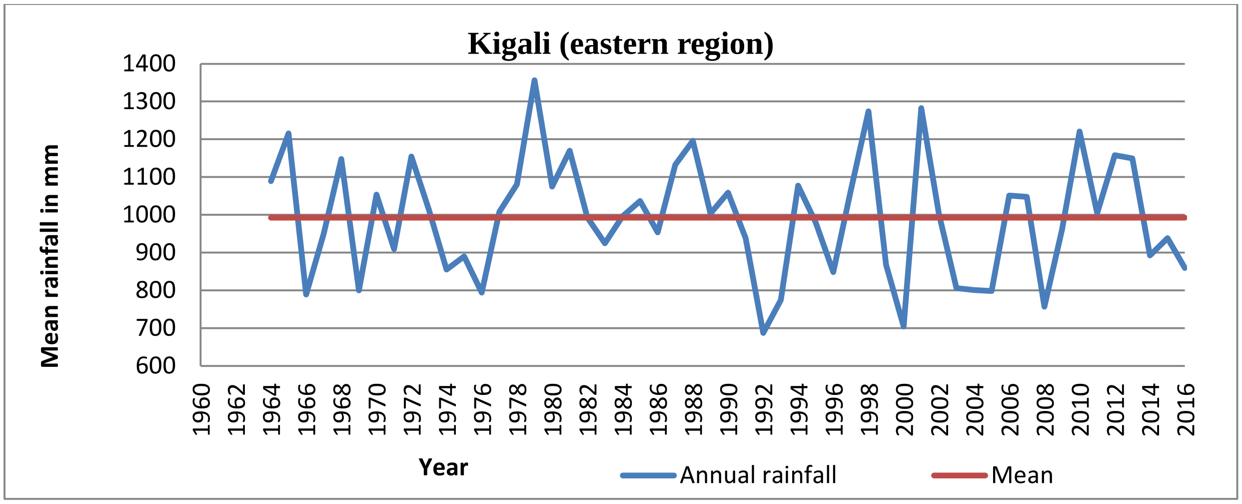
Rwanda experiences four climatic seasons, in which the long rainy (March-April-May) and short rainy (September-October-November) seasons alternate with long dry (June-July-August) and short dry seasons (Mid-December-January-February) throughout the year. The four seasons are largely controlled by the position and intensity of anticyclones such as Mascarenes, Saint Helena, Açores and Siberian (Ilunga *et al*., 2004; Anyah and Semazzi, 2007; Kizza *et al*., 2009; Muhire *et al*., 2015).

1.2.1.2 Climate variability

The annual rainfalls in Rwanda exhibited very high fluctuations since 1961 to 2016. The mean rainfall dominantly decreased in January, February, May and June with a dominant increasing trend in the remaining months of the year across the country. Arise in rainfall was observed in northern region from 1960, reaching the apex in 1982 while the period of 2000-2009 was the driest with more fluctuations in mean rainfall for 2009-2016. This is the reason why a general decline of mean rainfall was observed for 1961 to 2016 in the northern region of the country. A dry period was seen from 1998to 2005 while 2008-2014 was the wettest period in the western region along with volcanic region. Contrary to eastern region which experienced the dry and wet years for1992-2008 and 1978-1990 respectively. This shows that the eastern region has faced frequently the dry episodes. Furthermore the period of 1978-1992 was the wettest while 1998-2010 was the driest in the central plateau region. Hence, the period of 1961-1991 was wetter than 1991-2016 across the country.

It is worth noting that a general progressive increasing trend in temperature was observed across the country for the period of 1961-2016 resulting into progressive warming of the country.





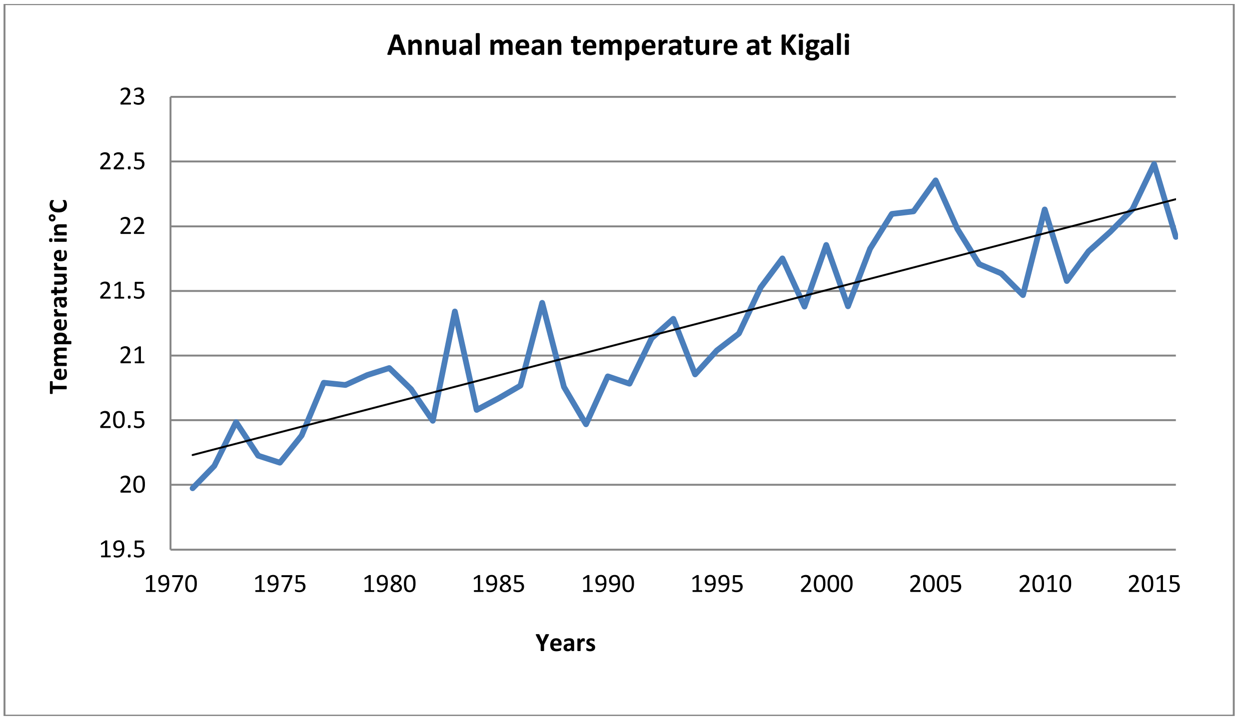


Figure 1.4 Variations of annual mean rainfall at Kamembe and Kigali stations for 1961-2016

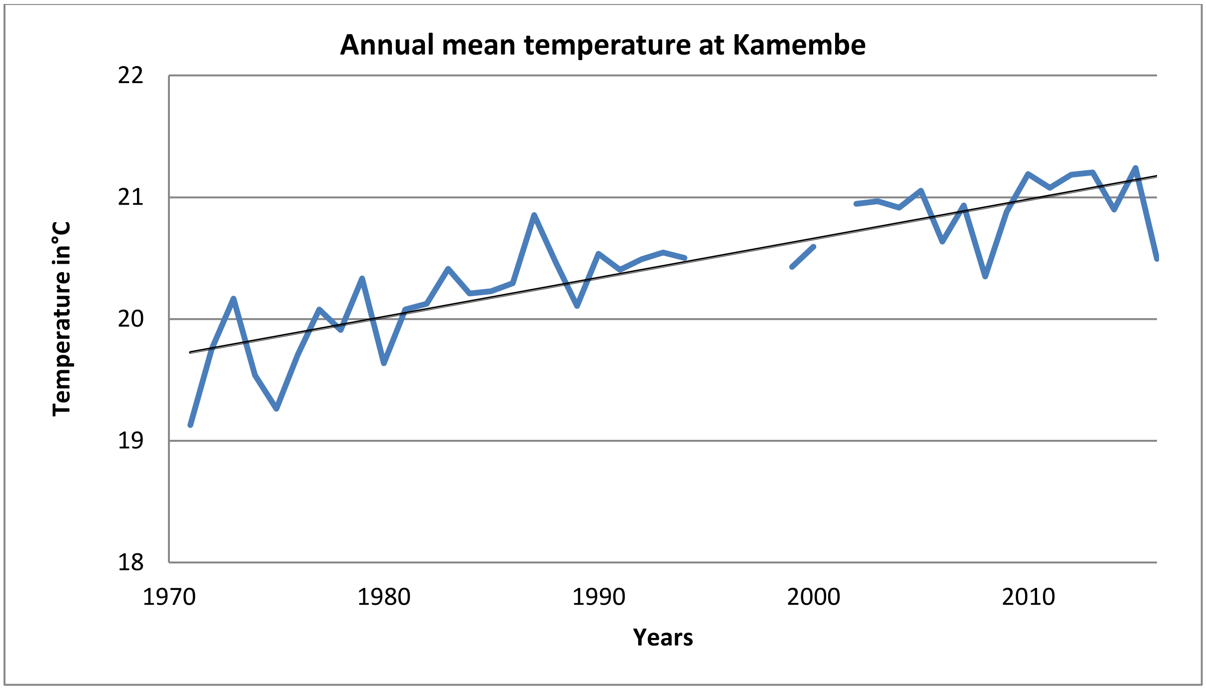


Figure 1.5 Annual variations of temperatures at Kigali and Kamembe stations for 1971-2016

1.2.3 Climate Projection

A decline in mean rainfall and number of rainy days was projected for the period 2017-2050 especially in the south, central and south-eastern regions of the country and it is bound to lead to more reduced water supply in the same regions. However, the recent studies are not very clear about the predicted precipitations over East Africa (EA); some suggest that local circulation effects could result in a general decreased precipitation (Brown and Funk, 2008) while others predict an increase in rainfall (by 5%-20% from December to February, and decreased rainfall by 5%-10% from June to August by 2050) in relation to the projected increase in temperatures (Hulme, 2001; WWF, 2006; IPCC, 2007; Eriksen *et al.*, 2008).

It emerges that the period 2015-2050 is generally expected to have a general decreasing trend at in mean rainfall across the country with exception in the north-western highlands. It was predicted that the periods 2015-2038 and 2043-2047 will experience a decreasing trend particularly in eastern region while the periods 2039-2042 and 2048-2050 will have an increasing pattern. High variability in mean rainfall with a tendency to decrease is expected especially in 2015-2023 and 2033-2042. Hence, more occurrences of extreme weather events (flooding and droughts episodes) might be also predicted from the fact that a number of positive and negative rainfall anomalies (above -1 and 1) are projected in the period of study.

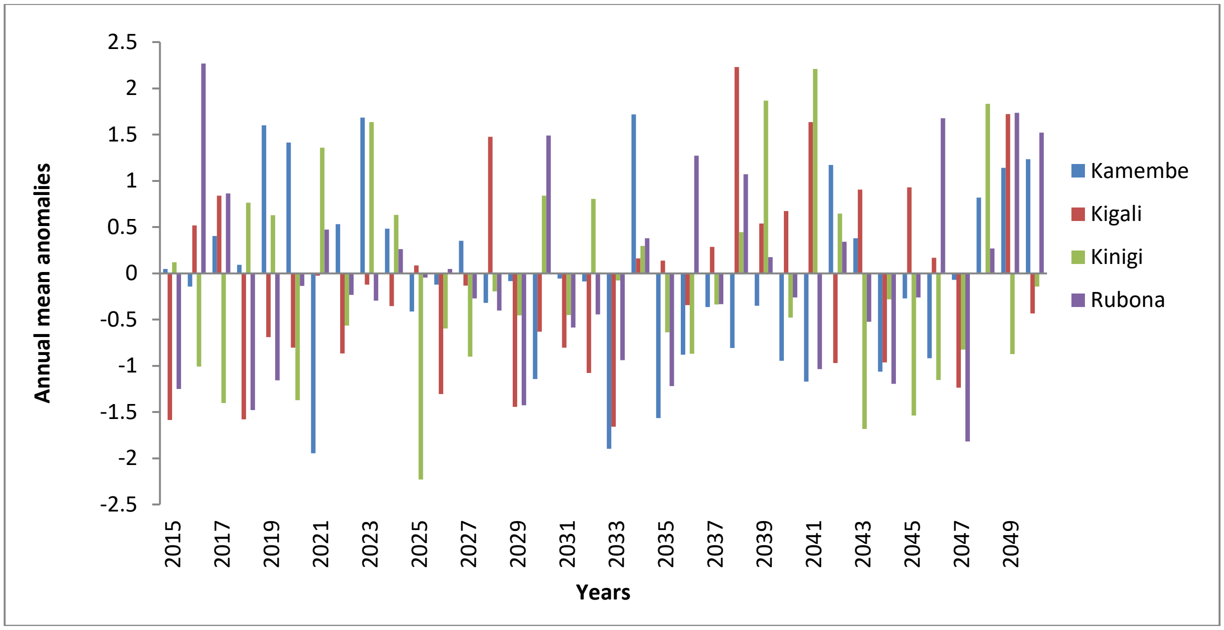


Figure 1.6 Variations of annual mean standardized rainfall anomalies for selected weather stations (2015-2050)

1.2.4 Environment and Natural resources

Social economic development of Rwandan people is dependent on the environment and natural resources such as water, land, air, minerals and biodiversity.

1.2.4.1 Land

The total Rwandan arable land is evaluated to 14,000 km^2 or 52% of the country's total surface area (26,338 km^2). However, in 2014 the total cultivated area rose up to 1,747,559 hectares or 66.35% of the national territory including 93,754 marshlands hectares under cultivation. This means that some lofty, rugged mountainous and protected areas have progressively been put under agriculture, which exposes the country to be more vulnerable to climate change and variability effects (MINAGRI, 2012; MINIRENA, 2012). Furthermore, farm ownership per household has decreased from 1.2 ha in 1984 to 0.89 ha in 1990 and 0.6 ha in 2010 (Philip, 2002; NISR, 2011 and 2015). This small plots are overexploited leading to more degradation and decrease in soil fertility (World Food Program, 2009; NISR, 2011).

1.2.4.2 Water resources

The Rwandan's hydrographic system is split into two basins divided by the Congo-Nile ridge, with water systems to the west of the ridge flowing into the Congo basin, whereas those to the east of ridge pour into the Nile basin. The country's hydrologic network covers 8% of the national area equivalent to about 2143 km^2, on which 101 lakes cover about 8% of Rwanda total area, means 1300 km^2 (RNRA, 2015), 861 rivers occupy about 72.6 km^2 with 6,462 km in length while the water of 860 wetlands and valleys covers 770 km^2 (Sirven and Gotanegre, 1974; REMA, 2009; MINIRENA, 2012).

The Congo basin drains around 33% of the national territory with 10% of the country water. The Nile basin flowing towards Lake Victoria drains around 67% of the national area with 90% of territory water(Sirven and Gotanegre, 1974).

Table 1.2 Potentials of water resources

Source of water	Potentials		
	2012	**2013**	**2014**
Surface Water	7-6 billion m^3/ year	6.826 billions of m^3	6.826 billions of m^3
Ground Water	5-4.5 billion m^3/year	4.554 billion m^3	4.554 billion m^3
Rainfall Water	28-25 billion m^3/year	27.505 billion m^3	27.505 billion m^3
Water yield/person	1,135 - 193 m^3/person/year	670 m^3/per year per person	670 m^3/per year per person
Water storage/person	7-5 m^3/person /year	447m^3/year/person	447m^3/year/person

Source: NISR, Statistical year 2015

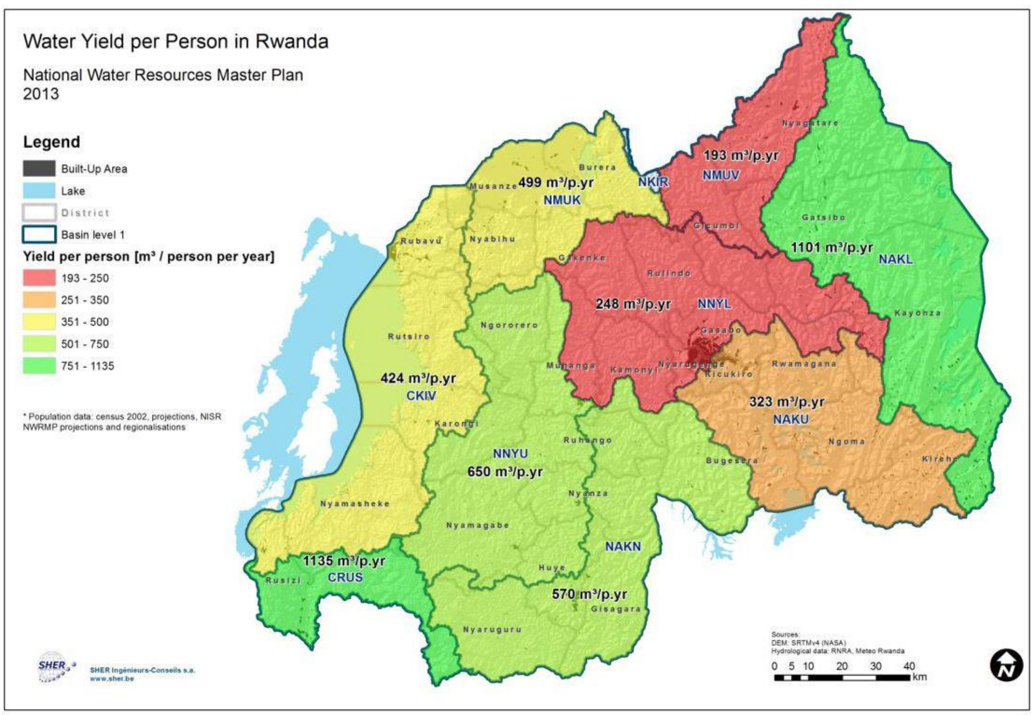


Figure 1.7 National Water Resources Master Plan
Source: RNRA, 2014

1.2.4.3 Biodiversity and wetlands

The Rwandan territory is covered with diverse ecosystems which include; natural ecosystems (consisting of mountain rainforests, gallery forests, savannah woodland, wetlands and aquatic forests), Forested area and agro- ecosystems. All these ecosystems are very rich with flora and fauna.

Protected areas are mainly four national parks: **(***i) Volcanoes National Park which is* famous worldwide due to the presence of mountain gorillas and variety of plants and animal species, (ii) *Nyungwe National Park has* more than 1,200 species of flora, 275 species of birds, (iii) *Akagera National Park* covers a surface area of about 108,500 ha and inhabits more than 900 species of plants and 90 mammals. (iv) Gishwati-Mukura National Park covering an area of 4,520 hectares. However, it should be realized that the protected areas of Rwanda have lost around 50% of their original surface area during the last 40 years. There are also small reserve forests of. Busaga, Buhanga, Sanza, Iwawa, Rubirizi, Makera; public and private plantation forests as specified below.

Table 1.3 Forest area by forest type (2017)

Forest management status	Forest name/ Province	Forest area(ha)	Vegetation Characteristics
National parks	Nyungwe NP	111,561	Montane tropical rainforest
	Volcanoes NP	16,000	Montane tropical rainforest
	Akagera NP	113,160	Shrub land/Savannah
	Gishwati-Mukura NP	4,520	Montane tropical rainforest
Forest reserves (107)	e.g. Busaga, Buhanga, Sanza, Iwawa, Rubirizi, Makera, etc.	37,886	Montane tropical rainforest/ shrubland /savannah woodlands
Unprotected shrub land/savannah woodlands	Public and Private lands	116,210	Mostly arid species, e.g. Acacia, combretum spp.
Public and Private Plantation forests	West Province	74,905	Mainly *Eucalyptus spp., Pinus sp., Grevillea robusta, Acacia melanoxylon* and *Callitris*
	South Province	109,765	
	East Province	35,986	
	North Province	54,813	
	Kigali city	11,340	
	Country (National)	286,809	

Sources: DFS et al., 2016 (National Forest Inventory, 2015); Department of Forestry and Nature Conservation (2016), Nyirambangutse et al. (2017) (Nyungwe studies)

Wetlands of Rwanda are composed of marshlands, lakes, rivers and streams and represent about 14,9% of the national territory of which 6,3% are marshlands and 8,6% are lakes, streams that are permanent or seasonal.

Wetland classification indicates that the total wetlands cover 276,477 ha where 74% of total wetlands are conditional exploitation, 6% are unconditional exploitation and 20% of the total wetlands are fully protected. They are dominated by papyruses especially in Kamiranzovu, Gishoma, Rugezi marshlands and around lakes such as Muhazi, Burera and Ruhondo. Planted forest are scattered in different part of the country and they are dominated by exotic species like Eucalyptus, Pinus, and Grevillea.

1.3. Population

The Fourth Rwanda Population and Housing Census (RPHC4) conducted in 2012 indicates that the total population has increased from 8,128,553 people in 2002 to 10,515,973 people in 2012. The female are 5,451,105 corresponding to 51.8% of total population while the male 5,064,868 corresponding to 48.2% of total population. About 83.5% of the resident populations (8,778,289 inhabitants) live in rural areas and 16.5% (1,737,684) in urban areas. The population projection (NISR, 2014) indicates the total population of 11,262,564 in 2015 according to medium scenario with a density of 494.9 inh./$km^2$and it is reported in statistical year book 2017.

The Pyramid of the resident population of Rwanda in 2012 indicates that the population of Rwanda is young with 53% of the population aged 19 years and around 82% of the population is under 40 years old. Population aged 65 years represented 3% of the total population. The population density in 2012 was 415 persons per km^3; and 494.9 in 2016 (SYB, 2017); making Rwanda one of the most densely populated countries in the world (NISR, 2012).

Table 1.4 Distribution of population by province, urban, rural and sex

Location	Female	Male	Total	%	Urban%	Rural%
Rwanda	5,451,105	5,064,868	10,515,937	100	16.5	83.5
City of Kigali	546,563	586,123	1,132,686	10.8	75.9	24.1
South	1,356,221	1,233,754	2,589,975	24.6	8.9	91.1
West	1,302,794	1,168,445	2,471,239	23.5	12.2	87.8
North	907,914	818,456	1,726,370	16.4	9.3	90.7
East	1,337,613	1,258,090	2,595,703	24.7	7.2	92.8

Source: NISR, Rwanda 4th Population and Housing Census, 2012

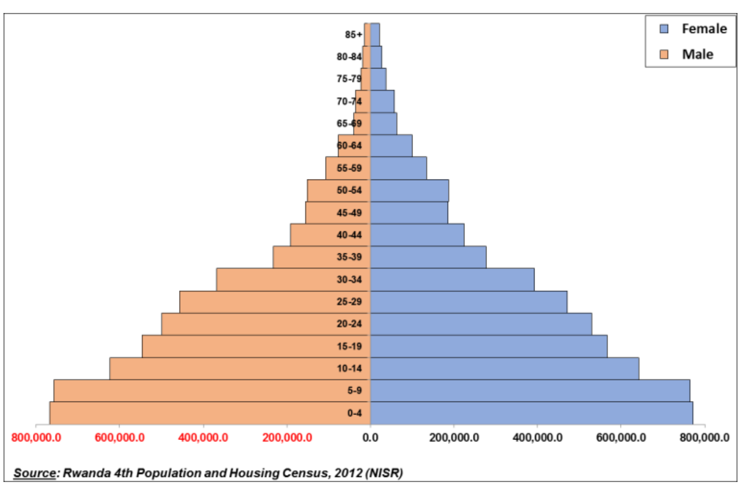


Figure 1.8 Age pyramid of the resident population of Rwanda 2012

1.3.1 Population growth rate

Population growth rate have been increased to 3.1% from 1978 to 1991 and decreased at 1.2% from 1991 to 2002 due to the Genocide of Tutsi. Between 2002 and 2012, the population growth rate has been doubled at 2.6% due to the improved living conditions with other factors and this will put pressure on services, economic opportunities and natural resources.

Table 1.5 Evolution of average population growth rate

Years	Population	Average annual growth rate (%)
1978	4,831,527	
1991	7,157,551	3.1
2002	8,128,553	1.2
2012	10,515,973	2.6
1978-2012	-	2.3

Source: *NISR, 4th RPHC 2012; Main indicators report*

Population projection from 2012 up to 2032 indicates that the population of Rwanda will reach 16, 875,142 high scenario projections, 16,332,184 medium scenario projections and 15,402,934 low scenario projections in 2032. In 2062, the population is expected to reach 25.4 million (NISR, RPHC 2012**)**.

1.3.2 Fertility and Mortality rate

Low income households with many children often find it more difficult to get out of poverty than those with less children, and high fertility societies face greater demands for services from their youthful populations.

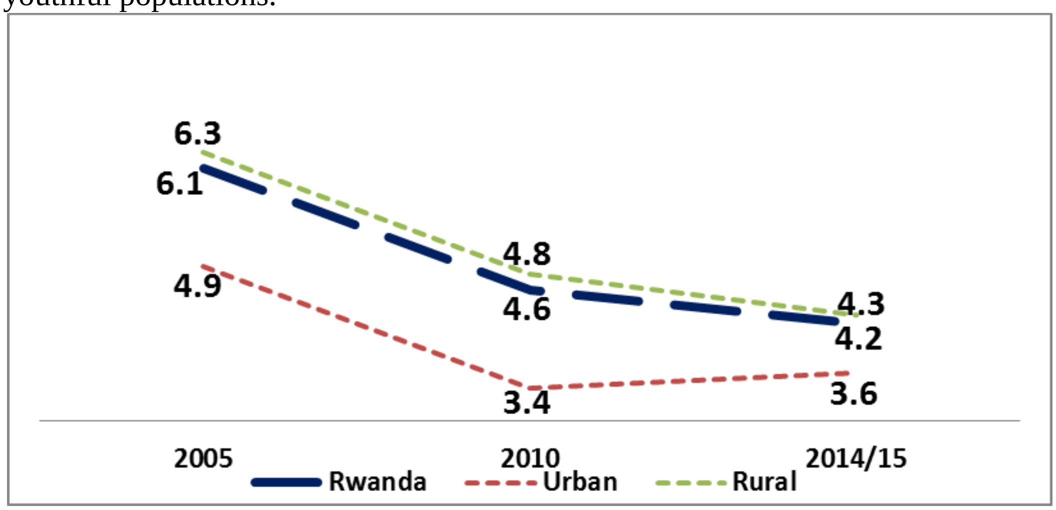


Figure 1.9 Fertility trends

Source: NISR, EICV4, 2015

This figure illustrates the trends in fertility rate from 2005 up to 2014/2015. The fertility rates have decreased from 6.1% in 2005 to 4.2% in 2014/2015.The fertility rate is high in rural area 4.3% in 2014/2015 compared to 3.6% in urban area.

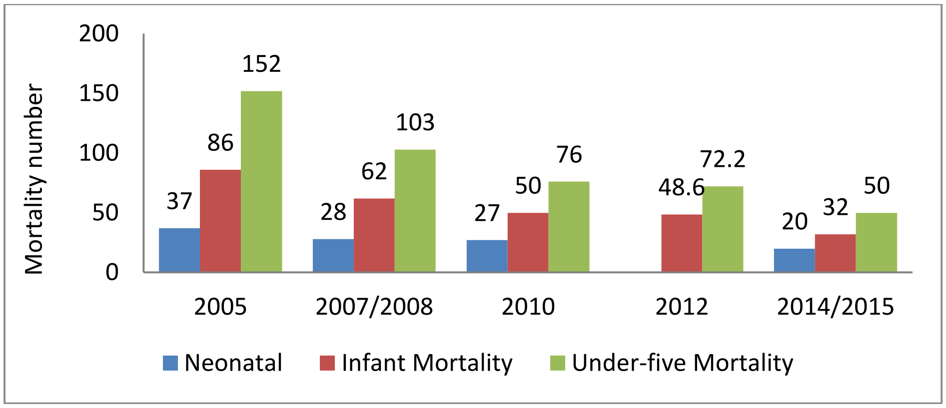


Figure 1.10 Trends in Mortality rates

This figure shows the trends in mortality rates from 2005 up to 2014/2015 and informs that under-five mortality has decreased from 152 to 50, infant mortality decreased from 86 to 32 while the neonatal also decreased from 37 to 20.

1.3.3 Life expectancy

Based on the 2012 Population and Housing Census of Rwanda, NSIR (2015) estimated that life expectancy at birth for women in Rwanda will increase by 3.5 years, from 66.2 in 2012 to 69.7 years in 2020 while for men it will increase by 3.2 years from 62.6 to 65.8 years for the same period. The life expectancy at birth in Rwanda has decreased from 54 to 51 years in 2002 and increased up to 64 years in 2012 and 65.7% in 2015 (63.7 for men and 67.5 for women) while the Vision 2020 target is 66 years. This growth of the life expectancy at birth in Rwanda reflects the development of Rwanda in various domains, especially the health system and wellbeing of the population. The application of UN model of life expectance improvement to RPHC4 data gives expected life expectance at birth in 2032 of 69.3 years for men and 73.4 years for women (NSIR, 2015).

1.4. Social condition

1.4.1 Poverty

The Government of Rwanda through its long term vision 2020 has committed to reduce poverty from 44.9% in 2011 to 20% in 2020. The Results of the 2013/14 EICV indicate that poverty is at 39.1% as of 2013/14, down from 44.9% as was reported in 2010/11. During the same period, extreme poverty dropped from 24.1% to 16.3%.

The poverty reduction was supported by different social programmes developed in National Social Protection Strategy (approved in 2011). The strategy provides two programme mainly Vision 2020 Umurenge Programme (VUP) which provides initiatives that generate income or consumption transfers to the poor and protect livelihood with the objective of reducing the economic and social vulnerabilities and access of poor people to financial services. Vision 2020 Umurenge Programme (VUP) provided three types of support such as public works, financial services and direct support. The majority public works projects implemented are land rehabilitation works. Direct support provides unconditional cash transfers to extremely poor households. Financial Services help poor households with increasing access to credit for promoting income generating activities (IGAs) to support them build sustainable livelihoods. The median annual consumption for households in Rwanda stands at Frw 187,027 per adult equivalent per year (NISR, 2015).

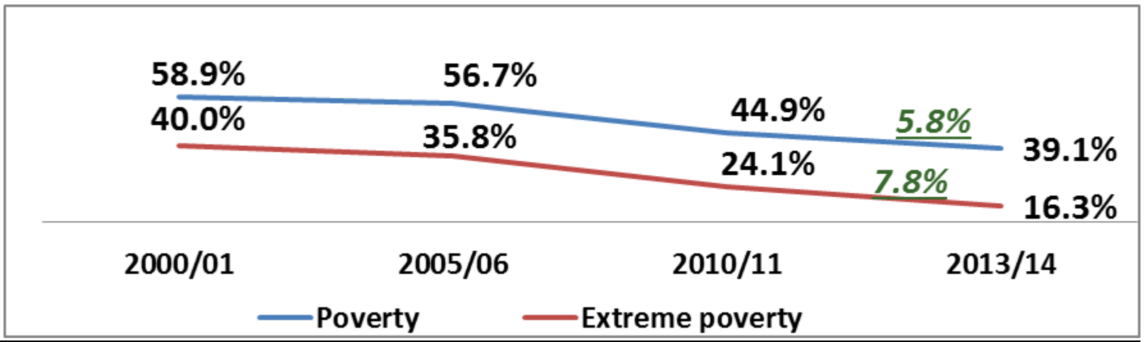


Figure 1.11 Poverty and extreme poverty trends
Source: NISR, Rwanda Poverty Profile Report, 2013/14, August 2015

EICV4 shows the progress observed in the use of improved drinking water source (85% compared to 74% in EICV3 over the period of three years at national level. Usage rates are higher in Urban areas (90%) compared to rural areas (84%). The proportion of households having access to improved sanitation increased from 75% in 2010/2011 to 83% in 2013/2014. (NISR: 2016).

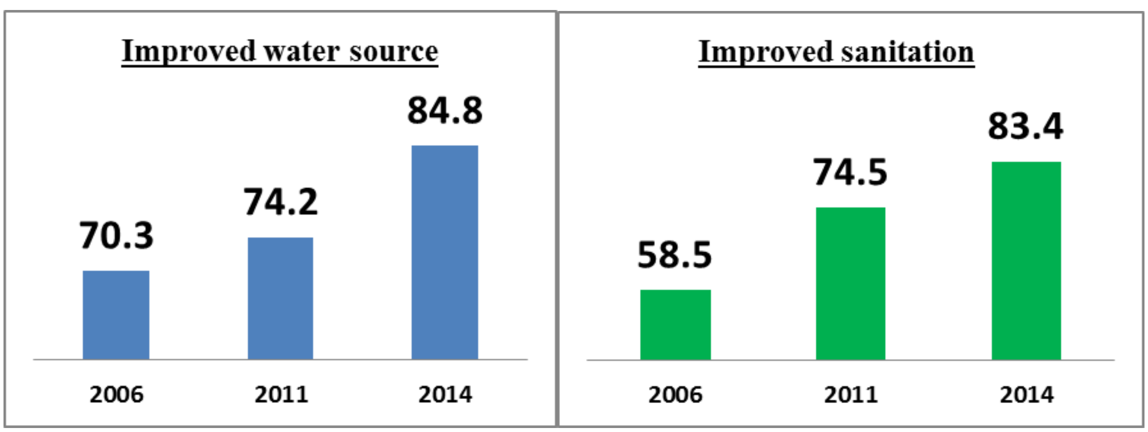


Figure 1.12 Percentage of households with improved water source and improved sanitation
Source: NISR, Rwanda Poverty Profile Report, 2013/14, August 2015

1.4.2 Gender

In practice, women represent 39.5% of officials in the land commission (MINIRENA, 2013). The process of land registration is participatory and community led. During the registration of claimants, both men and women are requested to be present.

This is of particular importance for couples who are legally married to ensure they are registered against the property as joint owners. Women are registered in the same way as men, with equal rights. 50% of the people involved in watershed management are women, and that women comprise at least 30% of the membership of local watershed management committees. In the mining sub-sector, it is projected that 40,000 jobs should be created by 2017/2018 for both youth and women. At least 30% of the work force employed in the mining sub-sector should come from women's organizations.

1.5. Economic structure

NSIR (2016) indicates that the GDP at current market prices is Frw 5,837 billion in 2015, up from Frw 5,395 billion in 2014. The Services sector contributed 47 percent of GDP while the agriculture sector contributed 33 percent of the GDP. The industry sector contributed 14 percent of the GDP and 6 percent was attributed to adjustment for taxes and subsidies on products. The GDP account 2015/2016 indicates that agriculture sector grew by 5 % and contributed 1.6 % to the overall GDP growth while industry sector increased by 4 % with a contribution of 0.6 % and the service sector increased by 8% and contributed 3.9 % points to the overall GDP **(**NISR, 2015/2016**).**

Table 1.6 National Account 2006 up to 2015

Indictor	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
GDP at Current prices (Frw Billions)	1,716	2,046	2,574	2,985	3,323	3,846	4,435	4,864	5,395	5,837
Growth rate (%)	19	19	26	16	10	16	15	10	11	8
GDP at constant (2006 and 2011 prices (Frw Billions)	1,716	1,847	2,060	2,184	3,566	3,846	4,184	4,380	4,687	5,011
Growth rate (%)	9.2	7.6	11.5	6	7.3	7.8	8.8	4.7	7	6.9
Implicit GDP deflator	100	111	125	137	93	100	106	111	115	116
Growth rate	9	11	13	9	2.6	9.3	6	4.7	3.7	1.2
GDP per head (in '000 Frw)	186	214	262	295	333	376	423	453	491	518
GDP per head (in current US dollars)	333	391	479	519	572	627	689	701	719	720
Total final consumption expenditure by Government (%)	18	17	15	15	15	14	14	14	15	12
Total final consumption expenditure by Private(includes changes in stock)%	80	80	78	83	79	79	78	76	75	78
Gross capital information (%)	16	18	23	22	23	24	26	27	26	26
Resource balance %	-14	-14	-16	-19	-17	-16	-18	-17	-17	-16
Value added to GDP by Agriculture (%)	38	36	32	34	33	32	33	33	33	33
Value added to GDP by Industry (%)	14	14	15	14	13	14	14	15	14	14
Value added to GDP by Services (%)	42	45	46	45	48	47	47	47	47	47
Value added to GDP by adjustment (%)	6	6	6	6	6	7	5	5	5	6

Indictor	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Gross capital formation (%)	16	18	23	22	23	24	26	27	26	26
			National Income and expenditure (Frw billion)							
Factor income from abroad, net	-16	-9	-19	-21	-25	-34	-59	-88	-107	-132
Gross National Income	1,700	2,035	2,555	2,964	3,298	3,811	4,377	4,776	5,288	5,705
Current transfers, net	139	198	244	298	330	435	276	362	272	265
Gross National Disposible Income	1,839	2,233	2,799	3,262	3,628	4,247	4,653	5,138	5,560	5,970
Gross National Saving	153	263	404	344	523	701	550	759	677	710
Exchange rate: FRW per US dollar	558	547	547	568	583	600	614	647	683	720
Growth rate	0	-2	0	4	3	3	2	5	6	5

Source: NISR: Statistical year books, 2012-2016

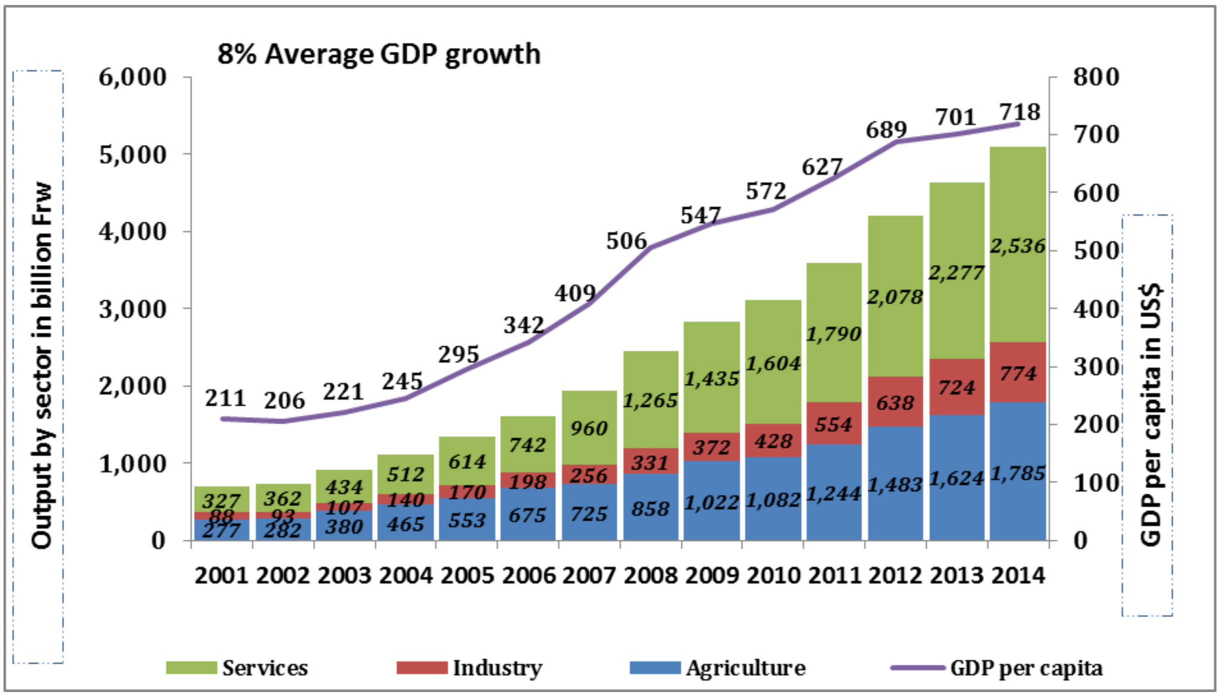


Figure 1.13 Output by sector and GDP per capita

Source: NISR, Rwanda Poverty Profile Report, 2013/2014, August 2015

1.5.1 Employment

NISR (2016) reported that the working population (16 years and above) in Rwanda was 6,400,000 whereas female represent 54% and males (46%). The majority of them 82% live in rural areas and 18% live in urban area. The labor force participation rate was 87.4% and it was lower in urban areas (79%) compared to rural areas (89%). The employment represents 85% of the working age population. The majority of employed population is independent farmers (55%) followed by employees in non-agriculture jobs (21%). The agriculture sector employed the majority of workers (68%) and other sectors with a high number of workers are whole sales and retail trade (10%) and construction (5%).

1.5. 2 Urbanization and infrastructures

National Urbanization Policy to promote good urban development that enhances local and nationaleconomic growth and ensures a minimum standard of quality of life to everyone was developed (MININFRA, 2015**).** Rwanda's Vision 2020 target at least 70 % of households living in rural areas to settle in integrated viable settlements. It also target 35% of population living in urban areas in 2020 from 10% in 2000 and 16.5% in 2012.

Average urban density in 2012 was 1,871 inhab/km^2 and the current annual growth rate of the urban population is 4.1% and the capital City of Kigali accommodated about half of the urban population. In 2012, planned housing was 11%, informal housing was 58% and 15% urban household of the total household in the country.

Through EDPRS 2 and urbanization and rural settlement sector strategic plan, 6 secondary cities were selected for the promotion of urban development outside of Kigali. These cities are: Muhanga, Rubavu, Huye, Rusizi, Nyagatare and Musanze.

1.5 Description of Economic sectors

1.6.1 Agriculture, Forest and Fisheries

The majority of Rwandan household is reliant on agriculture as their source of food and other income. The agricultural sector employs over 70% of the working population and is characterized by low productivity and low economic value (NISR, 2014a). Almost 90% of households practice traditional subsistence agriculture, mainly on narrow plots of land exhausted by continuous utilization (RoR, 2013).

Agriculture is the most important sector of the Rwandan economy and NSIR (2016), GDP at current market prices indicates that Agriculture contributed 33% of the GDP. In this year, agriculture sector grew by 5 % and contributed 1.6 % points to the overall GDP growth Coffee and tea constitute the main export crops. Extensive agricultural practices by the population contribute to the degradation of the environment.

Table 1. 7 Percentage of land area irrigated, protected against soil erosion, and affected by land consolidation by province, urban/ rural

EICV4(2013/2014)	Percentage of land irrigated, protected against soil erosion, and affected by land consolidation			
	% of land irrigated (in 000 ha)	% of land protected against soil erosion	% of land affected by land consolidation	Total cultivated land area % of land irrigated (in 000 ha)
Rwanda	4.0	73.0	15.7	1,310
Urban	6. 6	66 .1	14 .1	10 9
Rural	3.8	73.6	15.9	1,200

Source: NISR, EICV 4, 2013/2014.

Table1. 8 Land-Use Strata Definitions and Area

Stratum	Description	Total (Hectares)	Percent
1.1	Intensive agricultural land(seasonal A and B)	1,479,081.4	81.9
1.2	Intensive agriculture land (Season A and B, with potential for	48,388.2	2.7
2.1	Other marshlands	95,820.7	5.3
2.2	Marshlands potential for rice	20,200.9	1.1
3.0	Rangeland	133,848.5	7.4
10.0	Tea plantation	28,763.1	1.6
	Total agriculture land	1,806,102.9	100.0

Source: NISR, 2016 Seasonal Agriculture Survey Season A

1.6.1.1 Farm characteristics

The main crops grown in 2016 Season A (September to December) were: Banana (23% of the total cultivated area), Cassava (21% of the total cultivated area), Beans (20% of the total cultivated area), and Maize (12% of the total cultivated area); other crops took 24% of the total cultivated area. Fallow land represented 15 % of the total arable land of Rwanda. Crop production by groups of crops in Rwanda was highest for Tubers and Roots (37%) followed by Banana (28%) and Cereals (11%). Other crop groups contributed as follows: Legumes and Pulses (8%) and Vegetables and Fruits (5%). About 74.6% of Agricultural operators used traditional seeds while 25.4% of them used improved seed. For LSF, 30.5% used traditional seeds whereas 69.5% used improved seeds (NISR, 2016). Eight five percent of crop-producing households in Rwanda have at least one of their plots protected from erosion, and 13% had at least one of their plots irrigated (NISR, 2016).

1.6.1.2 Use of fertilizers in agriculture

The use of chemical fertilizers has increased from 29% to 37% between 2010/11 and 2013/14. The expenditure on organic fertilizers has also increased from 9% (EICV3) to 12% (EICV4) while the expenditure on chemical fertilizers is higher (28.9%) than 9.3% of manure. The country committed to reduce the population working in agriculture from 80% to 50% by 2020 by increasing the production per hectare and promoting the recycling of organic waste and use them to generate the manure for improving soil fertility.

Concerning the use of fertilizers for Agricultural operators, 71.3% used organic fertilizers while inorganic fertilizers were used by 32.1% of Agricultural operators. The percentage of agricultural operators who used pesticides is 16.1% for Agricultural operators and 62.6% for Large Scale Farmers and 1.6% of Agricultural operators practiced irrigation.

1.6.1.3 Livestock

The largest livestock population is concentrated in the eastern and southern parts of the country. Goats, cattle and chickens remain the most commonly owned types, at 51 %, 50 % and 46 %, respectively (NISR, 2015).Cattle predominate on the larger farms in the east and central regions while in the Southern Province, where farms are often as small as 0.5 ha, few households own cattle. In these areas, MINAGRI is promoting the One-Cow-per-Poor-Family program, or Girinka, which has a number of interrelated benefits, including increasing agricultural production, through manure supply and reducing childhood malnutrition (NISR, 2010a).

1.6.1.4 Fisheries

From 2009 to 2013, fish production increased from the main fishing areas and the trend in total fish harvests highlights the significant increase in production since 2011 (from 11 662 tons in 2011 to 24 550 tons in 2013).

1.6.1.5 Forestry

Rwanda is turning around a legacy of deforestation in keeping with its 2020 goal to increase forest cover to 30 % of the land area (MINIRENA, 2015) and currently, 2015, the total areas covered by the forests are 29.2 % of the country (REMA, 2015). Natural forests, which cover 10.8 % of the country, are comprised of an association of forested belts in National Parks, forest reserves, natural and gallery forests and other remnant forests.

Human made forests consisting of forest plantations of exotic tree species (mostly eucalyptus and pine), woodlots and agro-forestry plantations cover 18.4 % and represent nearly 63 % of all forest cover. Planted forests supply almost all fuelwood, with charcoal accounting for about 15.2 % of households' primary energy sources. Rwanda is actively promoting agro-forestry to provide wood for fuel during the transition to available and affordable electricity for all.

Agro-forestry also are used to control erosion, provides fodder, improves soil fertility and contributes to social well-being and green economic growth. In 2011, Rwanda's National Forest Policy, which aims to make the forestry sector bedrock of the country's economy, won the World Future Council's Future Policy Award as the world's most inspiring and innovative forest policy, and through the global Bonn Challenge, Rwanda has pledged to restore 2 million hectares of deforested and degraded lands (REMA, 2015).

Table 1.9 Natural forest by type and covered area

National forest	Forest type	Area(ha)
Nyungwe National park(including Cyamudongo)	Humid natural forest	70,363
	Natural forest	33,500
Volcanoes national park	Humid natural forest	7,211
	Natural forest	4,628
	Bamboo	4,380
Akagera National Park	Savanna	1,277
Gishwati-Mukura National Park	Humid natural forest	2,043
	Natural forest	899
Busaga Natural reserve Humid	Humid natural forest	82
	Natural forest	70
Other		2,565
Total		**127,016**

Source: REMA, State of Environment and Outlook report, 2015

1.6.2 Service and Tourism

In general services contributed 2.536 billion Rwandan francs to GDP in 2014 (NISR, 2015) and tourism sector contributed USD 428 Million to GDP in 2017. These services are provided from various categories like banking, insurance, transport, and others. There are 17 licensed banks in Rwanda, 90 Forex bureau institutions (BNR, 2015) and other several non-banking financial institutions. In banking sector, commercial and hotels projects combined are the ones who obtained the biggest amount of loans in 2014 for medium and short terms while Mortgage industries projects are the ones who received the largest amount of loans for long period in 2014 (NISR, 2015).

Services exports grew by 10% per annum between 2009 and 2014. The travel sector (including tourism) has steadily increased its share of total services exports in recent years. In 2014, 76% of services receipts were generated in the travel and tourism sector, contributing USD 303 million in export revenue up from USD 174 million in 2009. Freight and other transportation services are also important, accounting for 18% of services export revenue in 2014 or USD 72 million (BNR, 2014/2015).

The number of visitors has increased from 1,122,150 in 2013 and 1,219,529 in 2014. Especially in 2014, 90% of them used land as mode of transport, 87% of visitors in Rwanda are coming from Africa. In 2015 national parks counted 72,790 visitors, where 45 % of them went to Akagera national park and 64% where Foreign Visitors.

1.6.2.1. Statistics of National Parks Visits

The Volcano National Park has the highest historical visits (44.3%) followed by the Akagera National Park (43.6%; Table 1.10). Statistics of visits to national parks from 2008 to 2015 indicated that foreign visitors were the most dominant (65.2%; Table 1.11).

Table 1.10 Statistics of national parks visits from 2005 to 2015

Year	VNP	ANP	NNP	Total
2005	10 495	11 476	2 386	24 120
2006	14 008	13 720	3 088	30 816
2007	18 001	16 323	3 981	38 305
2008	19 783	18 490	4 810	43 083
2009	18 865	14 890	4 695	38 450
2010	23 372	16 180	5 755	45 307
2011	26 821	22 457	8 274	58 153
2012	28 483	25 200	7 621	61 301
2013	25 199	29 687	6 902	61 788
2014	27 885	30 846	9 140	67 871
2015	27 111	36 862	8 817	72 790
Total	240 023	236 131	65 469	541 623
%	44.3	43.6	12.1	

Source: NISR (2015) and RDB. Abbreviations: VNP: Volcano National Park; ANP: Akagera National Park; NNP: Nyungwe National Park.

Table 1.11 Parks Visits from 2008-2016

Year	Volcanoes National Park		Akagera National Park		Nyungwe National Park		Total
	Number	%	Number	%	Number	%	
2008	19,783	46	18,490	43	4,810	11	43,083
2009	18,865	49	14,890	39	4,695	12	38,450
2010	23,372	52	16,180	36	5,755	13	45,307
2011	26,821	47	22,457	39	8,274	14	58,153
2012	28,483	47	25,200	41	7,621	12	61,304
2013	25,199	41	29,687	48	6,902	11	61,788
2014	**27,885**	**41**	**30,846**	**45**	**9,140**	**14**	**67,871**
2015	**27,111**	**37**	**36,862**	**51**	**8,817**	**12**	**72,790**
2016	**32,743**	**37**	**41,797**	**47**	**13,644**	**15**	**88,184**

Source: NISR, 2018

1.6.2.2. Tourism contribution to Rwandan Economy

In 2012, tourism and hospitality sector had a total of 20,860 employees working as managers, financial and insurance professionals, liberal professionals, technicians, and artisans. Women accounted for 35.7% of labor units in that sector. The expatriates in the tourism sector were 3.7%, and majority (65.8%) of which were employed in the hotel and accommodation subsector. The indirect employment accounted for 74,300 jobs in 2009 representing 4% of total employment in Rwanda (RDB, 2012).

In 2015, the following figures were published for the Tourism and Travel sector in Rwanda: (i) the direct contribution to GDP was 185.7 billion Frw, equivalent to 3.6% of total GDP in 2014; the total contribution to GDP was 478.4 billion Frw, equivalent to 9.1% of GDP in 2014; (iii) In 2014, the total contribution to employment including jobs indirectly supported by the sector was 176,000 jobs, equal to 7.9% of total employment; (iv) the visitor export generated 251.9 billion Frw, equal to 33% of total export in 2014; and (v) Investment was 107.4 billion Frw or 9.0% of total investment (WTTC, 2015)and 15.3 million $USD were generated in 2015. The VNP generates the highest income: it was 14.2 million USD, equivalent to 93% of all park revenues in 2015, and 15.1 million USD in 2014 (Table 3.10).Considering all services that are driven by tourism activities in Rwanda, tourism activities were a source of revenue estimated to 33 million US$ in 2006, 100 million USD in 2010, 367.7 million USD in 2015 and 404 million USD in 2016 (macroeconomic figures). These figures support the statement by the Ministry of Trade and Industry (2009) that "tourism industry is very important for Rwanda's macroeconomic stability and prospects of economic growth" and based on the fact that 20% of foreign direct investment and 16% of local investment went into hostels, restaurant, and tourism activities from 2000 to 2009.

1.6.3 Trade and Industry

Industry sector in Rwanda is mainly composed by construction, manufacturing, Mining and Quarrying subsectors and the industrial survey of 2011 indicates the total number of 4,752 industrial firms operated in Rwanda. To ensure economic transformation, the EDPRS II targets the industrial (manufacturing, construction and mining) sector to contribute 20% to GDP by 2018 and to grow at an annual rate of 11.5% (REMA, 2015). In 2011, MINICOM developed National export strategy aiming to Transform Rwanda into a globally competitive export economy". NISR, 2016 shows that in the fiscal year 2015-2016, industry sector contributed 14% to the GDP.

The Ministry of trade and Industry, MINICOM (2012/2013) has initiated the construction of Special Economic Zone in Gasabo District since 2013/2014 for industrial firm's relocation from Gikondo wetlands.

Table 1.12 Industry, GDP by Kind of Activity Shares at current prices in %

Activity	2010	2011	2012	2013	2014
Industry	13	14	14	15	14
Manufacturing	5	5	5	5	5
Construction	6	7	7	7	7
Mining and Quarrying	1	2	2	2	2

Source: NISR,2015 statistical year book

In the fourth quarter of 2017, Rwanda's total trade amounted to USD959.48 million, an increase of 19.8 per cent over the fourth quarter of 2016. Exports totalled USD157.53 million, imports totalled USD 724.15 million and re-exports were valued at USD77.70 million (NISR, 2017).
The deficit in the balance of formal trade in goods was USD136.17 million in January 2018, a decrease of 24.06 per cent compared to the previous month of December 2017. Year-over-year, the formal trade in goods deficit increased by 1.45 per cent on the deficit of January 2017. (NISR, 2018).

For the fiscal year 2014/2015 the total exports (formal& informal) value grew by 0.3% with amount of USD 709.32 Million from 707.32 million registered in 2013/2014. The total import FOB during this period reduced by 0.2% to 1,916.71Million from 1,920.25 Million. The total volume of exports products is 363.08 thousand tons in 2014/2015 from 3.05.81 in 2013/2014 while the total value is 581.48 from 576.64 in 2013/2014. This total volume is dominated by re-exports products (122.33), tea (24.79) and coffee (16.53). The total value of export products is dominated by the minerals which recorded USD 174.10 Million.

Tea and coffee recorded good performance in 2014/2015 in both value and volume increasing by 17.8% and 14.3% respectively due to the increase of 14.3% in production from 22432.9 tons in 2014/2015 and 3.3% in unit price from USD 2.41kg in 2013/2014 to 2.49kg in 2014/2015. Minerals have decreased by 11.7% in volume and 14.8% in value from USD 204.28 in 2013/2014 Million to USD 174.10 Million in (BNR, 2014/2015).

This reduction was caused by the fall of unit price of cassiterite and wolfram. In Total, 8,955.11 tons of skins and hides were exported at the value of USD 1.36kg compared to 10.993.12 tons exported at the value of USD 1.55kg in 2013/2014.

Regarding re-export products which include other minerals, petroleum products, machines, vehicles and engines, they declined in value by 10.2%. Non- traditional export recorded a significant increase in both value and volume by 35% and 29.9% respectively. The imports products have decreased by 2.6% in value to USD 2,325.98million from USD 2,387.16 million in 2013/2014 while the volume grew by 12.1% to 2,005.28 tons against 1,788.32 tons recorded in 2013/2014.

1.6.4 Energy

Rwanda energy primary use is dominated by biomass, which accounts for 86.3% of the total. Rwanda has one of the lowest electricity consumption per capita in the region, and generation capacity is low. EICV 4, (2013/14) shows that 83.3% of Rwandan households use wood for their cooking fuel, followed by charcoal (15.2 %), crop waste (0.8%), gas or biogas (0.2%) and other 6%. At national level, the use of electricity for lighting changed from 11% in 2010/11 to 20% in 2013/14. Of the 14% of non-biomass primary energy, petroleum products account for 11% (used mainly in the transport sector) and electricity for approximately 3%. (NISR: EICV4 Environment and natural resources (2016).

Households are also the dominant consumers of electricity (51%), the bulk of which demand is primarily used for lighting. The industrial sector (42%) is the second largest consumer of energy, which mainly comes from motor-drivers and lighting. Public sector consumption of electricity (6%) is mainly for powering public buildings, street lighting and water pumping. The average household uses around 1.8 tons of firewood each year to satisfy its cooking needs with a traditional stove. The average monthly consumption per household on fuel wood is Frw 1,930.

1.6.4.1 Petroleum

As it could be seen from **NISR (Statistical yearbooks 2009, 20013, 20015, 2016)**, liquid fuels consumed in energy sector include diesel/gas oil, heavy fuels oil, kerosene, motor gasoline, Liquid petroleum gas, etc. The latter fuels are mainly used in transportation, electricity generation, manufacturing industries, construction, and other activities. The use of liquid fuels in these activities contributes heavily to GHG emissions and constitutes an economic constraint since the total of liquid fuels is imported from abroad. The dominant activities in which liquid fuels are used include transportation and electricity generation.

Table 1.13 Imported liquid fuels between 2006 and 2015 in Rwanda (in Tonnes)

Fuels	Motor gasoline	Jet Kerosene	Aviation gasoline	Other Kerosene	Gas/diesel oil	Residual fuel oil	LPG
2006	50,264	0	0	19,218	80,186	18,664	351
2007	51,894	0	0	16,351	104,005	15,394	559
2008	53,704	642	1	14,041	112,055	16,423	638
2009	55,321	62	90	6,427	98,958	17,512	645
2010	55,880	446	36	12,300	93,070	25,090	724
2011	62,242	1,384	35	12,422	103,282	32,034	1,023
2012	74,170	1,525	7	13,406	113,839	37,546	1,442
2013	76,671	629	0	11,300	132,308	38,234	1,580
2014	77,761	563	1	9,252	138,867	40,732	2,143
2015	87,838	953,147	100	7,142	142,281	34,184	2,814

Source: NISR (Statistical yearbooks 2009, 20013, 20015, 2016)

While the all of transportation activities rely on liquid fuels, it is estimated that approximately 40% of the total electricity in Rwanda is generated via oil-fuelled thermal power plants (REMA, 2015a). Obviously, these two subcategories contribute heavily to the national GHG emissions. However, Rwanda has a huge potential of both renewable and non-renewable (conventional) energy resources that are potentially expected to exceed the Rwanda energy needs by 2020 and replace the oil-fuelled thermal power plants.

1.6.4.2 Biomass

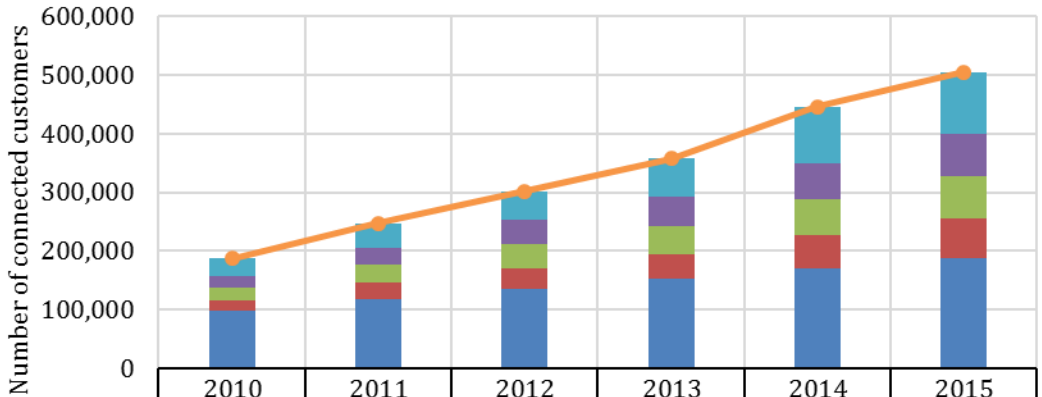
In Rwanda biomass energy resources represent remains the energy resource of all consumption. In urban areas, electric stoves and microwaves are used only to a limited extent. Commercial establishments and wealthier households in urban areas are also increasingly using Liquefied Petroleum Gas (LPG) (MININFRA, 2017). Biomass energy is consumed in the form of fuel wood, charcoal, cow dung, agriculture residues, briquettes (carbonized and non-carbonized) and biogas. Biomass energy is specially preferred fuel for cooking because it is cheaper and readily available. In 2015, biomass use for final energy was projected as follows 90% wood, 9% charcoal and 1% others including agro-residue, dung and briquette (MININFRA, 2017). Emerging modern energy for cooking are electricity, LPG and biogas the former gaining interest in urban and the latter being progressively promoted in rural areas. Most people cannot afford to use electricity for cooking because of the high tariff. The use of LPG is limited due to high initial cost.

1.6.4.3 Electricity

1.6.4.3.1. Electricity access

In Rwanda, the electrical power generation has shown a substantive increase since 2004, when the country experienced a serious power shortage and the total consumption has been growing on an annual basis, following a logarithmic trajectory. As of the end 2017, 42 % of households had access to electricity including 31 % connected to the national grid and 11% accessing electricity through off-grid facilities (REG, 2017a).

During the period between 2012 and 2015, which is the period of this assignment, electricity generation increased by 72% and access to electricity has improved but is still substantially lower than targeted. The number of connected customers increased from 187,624 to 504,065 (Figure 1.11).



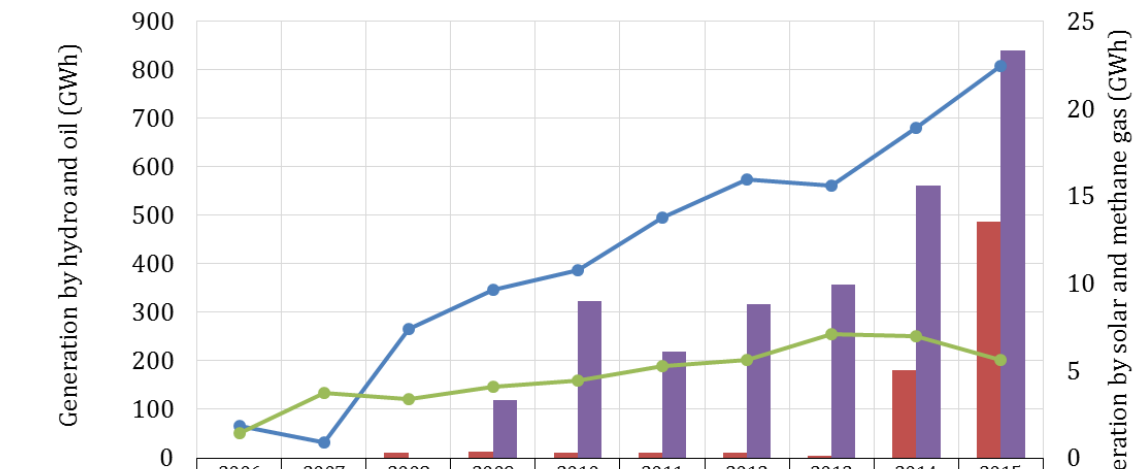
	2010	2011	2012	2013	2014	2015
West	29,383	40,709	49,529	65,347	97,023	103,825
East	20,707	30,180	41,419	48,731	61,082	72,694
South	20,822	30,180	41,419	48,731	61,082	72,694
North	18,998	26,921	33,445	40,551	55,560	66,362
Kigali	97,714	118,760	135,886	153,414	171,025	188,490
Total	187,624	246,750	301,698	356,774	445,772	504,065

Figure 1.14 Evolution in the number of connected customers between 2010 and 2015
Sources:(NISR,2014 and NISR, 2015)

Rural households with access to electricity increased from 5% to 27% over the period, but fell below the EDPRS 2 target of 50% in 2016 (MININFRA, 2016). Investments in increasing generation capacity have led to reduction in the electricity tariff for industry; however, challenges remain on ensuring reliability and consuming excess power generated. Rwanda has a very pronounced peak demand load, which was registered at 87.9 MW on average annually in 2013. Supply is occasionally unable to match demand in these peak hours. Future demand for electricity by 2017/2018 is projected to reach 470 MW and it is projected that the access will reach 100% by 2024 (MININFRA, 2016). The increase in electrical power access will greatly contribute to the economic growth of the country since priority will be given to productive users.

1.6.4.3.2. Electricity generation

As of the end 2017, the installed capacity was estimated at 216 MW (Appendix 1). The electrical power in Rwanda is mainly generated from hydro and fuel oil, which have generating facilities in Rwanda, together with the power imported from neighboring countries. The latter sources are supplemented by small-scale power sources such as small and micro hydro, together with photovoltaics. Figure 1.12shows the contribution of various energy resources to total electricity generation in Rwanda between 2006 and 2015. It is clear that the hydroelectricity had a dominant contribution to total electrical power generated during the whole period between 2006 and 2015 followed by the thermoelectricity generation (electricity generated from fuel oil and methane gas) and solar electricity had a modest contribution. The decline in the observed in the electrical power generated by fuel oil in 2015 could be explained by the implementation the Rwanda’s policy of reducing the electricity generated by the latter.

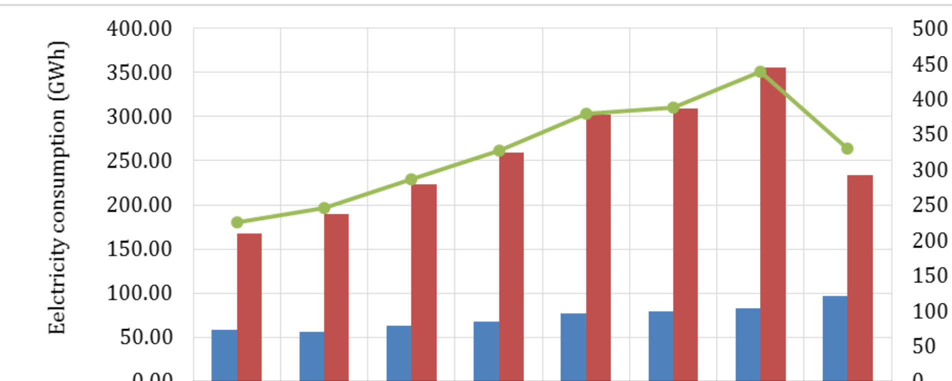


	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Solar	0	0	0.31	0.36	0.32	0.3	0.31	0.14	5.03	13.55
Methane Gas	0	0	0	3.31	8.97	6.11	8.83	9.94	15.62	23.35
Hydro	65.73	32.09	266.58	347.22	388.09	494.82	574.44	561.26	680.57	808.13
Oil	50.12	133.24	122.06	145.75	159.86	189.76	202.4	254.95	250.64	202.42

Figure 1.15 Contribution of various energy sources to electricity generated in Rwanda between 2006 and 2015
Source:(NISR, 2014 and NISR, 2015)

1.6.4.3.3. Electricity consumption

The electricity consumption profile of Rwanda between 2008 and 2015 is shown on Figure 1.13. Obviously, Households were the dominant consumers of electricity (51%), the bulk of which demand is primarily used for lighting. The industrial sector (42%) is the second largest consumer of energy, which mainly comes from motor drivers and lighting. Major industrial consumers include companies in the cement, mining, textile, and agricultural sector (including tea estates). Public sector consumption of electricity (6%) is mainly for powering public buildings, street lighting, and water pumping.



	2008	2009	2010	2011	2012	2013	2014	2015
Industries	58.00	55.51	63.06	67.73	77.38	78.73	82.90	96.26
Household	167.31	190.11	223.53	258.67	302.09	309.32	355.36	233.30
Total	225.31	245.61	286.59	326.41	379.47	388.06	438.26	329.56

Figure 1.16 Electrical energy consumption in Rwanda between 2006 and 2015
Source: (NISR, 2014 and NISR, 2015)

The electricity tariff is currently not cost reflective and heavily subsidized (MININFRA, 2016). A reliance on costly petroleum-based power generation, which was brought in temporarily to respond to an extended drought over a decade ago, has led to high costs; the cost of supplying electricity is around 50% higher than the average tariff in East Africa, and over 20% higher than the regional average in sub-Saharan Africa. Approximately US$ 56,000 is spent per day as operational expenditure on diesel imports. A combination of high-cost generation from diesel and Heavy Fuel Oils and low demand for electricity has also impeded the financial sustainability of the Utility.

1.6.4.4 Geothermal

Rwanda's geothermal power generation resources are roughly estimated at 700 MW of which 490 MW are considered feasible (MININFRA, 2015). However, this potential is yet to be confirmed. Appropriate geo-scientific studies are underway to develop necessary drilling strategies and confirm the resource potential. A quantitative estimation of Rwanda's geothermal potential would thus be premature now.

1.6.4.5 Solar Energy

Rwanda is located near equator at about 2 degrees below the equator; a region characterized by higher solar radiation intensity. Its geographical location endows it with sufficient solar energy resources and radiations. According to previous studies, the radiation intensity of Rwanda is approximated to 5kWh/m^2/day and peak sun hours of approximately 5 hours per day. Among others, the Eastern province was identified as the region with greatest potential for generating energy from solar resources (C. Museruka and A. Mutabazi., 2007).

Rwanda's total on-grid installed solar energy is 12.08 MW (Appendix 1). Households far away from the planned national grid coverage are encouraged to use Solar Photovoltaics (PVs) to reduce the cost of access to electricity. Whereas grid connected power systems are relatively new, standalone systems have been use for decades. However no studies have been conducted to assess the vulnerability. We recommended that studies on these systems should be conducted as the off-grid electricity is expected to play a role in future electricity generation of the country.

1.6.4.6 Methane Gas

Methane gas resources are found in Lake Kivu located in Eastern African Rift Zone and the Democratic Republic of Congo. It is estimated that Kivu Lake contains 60 billion cubic meters of CH_4 with an annual regeneration of 120 to 250 million cubic meters. The methane gas contained in the lake could be sufficient to generate 700 MW of electrical power over a period of 55 years. It has a potential of generating additional of 90 to 130 MW per annum. The generated power could be shared equally between Rwanda and RDC (MININFRA, 2015; REMA, 2015c). Pilot projects have demonstrated the commercial and technical viability of extracting methane for power generation and recently a 26 MW power plant was successfully installed.

1.6.4.7 Biogas

About 4,700 household and 76 institutional digesters have been constructed countrywide. From 2011, More than 200,000 stoves (Canarumwe and Canamake combined) have been disseminated. The target is 78 % of households have and use improved cook stoves all models combined by end of FY 2015/2016 and 100% by the end of 2018.

Table 1.14 Installed Biogas plants in Rwanda between 2006 and 2015

Period	Number of biogas plants
2006	82
2007	101
2008	120
2009	213
2010	627
2011	785
2012	776
2013	898
2014	1,392
2015	2,648

1.6.4.8 Peat

Currently peat is generally used for cooking and industrial heat generation. In this inventory the peat used in non-metallic mineral manufacturing industries is considered. However, Rwanda is endowed by a huge potential that could also be used for electricity generation. The theoretical potential (assuming all peat bogs are exploited) for electricity energy generation from peat is estimated to about 1,200 MW (MININFRA, 2015). However, according to a peat master plan developed in 2012, the peat-to-power potential is estimated at around 230 MW of peat generation based on estimated reserves of 12.5 million tons (JICA, 2016). The cost of electricity produced from peat is expected to be slightly higher than that from methane gas, due to the cost of peat mining. In addition, Peat is considered less risky for power generation compared to methane gas.

1.6.4.9 Hydropower

Hydroelectricity has been and is expected to remain the dominant electrical power source in Rwanda (JICA, 2016). As of the end of 2017, domestic hydropower contribution to national generation was 45.1%.

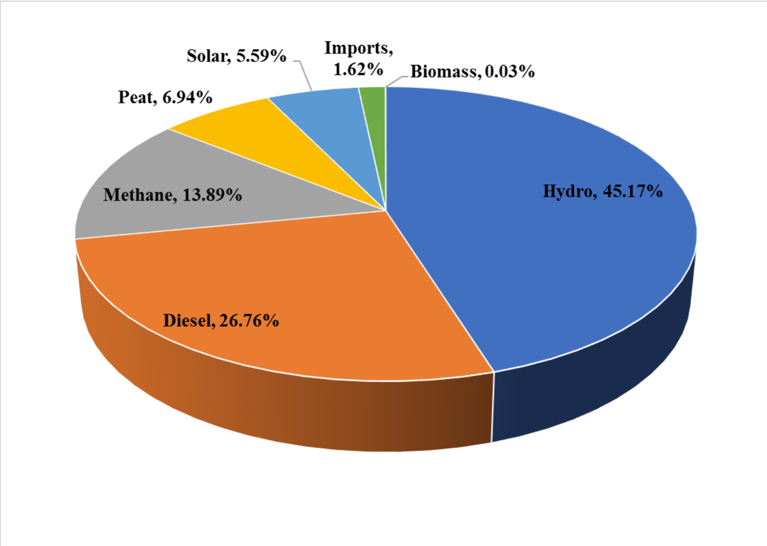


Figure 1.17 Energy mix in electricity generation in 2017 (Source EDCL)

1.6.4.10 Energy efficiency

Government is undertaking various *ad hoc* energy efficiency programs, although these are not streamlined in an energy efficiency and demand-side management strategy. Current programs include:

Compact Fluorescent Lights (CFL): Lighting is the main use of electricity in Rwanda. A CFL distribution program took place in 2007, and targeted residential customers: 400,000 CFLs were sold to the existing 95,000 beneficiaries over several phases, and 400,000 CFLs were provided to 80,000 new customers as part of a 'welcome pack'. It was estimated that 54 GWh per year were saved, along with 260,000 tCO2e.

'SolaRwanda' Solar Water Heaters (SWH): Initiated in 2012, the project aims to establish a SWH market through promotion and financial incentives to suppliers. The target is to distribute 12,000 units by 2015 with an estimated saving of 23,000MWh per year. However, currently only 800 units have been distributed, mainly due to supply and incentives issues.

Street Lighting: A pilot project was implemented by the City of Kigali to replace high-pressure sodium (HPS) lamps with LEDs in street lights. This led to a 60% reduction of power consumption from the baseline level. The financial savings or payback of the program requires further analysis in order to justify scale-up and replication.

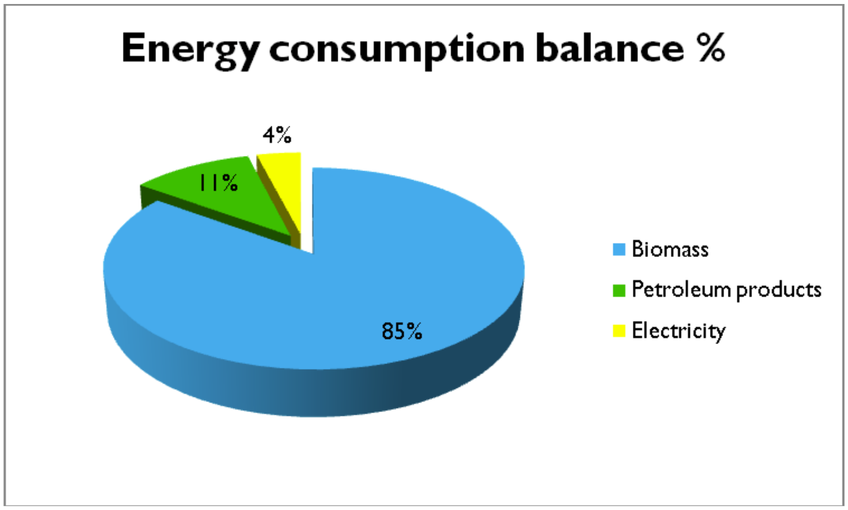


Figure 1.18 Energy consumption balance %
Source: MINENFRA, 2011, Energy policy 2011/2015

1.6.5 Transport

In Rwanda, Transport sector is dominated by land transport due to the improved national and districts road network and increased infrastructures for public transport and then the Air transport industry which is also growing fast. NISR (2015) indicates that the value added to the GDP at current prices by transport services is 3% in 2014 while the growth rate of transport services to GDP is 8% in 2014.

In Rwanda, transport is mainly done by roads with a current classified road network consisting of national roads (2749 km), district roads class 1 (3906 km) district roads class 2 (draft: 9706 km) and other unclassified roads.

The number of commercial passengers increased from 559,531 passengers in 2013 to 568,981 passengers in 2014. The number of vehicles increased also from 140,149 vehicles registered in 2013 to 152,085 vehicles registered in 2014 (NISR, 2015).

Table 1.15 Installed Biogas plants in Rwanda between 2006 and 2015

EICV4(2013/2014	% of households owning		
	Bicycle	Motorcycle	Car
All Rwanda	15.8	0.8	0.8
Urban	9.7	1.8	4.5
Rural	17	8.8	00

Source: NISR, 2016. EICV4 Thematic report Utilities and amenities

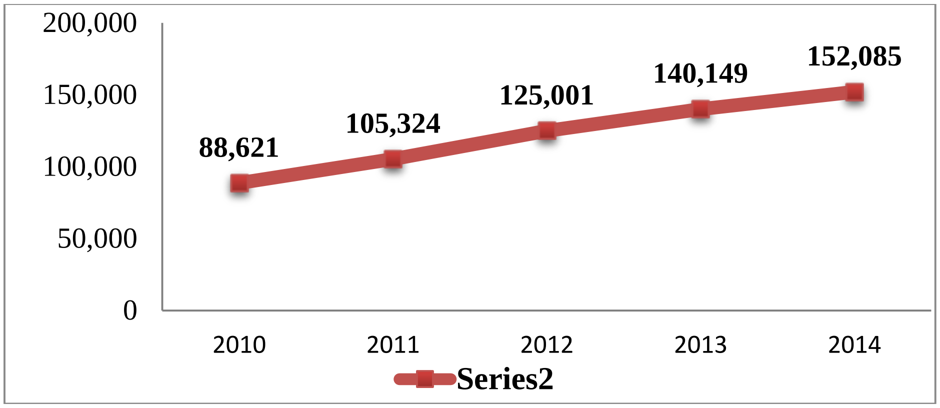


Figure 1.19 Evolution Cummulative total number of Registered Vehicles (2010-2014)
Source: *NISR, 2016. EICV4 Thematic report Utilities and amenities*

To reduce technical default related accidents on Rwanda's roads, Motor vehicle Inspection center was created as an integral part of the department of traffic and road safety at Rwanda National Police. Three lines for vehicle inspection with the engine gas emissions tester are installed and used. Other 3 branches have been established at Huye, Musanze and Rwamagana. The total number inspected by MIC is 195,388 Moto vehicles in the period from 2009 to June 2013. Motor Vehicle Inspection with mobile tester was initiated and inaugurated during World Environment Day Commemoration 2016. Government of Rwanda committed to reduce the number of imported old cars emitting toxic gases by increasing taxes on them and to set up a centre for generally to calculate air emissions in Rwanda.

1.6.6 Health

1.6.6.1. Statistics of health facilities and staff

Heath facilities in Rwanda (public and private), have increased in number from 2009 to 2015, with dominance of health centers and health posts, 40.5% and 33.2% respectively in 2015. Administratively, it is estimated that 65.5% of health facilities are public, and 19% private, and 13.9% owned by religious organizations (MoH, 2014). The numbers of staff in the health sector have also increased from 13,790 in 2009 to 18,577 in 2015. These employees were dominated by nurses (47.1%), followed by administrative workers (21.5%) and laboratory technicians (8.3%) in 2015. Medical Doctors were only 3.9% of total staff in health sector in 2015.

1.6.6.2. Prevalence of diseases (morbidity rate & mortality) from 2009 to 2015

The major indicators of presence of diseases among a population may be the number of people that visit the health facilities, categories of diseases, as well as the statistics of reported mortality. The top ten diseases that affected Rwandans from 2009 to 2015 were here reviewed depending on the availability of data. A focus has been done on diseases that have been recognized to have linkage with climate change, such as malaria, which is a vector borne disease, tuberculosis which is affected by environmental pollution and malnutrition which may indicate the persistence of food insecurity among population.

Visits to health facilities: Respiratory infections and malaria are major causes of outpatient visits to health facilities: (i) in 2010, the proportion of visits with acute respiratory infections (ARI) were 39%, and 8% with malaria (Table 4.1); (ii) In 2013, visits with respiratory infections were 52%, malaria 11% and 9% for intestinal parasites (Table 4.2); (iii) In 2014, visits with ARI were 25% and 20% for malaria (Table 4.2); In 2015, acute respiratory infection was 27.4% and 20.1 for malaria; (iv) tuberculosis suspects also increased from 68,172 cases in 2009 to 204,742 cases in 2014; (v) total visits to health facilities increased from 9.5 million in 2009 to 14.3 million in 2015. Morbidity statistics in hospitals were not reported here because the total annual visits remained less than 500,000 patients in all years observed and the first cause of morbidity in hospitals had less than 150 thousand cases per year.

Statistics of deaths: (i) total deaths reported in public health facilities increased from 7,115 cases in 2009 to 11,085 deaths in 2014 (Table 4.8); (ii) Neonatal illness and prematurity are the leading causes of death, 47% in 2013 and 41% in 2014 (Table 4.3); (iii) malaria deaths represented 13% of total deaths in 2010 (Table 4.4; MOH, 2010), and was 19.2% at district hospitals and 16.3% in 2009 (MoH, 2010), and malaria death rate has decreased to 7% in 2013 and 6% in 2014; (iv) Under 5-year proportional mortality due to malaria has decreased from 22.7% in 2009 to 3.4% in 2014; and above 5-year malaria proportional mortality has also decreased from 17.7% in 2009 to 9.4% in 2014; (v) Tuberculosis deaths remained constant from 2009 to 2014, with a rate of 5%; (vi) Statistics of malnutrition cases have been variable from 2009 to 2014, and the death rate due to malnutrition was 3% in 2010.

Table 1.16 Top ten causes of morbidity in health centers in 2010 for all age groups (MoH, 2010)

Rank	Cause of outpatient visit	Cases	%
1	Respiratory infections acute (ARI)	3,254,778	39
2	Intestinal parasites	770,094	9
3	Malaria	653,153	8
4	Diseases of bones and joints	564,673	7
5	Gastro-intestinal disorders	440,588	5
6	Diseases of teeth and gums	330,088	4
7	Skin diseases	413,543	5
8	Physical trauma	380,147	5
9	Diarrhoea	357,577	4
10	Eye diseases	208,365	2
	Other causes	1,064,844	13

Table 1.17 Top ten causes of morbidity in health centers from 2013 to 2015 for all age groups

Rank	Cause of outpatient visit	Cases in 2013	%	Cases in 2014	%	Cases in 2015	%
1	Respiratory infections acute (ARI)	2,552,814	29	2,051,749	25	3,331,300	26.4
2	Malaria	941,037	11	1,594,708	20	2,444,644	19.4
3	Intestinal parasites	777,629	9	655,416	8	694,988	5.7
4	Respiratory infections acute other	1,998,538	23	552,908	7		
5	Physical trauma and fractures	468,252	5	490,928	6		

6	Gastro-intestinal diseases	380,817	4	386,303	5	414,423	3.4
7	Tooth and gum diseases	354,212	4	374,607	5	390,618	3.2
8	Skin infections	400,364	5	356,812	4	426,423	3.5
9	Eye problems	243,007	3	286,332	4	325,572	2.6
10	Diarrhea	244,386	3	260,033	3	150,981	1.2
	Other causes of morbidity	505,002	6	1,102,970	14	3,983,057	32.8

Source: (MoH, 2014; NISR, 2014; NISR, 2015; NISR, 2016)

Table 1.18 Top 10 causes of death in health centres and district and provincial hospitals from 2012 to 2015

Rank	Cause of death	Cases in 2012	%	Cases in 2013	%	Cases in 2014	%	Case in 2015	%
1	Neonatal illness	2,722	33	2,999	33	3,825	41	1713	13.7
2	Prematurity			1,247	14			1410	11.3
3	Gyneco-obstetrical complications			883	10	762	8	338	2.7
4	Cardio-vascular disease	608	7.4	629	7	743	8	1200	9.6
5	Pneumopathies	660	8	610	7	737	8	606	4.9
6	HIV opportunistic infections	432	5.3	446	5	570	6	356	2.9
7	Malaria	603	7.4	650	7	561	6	533	4.3
8	Physical trauma, bone and joint diseases	550	6.7	469	5	534	6	478	3.8
9	Cancer and tumors	321	3.9	423	5	356	4		
10	Diarrhoea	335	4			259	3		
11	Renal and urinary track diseases					238	3		
	Other disease	1032	13	654	7	843	9		
	Total deaths					**9,428**			

Source: (MoH, 2012b; NISR, 2014; NISR, 2015)

Table 1.19 Top 10 causes of death in health centers and district hospitals in 2010 (MoH, 2010)

Rank	Cause of death	Cases	%
1	Malaria	707	13
2	ARI	589	11
3	HIV & IOS	506	9
4	Premature birth	441	8
5	Cardiac diseases	412	7
6	Tuberculosis	223	4
7	Malnutrition	192	3
8	Diarrhoea diseases	188	3
9	Malignant tumors	139	3
10	Physical injuries	125	2
	Others deaths	2025	37

1.6.7 Waste generation and management

1.6.7.1 Solid waste

Rwanda is recording a rapid urbanization process associated with rapid population growth in cities. This increase is resulting in huge waste generation and high demand in public services including solid waste management services. For instance in City of Kigali, the wastes ending into the landfill has increased from 141.38 tons/year in 2006 for the closed Nyanza landfill to 495.76 tons/year in 2015 for current Nduba landfill. A routine "collect and dump" is the dominant waste management modality in Rwandan cities. Two governance structures are observed in solid wastes collection service throughout the country after the private sector involvement in 2012. First, the waste collection services is fully provided by the private companies and paid directly by households. The service user charge is set by the public sector represented by Rwanda Utility and Regulatory Agency (RURA) in collaboration with districts and private sector. Secondly, the management of dumping sites and landfills remains in the responsibility of the Districts and the Kigali City Council. Generally, the involvement of private sector has increased the service coverage where 90% of the population in Kigali has access to solid waste collection service in 2015 from 44% in 2012. The same improvement is also happening in other cities/Towns where in 2015 an increase in service coverage was estimated to 35% from 20% in 2012.

For secondary cities, licensed private companies sign the contract with Districts and the latter pays companies using hygiene tax collected from different commercial activities. Only households in city centres and mainly commercial activities benefit from the waste collection services which explains the low service coverage in these cities. Currently, three landfills have been constructed and others are under construction in different districts. These include Nduba, Nyanza, Nyagatare, Ruhango, Huye, Kamonyi, Rwamagana, Nyamagabe, Musanze, Rubavu, Rusizi and Karongi. Nevertheless, there is an emergent need to improve wastes sorting at the source which is the main factor shaping current trend in low reuse of solid waste and consequently the increased GHG emissions from solid waste disposal sites. On this issue, the city of Kigali has started public awareness and capacity development by providing wastes sorting know-how skills to various stakeholders involved in waste management. These include, but not limited to, wastes collection companies, households and local authorities in charge of hygiene and sanitation at district and sector level.

In addition, following the increase of electronic equipment and their corresponding waste, Rwanda has commissioned in 2017 an e-waste recycling facility located in Bugesera District, Eastern Province. This facility was following the e-waste management policy for Rwanda published in 2015. According to MINICOM, the overall objective of the e-waste management project is to offer an "end –of-life" solution for electronic and electrical waste, allowing a sustainable use of Information Communication Technology (ICT) in the country, by preventing a negative impact of electronic waste on the health or the environment once the equipment has reached its end-of life.

1.6.7.2 Wastewater

The main wastewater treatment and disposal systems in City of Kigali and secondary cities are dominated by septic tanks, soakaways and direct discharge in natural wetlands. In general, there are no centralized wastewater treatment systems but the main hotels, hospitals, new real estates, major governmental buildings and some industries have installed their own treatment systems, which is a prerequisite before they get permission to begin operating. Currently, studies related to the first Kigali centralised wastewater treatment plant has been completed and approved and the construction activities are expected to start by 2018. The first phase of this project will cover the central business district of Kigali in Nyarugenge where in 2020 these areas will generate an estimated 12,000 m^3/day average flow from a population of about 120,000.In addition, according to Rwanda NDC, the country envisages to promote the recovery and reuse of black water or fecal sludge in order to restore and maintain soil fertility.

1.7. Education

The structure of the education system in Rwanda covers Pre-primary Education organized in nursery schools for a period of three years, compulsory education lasts 12 years from age 7 to 18 with primary, lower and upper secondary education and commonly known as "Twelve Year Basic Education" (12YBE) and technical and Vocational Education Trainings with 7 levels according to Rwanda Technical Qualification Framework (RTQF) and then the Higher Learning Education.

MINEDUC (2015) indicates that pre-primary education recorded a significant increase in the number of Children, staff, and schools. The number of children increased from 159,291 in 2014 to 183,658 in 2015, while that of schools increased from 2,431 in 2014 to 2,618 in 2015. The Net Enrolment Rate increased from 13.3% in 2014 to 14.2% in 2015, while the Gross Enrolment Rate increased from 17.5% in 2014 to 20.2% 2015, and thus achieving the 2014-2015 Education Sector Strategic Plan target.

Concerning the primary Education,the actual number of children enrolled in primary schools in 2015 increased by 2.1%, and the increase was generally observed all over the country. The Gross Enrolment Rate increased from 134.3% in 2014 to 135.3% in 2015, while the Net Enrolment Rate increased from 96.8% in 2014 to 96.9% in 2015.

Table 1.20 Education indictors 2015

Indicator	Gross Enrolment Rate	Net Enrolment Rate	Transition rate	Pupil Classroom Ratio
Pre-primary	20.2	14.2	-	44
Primary	135.3	96.9	71.1	80
Secondary	38.0	28.3	82.8	33

Source: MINEDUC, Education Statistical year book, 2015

Enrolment in secondary education decreased from 565,312 in 2014 to 543,936 in 2015 and this level leading to a reduction in both Gross Enrolment Rate (40.7% in 2014 to 38.0% in 2015) and Net Enrolment Rates (35.7% in 2014 to 28.3% in 2015). On the other hand, Dropout rates in Lower and Upper Secondary have significantly improved from 14.4% in 2014 to 6.5% in 2015 in lower secondary, and from 5.9% in 2014 to 2.5% in 2015 in Upper Secondary.

The number of students in TVET schools was increased from 93,024 in 2014 to 94,373 in 2015, with an increase of 1.5%. However, a decrease of 2.9% in enrollment was observed in only

Vocational Training Centres. The participation of female trainees is still low compared to that of male, which is 7,913 and 13,024 in 2015 respectively.

The total enrolled students in HLIs increased from 87,013 in 2014 to 86,315 in 2015 the female students decreased while the number of male increased. The students enrollment is more concentrated in private Higher learning institutions (49,888 students) than Public institutions. The number of Tertiary Institutions reduced from 45 institutions in 2013/2014 to 44 institutions in 2015/2016 due to the merger of five colleges/schools into the University of Rwanda. Furthermore, four newly established institutions were added to the number of Private Tertiary Institutions. In general, the number of Adult literacy centres, learners and instructors decreased in 2015. Centres reduced from 4,602 in 2014 to 4,313 in 2015, learners declined from 112,656 in 2014 to 95,829 in 2015, and instructors from 5,571 in 2014 to 540 in 2015.

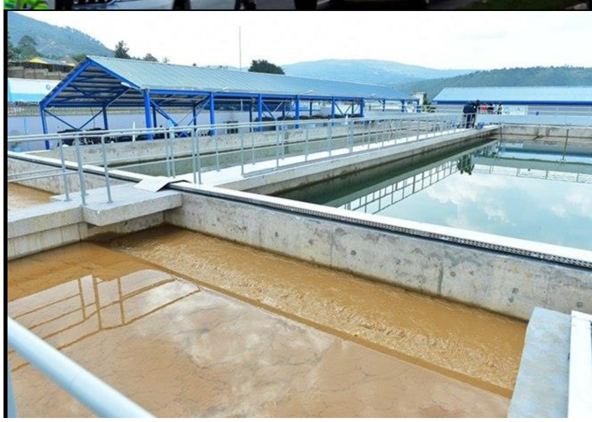
Table 1.21 Summary: Main social-economic indictors

Geographical Indicators	**Unit**	
Latitude		1^{0}04"S 2^{0}51"S
Longitude		28^{0}45"E 31^{0}15"E
Total surface area	Km2	26,338
Area under land		24,210 km2
Area under water and swamps		2,120 km2
Temperature		19.84^{0}C
Rainfall		1,230.73 millimeters
Economic indicators		
GDP at current market prices (2015)		5,837 (Frw Billions)
GDP Per capita at current market prices (2015)		720 (USD Dollars)
GDP growth rate at constant (base year) market prices		6.9%
Contribution of Agriculture to GDP at current market prices		33%
Contribution of Industry to GDP at current market prices		14%
Contribution of Services to GDP at current market prices		47%
Access to improved drinking water (EICV4)		85%
Primary source of lighting as electricity (EICV4)		19.8%
Demographic and Social-Economic Indicators		
Size of the Resident Population (4th Population and Housing Census Projection)		**11,262,564 (in 2015)**
Urban population (4th Population and Housing Census Projection) Medium scenario		2,214,421 (in 2016)
Rural population (4th Population and Housing Census Projection) Medium scenario		9,319,023 (in 2016)
Density of the urban population (4th Population and Housing Census Projection)		2,535 in 2017
Sex ratio of the population (EICV4		91.6%
Population density (4th Population and Housing Census Projection) medium scenario		467 people/km2 in 2017
Infant Mortality rate (DHS 2014/15)		32 per 1,000
Maternal mortality rate (DHS 2014/15)		210 per 100,000 live births
Life expectancy at birth (4th Population and Housing Census Projection) (2015)		66.7 (Male 63.7, Female 67.3)
Pupil Teacher ratio (Primary education 2015)		58

Pupil Classroom ratio (Primary education 2015)		80
Net secondary enrolment rate (Secondary education 2015)		28.3
Net Primary enrolment rate (Primary education 2015)		96.9
Forest cover area	%	29.2
Total wetland cover area	ha	276,477

CHAPTER 2

NATIONAL GREENHOUSE GAS INVENTORY



CHAPTER II: NATIONAL GREENHOUSE GAS INVENTORY

2.1 Introduction

This chapter presents a summary of Greenhouse gas (GHG) emissions inventory conducted in Rwanda for the period between 2006 and 2015. The inventory was conducted for anthropogenic GHG emissions from four sectors, viz., Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Land Use (AFOLU) and Waste. GHG emissions were estimated in compliance with the UNFCCC guidelines for National Communication (NC) from Parties not included in Annex I of the Convention and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Tier 1 methodology was mainly used with some country specific data such as physical characteristics of fuels, cement production, etc. Estimation of GHGs was conducted on a gas-by gas basis and estimates of the key sources, sensitivity analysis and uncertainty were provided. In addition, estimates of aggregated GHG emissions and removals expressed in CO_2 equivalent are reported. Other, indicators like CO_2/GDP and CO_2/Capita were also estimated and reported. Due to time constraints, only estimates of direct greenhouse gases, i.e., CO_2, CH_4,N_2O and HFC were considered in this inventory. It is interesting to note that, though, reporting on precursors and indirect emissions is not mandatory for Non Annex I countries, there is a need to consider these gases in future reports of national communication since they are linked with national air pollution management which is a priority for the GoR.

2.2 Brief description of institutional set up

The GHG inventory for Rwanda was developed by the GHG working group under the sole responsibility of Rwanda Environmental Management Authority (REMA) through its Single Project Implementation Unit (SPIU). REMA's Technical staffs including those from the Department of Climate Change and International Obligations (DCCIO) have been involved in technical implementation by contributing as member of GHG working group. The National Climate Change Committee (NCCC), which comprises of various stakeholders representing national institutions, were responsible for supervising the inventory report development including the evaluation of key outputs to ensure project activities are being carried out in a timely manner. The GHG working group is responsible for estimating GHG emissions and sinks in the republic of Rwanda, key sources analysis, quality assurance and quality control activities, uncertainty assessment, documentation and archiving of information related to GHG inventory preparation process.

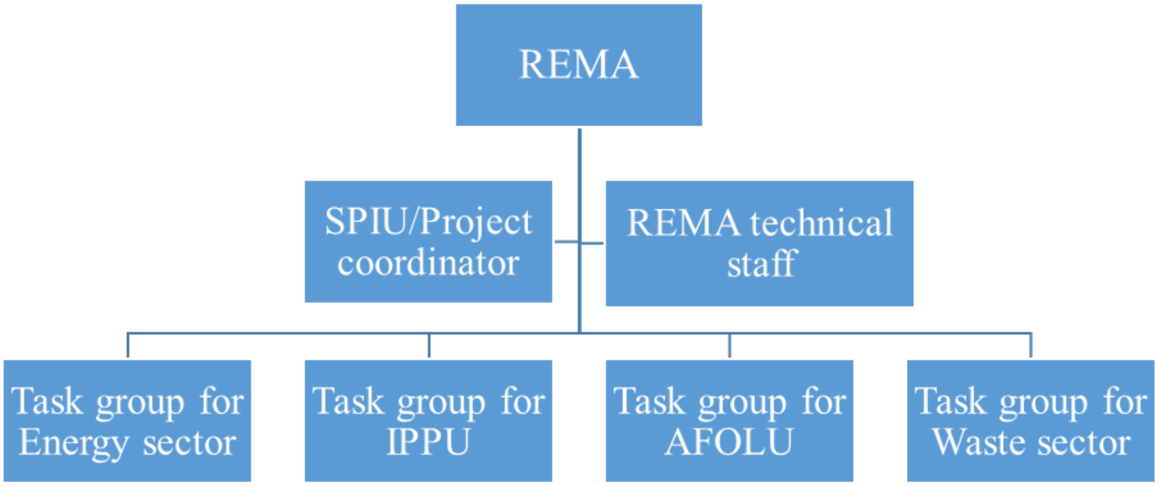


Figure 2.1 Organization chart of the Rwanda's GHG inventory working group

2.3 Methodological issues and data collection

The Rwanda's GHG inventory report was developed and structured according to the UNFCCC convention and in compliance with the 2006 IPCC guidelines. GHG emissions and their uncertainties were estimated for a period between 2006 and 2015 for energy, IPPU, AFOLU and waste sectors and their respective categories. In general, Tier 1 methodology was applied to estimate emissions of direct greenhouse gases (CO_2, CH_4, N_2O, HFCs) for all sectors and country specific data were considered where available. Activity data used for Rwanda's GHG inventory between 2006 and 2015 were mainly sourced from various stakeholders as summarized in table 2.1 below.

While the methodologies used for uncertainty assessment, quality assurance key category analysis, and completeness are provided in subsequent sections, details of the specific methodologies to various sectors are described below.

Energy GHG emissions were estimated based on both top-down (reference approach) and bottom-up (sectoral approach) methodologies, with appropriate choices of tiers as detailed in the 2006 IPCC guidelines. GHG emissions inventory was developed through different steps including the assessment of source categories to which filling data gaps was carried out, data collection, compilation of the GHG inventory, uncertainty assessment, key category analysis and reporting. Estimates on GHG were produced on a gas-by-gas basis considering direct GHGs. The 2006 IPCC software was mainly used for all categories and in general, default emission factors were used with country specific physical characteristics (Net calorific values, densities) of fuels where available. In addition, approaches used during Rwanda Second National Communication and during NAMA study for data estimation were considered. Reference and sectoral approaches were performed independently and the results from reference approach were used as a verification crosscheck of those from sectoral approach. According to the 2006 IPCC guidelines, the methodology for the reference approach was implemented via five steps as outlined below:

Step 1: Estimate Apparent Fuel Consumption in Original Units
Step 2: Convert to a Common Energy Unit

Step 3: Multiply by Carbon Content to Compute the Total Carbon
Step 4: Compute the Excluded Carbon
Step 5: Correct for Carbon Unoxidized and Convert to CO2 Emissions

In IPPU sector, GHG emissions were estimated for mineral industry metal industries, non-energy products from fuels and solvent use and product uses as substitutes for ozone depleting substances using the 2006 IPCC guidelines. For cement production, which is the main contributor to IPPU GHG emissions, an effort was used to combine Tier 1 and Tier 2 methodologies. The following input activity data and emission factors were used to compute CO_2 emissions: the types of cement produced and the clinker fraction of the cement to estimate clinker production. For the case of Rwanda, Portland cement type is produced. Data on cement production were collected from BNR (Nation Bank of Rwanda). The data collected in BNR were sent to CIMERWA for their validation at the plant level and it was reported that the clinker fraction used was 70% and a default emission factor of 0.52 was used.

GHG emissions in agriculture sector were estimated based on the national published data on livestock types and numbers, crop cultivated and harvested areas, agricultural inputs, and production volumes were collected from public and private institution reports: NISR, MINAGRI, RAB, FAOSTAT, NAEB, BNR, and RRA. For agricultural practices, Crop Research teams were consulted to describe the types of various agricultural practices applied and to record the major changes that affected them within the period of 2006-2015. Practices that altered C and N stocks in cultivated soils and specific crop were further quantified by estimating the proportions of cultivated area, where a practice was applied, and the year when the change happened. Because of large variation in quantity of urea imported and lack of the data on applied urea, three periods were considered: 2006-2008; 2009-2011 and 2012-2015. For each period, the sum, mean quantities per year and average growth rate per year were calculated. Considering this growth rate, amount of urea applied was recalculated successively. The detailed methodology is provided in the National Inventory Report.

Table 2.1 Institutions contributing to GHG inventory

Institutions	Responsibilities/data collected
Rwanda Natural Resources Authority	Data on forestry for land-use and estimation of GHG emission/sequestration in forestry, other land use, and biomass
Rwanda Agricultural Board (RAB)	Some data for livestock population, crop production data including fruits, fodder and tea, national consumption of fertilizers and soil fertility data. Estimation of GHG emissions in agriculture.
Rwanda National Institute of Statistics (NISR) Statistical Yearbooks (2006-2015)	Most of data were directly sourced from their published reports including the yearbooks
	Livestock number per type (Dairy cattle, Other cattle, Sheep, Goat, market swine, breeding swine) Manure production per livestock type (Dairy cattle, Other cattle, Sheep, Goat, market swine, breeding swine, chicken) Number of imported vehicles
MINAGRI	Imports data on Mineral fertilizer applied to soils
MINAGRI, NISR, RAB	• Wetlands organic soil cultivated area

	• Area of annual crops; Area of perennial crops; area converted to cropland; N content in compost, mulch and mineral fertilizers • Biomass quantity per crop; dead biomass applied to soil • Harvested area; biomass applied; N fertilizers applied; water regime
Rwanda Civil Aviation, NISR	Data on domestic flights
CGIS-NUR/PAREF/RNRA (2012); RNRA (2015)	• Land use/cover maps, Land use/cover change map, Land use change matrix • Biomass estimate for 5 IPCC pools (Above ground biomass, below ground biomass, deadwood, herb, litter and soil) • Land use/cover maps, Land use/cover change map, Land use change matrix • Biomass estimate for 5 IPCC pools (Above ground biomass, below ground biomass, deadwood, herb, litter and soil) • Land use/cover maps, Land use/cover change map, Land use change matrix
Rwanda Energy Group (EDCL and EUCL)	• Data on energy (General) • Data on electricity generation and distribution and other energy data. • Data on fuel consumption and fuels calorific values
Kigali city and COPED	Data on Wastewater Management and solid waste
Ministry of Trade, Industry and East African community affairs (MINEACOM) and Rwanda revenue authority (RRA)	Data on the IPPU sector and estimation, Data on liquefied petroleum gas (LPG) Data on ozone depleting substances substitutes and estimation of GHG emission from products use as ozone depleting substances
National Bank of Rwanda (BNR)	Data on lime and cement production

In waste sector, following the 2006 IPCC guideline, all disposal sites in Rwanda fall in the subcategory of unmanaged waste disposal sites as waste is disposed of on top of hills. From the expert judgment, unmanaged waste disposal sites in Rwanda were categorized into deep for Kigali, where waste is dumped into a whole of >5m deep and shallow for other cities where a big fraction of disposed of waste is dumped on the surface and small fraction dumped into a whole of <5m deep. From this observation, the expert has assumed that 60% of waste disposal sites are unmanaged deep and 40% are unmanaged shallow considering that the fraction of solid waste to SWDS is higher in Kigali than in other cities. From the expert judgment reflecting the reality of the country, only cities have disposal sites. For this, only urban areas have been the main target for this source category.

2.4 Summary of aggregated emissions/removals and trends

During the period between 2006 and 2015, the dynamic of Rwanda's GHG emissions with and without FOLU showed an increasing trend with average annual increases 4.54 % and 4.8%, respectively, while net GHG removals showed a nearly constant trend with an annual increase of 0.63% (Figure 2.2). During the whole period, GHG emissions from FOLU had a dominant contribution to net emissions, resulting in a net carbon sequestration. The increase in GHG emissions could be attributed to the Rwanda economy, the change in lifestyle, and the modernization of the agricultural sector. Rwanda recorded a rapid increase in GHG emissions during the period between 2014 and 2015.

The GHG intensity (i.e., the amount of GHG emitted per GDP) decreased from 14.4 Gg/USD in 2006 to 10.54 Gg/USD. This decrease could be explained by the rapid increase in Rwandan economy. During the same period, the GDP increased at higher rate than the GHG emissions.
The increase in GDP was estimated at 53.75 % between 2006 and 2015, while that of GHG emissions was only 36.83 % In addition, the GHG emissions per capita increased from 532.39 kg per capita to 676.23 kg per capita with an annual increase of 2.46 %(Table 2.2)

Figure 2.2 shows the trends in total GHG emissions (without FOLU) and accompanying variables (i.e., GDP, population, Fuel consumption, GHG per fuel consumption, GHG emissions from agriculture sector, GHG emissions per capita) for the period between 2006 and 2015. All the variables showed an increasing trend tracking the GDP trend, fuel consumption, and populations which are the main driver of GHG emissions in Rwanda. It is evident from the figure that the trend in GHG emissions from agriculture, which is the main economic activity in Rwanda had the same trend as the total GHG emissions.

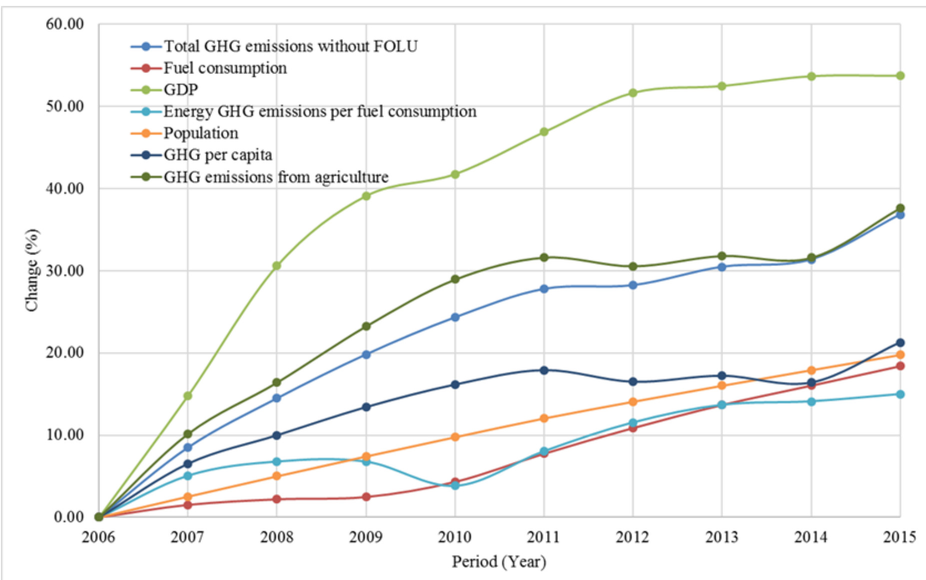
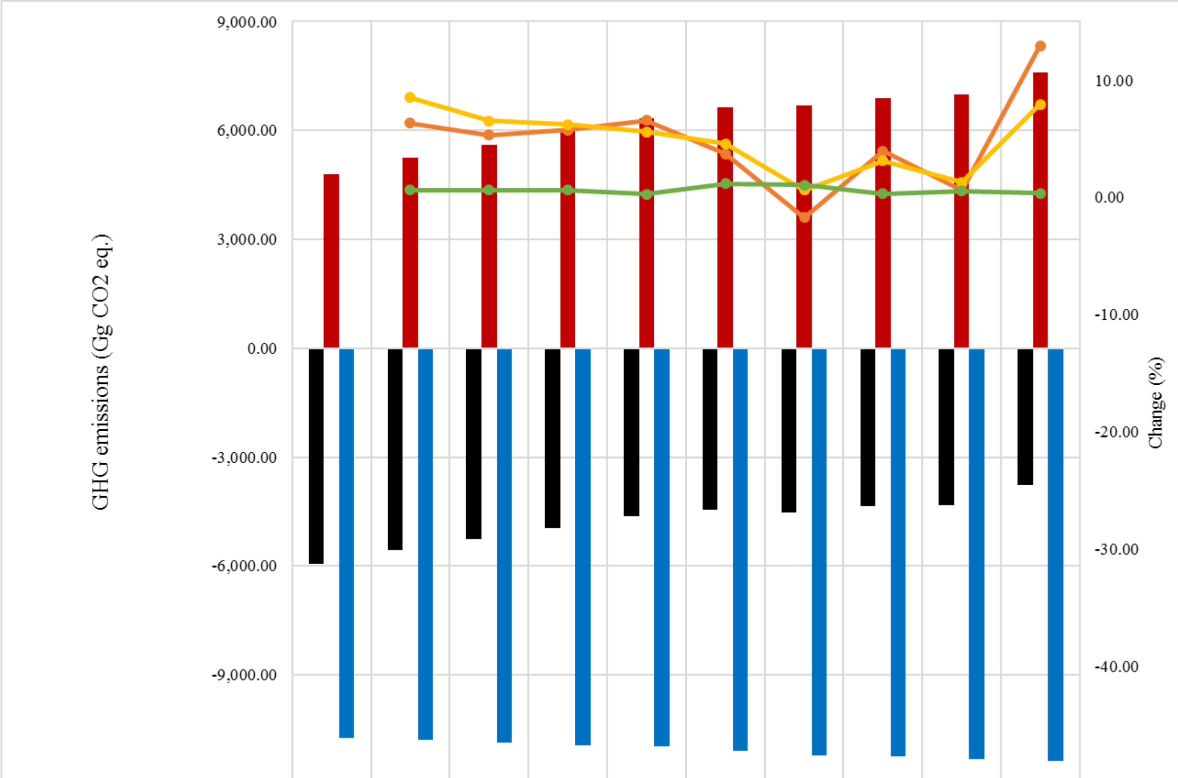


Figure 2.2 Trends in total GHG emissions and accompanying variables: GDP, population, Fuel consumption, GHG per fuel consumption, GHG emissions from agriculture sector, GHG emissions per capita



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total with FOLU	-5,933.19	-5,556.22	-5,260.04	-4,957.49	-4,632.26	-4,460.63	-4,536.70	-4,357.87	-4,330.53	-3,769.09
Total without FOLU	4,795.45	5,242.10	5,608.45	5,981.33	6,337.19	6,640.50	6,682.44	6,897.63	6,987.43	7,590.76
Total removals	-10,728.64	-10,798.32	-10,868.49	-10,938.82	-10,969.46	-11,101.13	-11,219.13	-11,255.49	-11,317.96	-11,359.85
Change in total with FOLU		6.35	5.33	5.75	6.56	3.71	-1.71	3.94	0.63	12.96
Change in toal without FOLU		8.52	6.53	6.23	5.62	4.57	0.63	3.12	1.29	7.95
Total removals		0.65	0.65	0.64	0.28	1.19	1.05	0.32	0.55	0.37

Figure 2.3 GHG Emissions/ removal and trends in emissions between 2006 and 2015

Table 2.2 Summary of GHG emissions in Rwanda between 2006 and 2015 (Gg CO2 eq.)

IPCC categories	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total National Emissions and Removals	-3,308.41	-2,784.10	-2,494.54	-1,773.82	-1,012.31	-389.84	-201.28	318.39	-3,254.45	1,605.82
1 - Energy	1,058.79	1,139.11	1,164.18	1,164.65	1,150.14	1,248.41	1,343.16	1,421.46	861.83	1,526.37
1.A - Fuel Combustion Activities	1,058.79	1,139.11	1,164.18	1,164.65	1,150.14	1,248.41	1,343.16	1,421.46	861.83	1,526.37
2 - Industrial Processes and Product Use	40.26	39.60	39.76	34.94	36.54	38.29	39.47	43.32	49.15	81.68
2.A - Mineral Industry	38.88	37.44	37.49	31.70	32.21	32.79	31.51	34.63	38.13	69.11
2.C - Metal Industry	NE	0.0036	0.0088	0.0479	0.0709	0.6995	1.8779	1.5940	2.1951	1.5174
2.D – Non-Energy Products from Fuels and Solvent Use	0.9592	1.32	0.99	1.47	2.06	2.09	2.81	2.81	3.20	3.88
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0.42	0.84	1.27	1.72	2.20	2.71	3.26	4.29	5.63	7.18
3 - Agriculture, Forestry, and Other Land Use	-4,769.72	-4,352.96	-4,113.86	-3,410.63	-2,656.88	-2,153.76	-2,081.17	-1,688.72	-4,183.34	-639.49
3.A - Livestock	1,360.06	1,521.75	1,664.70	1,729.65	1,846.73	1,760.94	1,730.81	1,725.91	59.02	1,808.56
3.B - Land	-10,728.64	-10,798.32	-10,868.49	-10,938.82	-10,969.46	-11,101.13	-11,219.13	-11,255.49	-11,317.96	-11,359.85
3.C - Aggregate sources and non-CO2 emissions sources on land	4,598.86	4,923.61	5,089.93	5,798.55	6,465.85	7,186.42	7,407.15	7,840.86	7,075.59	8,911.80
4 - Waste	362.26	390.14	415.38	437.22	457.89	477.22	497.26	542.33	17.91	637.27
4.A - Solid Waste Disposal	24.04	41.51	54.68	64.93	73.04	79.82	85.70	119.22	7.28	186.99
4.B - Biological Treatment of Solid Waste	105.50	110.44	115.62	121.04	126.71	132.65	140.36	145.38	2.59	159.33
4.C - Incineration and Open Burning of Waste	1.06	1.08	1.12	1.14	1.17	1.20	1.23	1.26	1.15	1.32
4.D - Wastewater Treatment and Discharge	231.67	237.11	243.97	250.11	256.97	263.54	269.98	276.47	6.89	289.63
International Bunkers	5.17	5.02	2.05	0.55	1.52	4.51	4.51	2.00	1.78	0.31
1.A.3.a.i - International Aviation (International Bunkers)	5.17	5.02	2.05	0.55	1.52	4.51	4.51	2.00	1.78	0.31

Table 2.3 Trends in GHG emissions in Rwanda between 2006 and 2015 (Gg CO2 eq.)

IPCC categories	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total National Emissions and Removals	-5,933.19	-5,556.22	-5,260.04	-	-	-	-	-	-	-
1 - Energy	1,058.79	1,139.11	1,164.18	1,164.65	1,150.14	1,248.41	1,343.16	1,421.46	1,438.43	1,526.37
1.A - Fuel Combustion Activities	1,058.79	1,139.11	1,164.18	1,164.65	1,150.14	1,248.41	1,343.16	1,421.46	1,438.43	1,526.37
1.A.1 - Energy Industries	91.73	95.94	58.03	104.99	105.67	130.34	143.78	179.54	183.60	144.99
1.A.2 - Manufacturing Industries and Construction	38.34	48.85	48.66	46.55	43.09	48.84	47.32	56.29	72.34	92.60
1.A.3 - Transport	301.94	369.40	432.87	394.17	355.50	393.54	458.29	468.53	487.05	547.35
1.A.4 - Other Sectors	626.77	624.92	624.62	618.94	645.87	675.68	693.78	717.10	695.43	741.44
2 - Industrial Processes and Product Use	40.26	39.60	39.76	34.94	36.54	38.29	39.47	43.32	49.15	81.68
2.A - Mineral Industry	38.88	37.44	37.49	31.70	32.21	32.79	31.51	34.63	38.13	69.11
2.A.1 - Cement production	38.10	36.84	36.84	30.88	31.38	31.47	29.63	31.39	35.97	65.44
2.A.2 - Lime production	0.79	0.60	0.65	0.81	0.83	1.32	1.88	3.24	2.16	3.67
2.C - Metal Industry	NO	0.0036	0.01	0.05	0.07	0.70	1.88	1.59	2.20	1.52
2.C.1 - Iron and Steel Production	NO	0.0008	0.0020	0.01	0.02	0.62	1.76	1.47	2.05	1.41
2.C.2 - Ferroalloys Production	NO	0.0028	0.01	0.04	0.06	0.08	0.12	0.12	0.15	0.11
2.D – Non-Energy Products from Fuels and Solvent Use	0.96	1.32	0.99	1.47	2.06	2.09	2.81	2.81	3.20	3.88
2.D.1 - Lubricant Use	0.78	1.28	0.99	1.11	1.42	1.52	1.98	1.93	2.05	2.47
2.D.2 - Paraffin Wax Use	0.18	0.04	0.0015	0.36	0.64	0.57	0.84	0.88	1.15	1.40
2.F - Product Uses as Substitutes for Ozone Depleting	0.42	0.84	1.27	1.72	2.20	2.71	3.26	4.29	5.63	7.18
2.F.1 - Refrigeration and Air Conditioning	0.42	0.84	1.27	1.72	2.20	2.71	3.26	4.29	5.63	7.18
3 - Agriculture, Forestry, and Other Land Use	-7,394.51	-7,125.08	-6,879.36	-	-	-	-	-	-	-
3.A - Livestock	1,360.06	1,521.75	1,664.70	1,729.65	1,846.73	1,760.94	1,730.81	1,725.91	1,526.04	1,808.56
3.A.1 - Enteric Fermentation	979.55	1,116.74	1,181.37	1,213.23	1,303.64	1,207.01	1,173.80	1,174.16	1,147.18	1,283.75
3.A.2 - Manure Management	380.51	405.02	483.32	516.42	543.08	553.93	557.02	551.76	378.86	524.81
3.B - Land	-10,728.64	-10,798.32	-10,868.49	-10,938.82	-10,969.46	-11,101.13	-11,219.13	-11,255.49	-11,317.96	-11,359.85
3.B.1 - Forest land	-10,728.64	-10,798.32	-10,868.49	-10,938.82	-10,969.46	-11,101.13	-11,219.13	-11,255.49	-11,317.96	-11,359.85
3.C - Aggregate sources and non-CO2 emissions sources on land	1,974.08	2,151.49	2,324.44	2,614.87	2,845.90	3,115.64	3,071.73	3,164.60	2,931.11	3,536.89
3.C.3 - Urea application	1,246.42	1,317.63	1,326.42	1,514.03	1,731.23	1,948.44	2,065.98	2,224.42	2,283.19	2,559.04
3.C.4 - Direct N2O Emissions from managed soils	368.82	392.99	526.02	584.54	637.81	675.36	560.60	508.17	342.75	540.31
3.C.5 - Indirect N2O Emissions from managed soils	132.28	140.43	175.31	201.78	212.08	222.46	196.57	185.07	115.24	191.03
3.C.6 - Indirect N2O Emissions from manure management	108.02	119.03	129.99	136.87	147.58	138.49	145.47	146.77	98.96	148.18
3.C.7 - Rice cultivations	118.54	181.40	166.69	177.66	117.20	130.89	103.11	100.17	90.98	98.33
4 - Waste	362.26	390.14	415.38	437.22	457.89	477.22	497.26	542.33	507.51	637.27
4.A - Solid Waste Disposal	24.04	41.51	54.68	64.93	73.04	79.82	85.70	119.22	152.82	186.99
4.B - Biological Treatment of Solid Waste	105.50	110.44	115.62	121.04	126.71	132.65	140.36	145.38	118.37	159.33
4.C - Incineration and Open Burning of Waste	1.06	1.08	1.12	1.14	1.17	1.20	1.23	1.26	1.24	1.32
4.D - Wastewater Treatment and Discharge	231.67	237.11	243.97	250.11	256.97	263.54	269.98	276.47	235.08	289.63
International Bunkers	5.17	5.02	2.05	0.55	1.52	4.51	4.51	2.00	1.79	0.31
1.A.3.a.i - International Aviation (International Bunkers)	5.17	5.02	2.05	0.55	1.52	4.51	4.51	2.00	1.79	0.31

Table 2.4 Summary of total GHG emissions, removals and total GHG emissions without FOLU and accompanying variables in Rwanda between 2006 and 2015

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total GHG emissions with FOLU (Gg CO2 eq.)	-5,933.19	-5,556.22	-5,260.04	-4,957.49	-4,632.26	-4,460.63	-4,536.70	-4,357.87	-4,330.53	-3,769.09
Change with respect to 2006 (%)	0.00	6.35	5.33	5.75	6.56	3.71	-1.71	3.94	0.63	12.96
Change with respect to previous year		6.78	5.63	6.10	7.02	3.85	-1.68	4.10	0.63	14.90
GHG emissions without FOLU (Gg CO2	4,795.45	5,242.10	5,608.45	5,981.33	6,337.19	6,640.50	6,682.44	6,897.63	6,987.43	7,590.76
Change with respect to 2006 (%)	0.00	8.52	14.50	19.83	24.33	27.78	28.24	30.48	31.37	36.83
Change with respect to previous year		8.52	6.53	6.23	5.62	4.57	0.63	3.12	1.29	7.95
Total removals (Gg CO2 eq.)	-10,728.64	-10,798.32	-10,868.49	-10,938.82	-10,969.46	-11,101.13	-11,219.13	-11,255.49	-11,317.96	-11,359.85
Change with respect to 2006 (%)	0.00	0.65	1.29	1.92	2.20	3.36	4.37	4.68	5.21	5.56
Change with respect to previous year		0.65	0.65	0.64	0.28	1.19	1.05	0.32	0.55	0.37
Total fuel consumption (TJ)	80,693.50	81,947.50	82,512.67	82,750.10	84,347.48	87,484.26	90,555.65	93,508.50	96,120.12	98,908.21
Change with respect to 2006 (%)	0.00	1.53	2.20	2.49	4.33	7.76	10.89	13.70	16.05	18.42
Change with respect to previous year		1.53	0.68	0.29	1.89	3.59	3.39	3.16	2.72	2.82
GDP (USD)	333.00	391.00	480.00	547.00	572.00	627.00	689.00	701.00	719.00	720.00
Change with respect to 2006 (%)	0.00	14.83	30.63	39.12	41.78	46.89	51.67	52.50	53.69	53.75
Change with respect to previous year		14.83	18.54	12.25	4.37	8.77	9.00	1.71	2.50	0.14
GHG Emission per GDP (Gg/USD)	14.40	13.41	11.68	10.93	11.08	10.59	9.70	9.84	9.72	10.54
Change with respect to 2006 (%)	0.00	-7.41	-23.25	-31.70	-29.98	-35.97	-48.48	-46.35	-48.18	-36.59
Change with respect to previous year		-7.41	-14.74	-6.85	1.30	-4.61	-9.20	1.43	-1.25	7.82
Energy GHG Emission per fuel (Ton/TJ)	13.12	13.82	14.08	14.07	13.64	14.27	14.83	15.20	15.27	15.43
Change with respect to 2006 (%)	0.00	5.08	6.79	6.77	3.83	8.05	11.54	13.68	14.10	14.98
Change with respect to previous year		5.08	1.81	-0.02	-3.16	4.40	3.79	2.43	0.48	1.02
Population	9,007,467.00	9,241,661.00	9,481,944.00	9,728,475.00	9,981,415.00	10,240,932.00	10,482,641.00	10,725,541.00	10,973,254.00	11,225,190.00
Change with respect to 2006 (%)	0.00	2.53	5.00	7.41	9.76	12.04	14.07	16.02	17.91	19.76
Change with respect to previous year		2.53	2.53	2.53	2.53	2.53	2.31	2.26	2.26	2.24
GHG emissions per capita (kg per capita)	532.39	567.22	591.49	614.83	634.90	648.43	637.48	643.10	636.77	676.23
Change with respect to 2006 (%)	0.00	6.54	9.99	13.41	16.15	17.90	16.49	17.22	16.39	21.27
Change with respect to previous year (%)		6.14	4.10	3.80	3.16	2.09	-1.72	0.87	-0.99	5.83
GHG emissions from agriculture	3,334.14	3,673.24	3,989.13	4,344.52	4,692.63	4,876.58	4,802.54	4,890.52	4,873.99	5,345.44
Change with respect to 2006 (%)	0.00	10.17	16.42	23.26	28.95	31.63	30.58	31.82	31.59	37.63
Change with respect to previous year		9.23	7.92	8.18	7.42	3.77	-1.54	1.80	-0.34	8.82

Source: GDP and population data were sourced from the statistical yearbooks: 20012, 2014, 2015 and 2016

2.5 Key category analysis

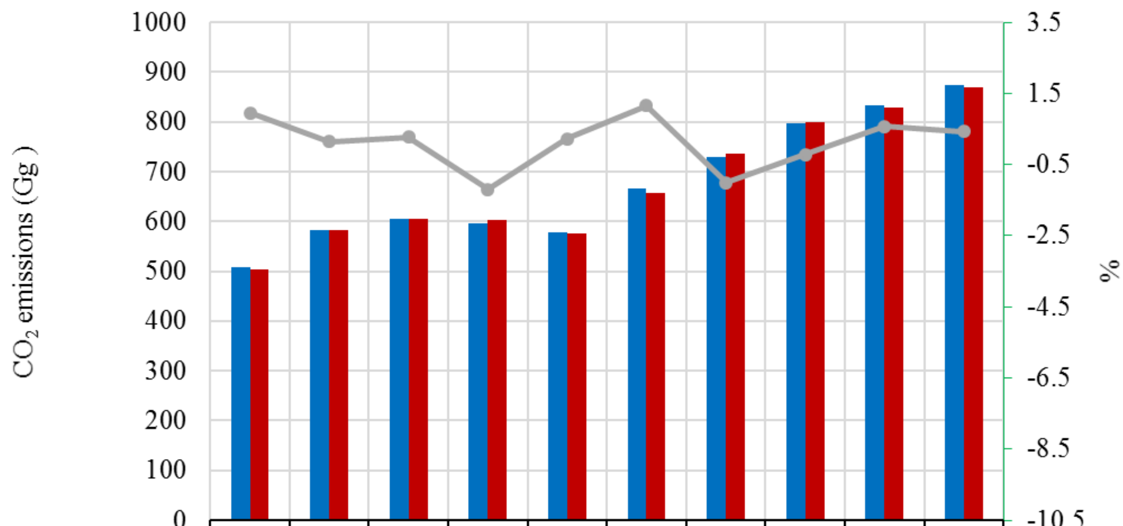
Key categories refer to sources/sinks that deserve special attentions within the national inventory system because their estimated direct GHG emissions have significant contribution to the country's total direct GHG emissions, in terms of both absolute level and trends in GHG emissions. According to 2006 IPCC guidelines, it is good practice to identify key source categories and related gases as it could help the government to prioritize efforts in the improvement of the overall quality of national inventory. In this inventory, key categories and corresponding key gases were identified based on tier 1 methodology of the 2006 IPCC guidelines and both level and trends analyses were conducted. The percentages of contributions to both levels and trends in GHG emissions were calculated and sorted in descending fashion using the 2006 IPCC software and 95% cumulative contribution threshold has been applied as an upper boundary for key category identification. Based trend analysis, 6 source/sink categories were identified (**Table 2.5**) as the main contributors to total direct GHG emissions in Rwanda between 2006 and 2015, while 12 source/sink were identified using a level analysis. As it could be seen from the table, identified key categories are mostly from Agriculture, Forestry and Land Use (AFOLU) and energy sectors, which are the main economic activities in Rwanda.

Table 2.5 Summary of key source categories and related key gases in Rwanda between 2006 and 2015

Key Categories by source/sink	Key gases	Trend Analysis (2006-2015)	Level Analysis (2015)	2015 GHG Emissions and removals (CO2 eq.)	Contribution to level assessment
Forest land Remaining Forest	CO2	X	X	-11,359.85	62.42
Urea application	CO2	X	X	2,559.04	14.06
Enteric Fermentation	CH4		X	1,283.75	7.05
Direct N2O Emissions from	N2O		X	540.31	2.97
Road Transportation	CO2	X	X	534.50	2.94
Other Sectors – Biomass	CH4	X	X	534.00	2.93
Manure Management	N2O		X	466.61	2.56
Indirect N2O Emissions from	N2O		X	191.03	1.05
Solid Waste Disposal	CH4	X	X	186.99	1.03
Wastewater Treatment and	N2O		X	151.58	0.83
Indirect N2O Emissions from	N2O		X	148.18	0.81
Energy Industries - Liquid Fuels	CO2		X	144.51	0.79
Rice cultivations	CH4	X	X	98.33	0.54

2.6 Comparison of GHG emissions from reference and sectoral approaches

In this chapter, both reference and sectoral approach were implemented separately to estimate the carbon dioxide (CO_2) emissions from energy sector and the results were compared. According to 2006 IPCC guidelines, their comparability is a good indication of the Quality Assurance (QA) and Quality Control (QC) for the sectoral approach. GHG emissions were estimated for a period of 10 years from 2006 to 2015. Obviously, results from the two approaches were slightly different with differences ranging from -1.19% to 1.16%. Clearly, these differences are in the acceptable range of the 2006 IPCC guidelines. Obviously, these results are good indication of the Quality Assurance (QA) and Quality Control (QC) the sectoral approach.

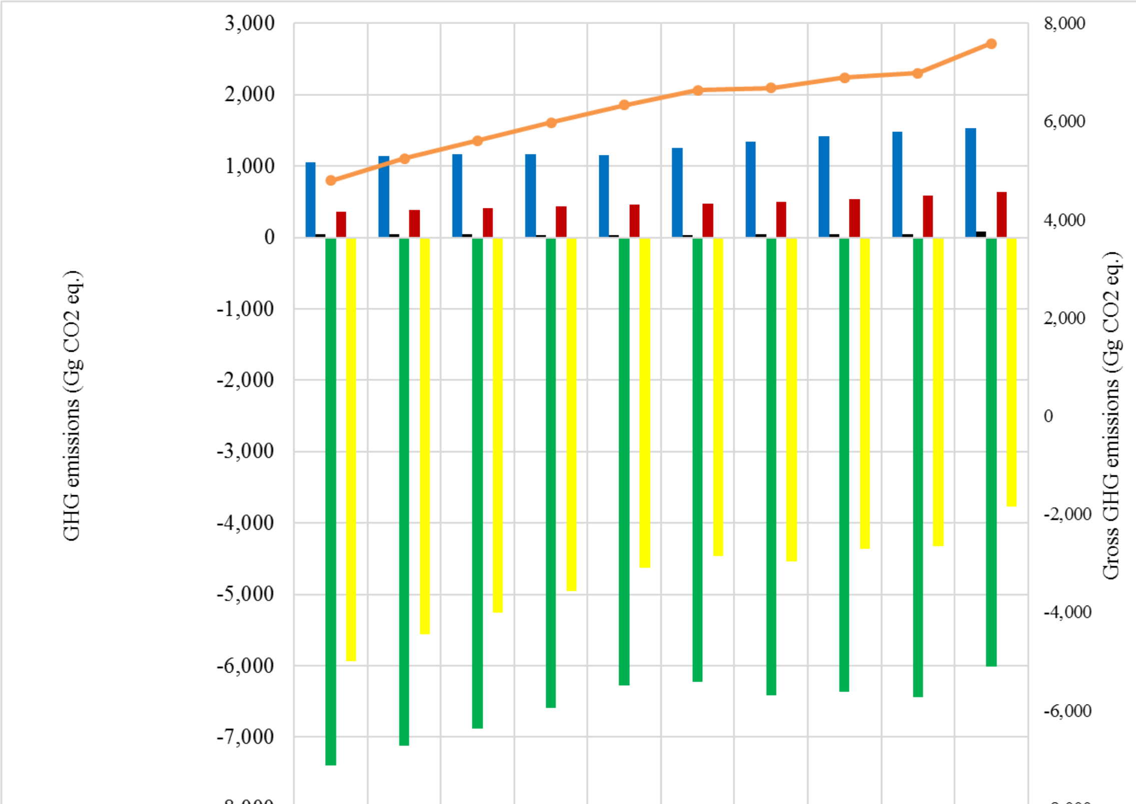


	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Reference approach	508.98	582.64	606.18	596.89	577.12	665.92	729.28	797.41	834.36	872.86
Sectoral approach	504.11	581.78	604.55	604.098	575.87	658.3	736.71	799.16	829.58	869.08
Difference	0.96	0.15	0.27	-1.19	0.22	1.16	-1.01	-0.22	0.58	0.43

Figure 2.4 Comparison of CO2 Emissions Estimated by using Reference and Sectoral Approaches in Rwanda between 2006 and 2015

2.7 Emission trend by sector

The GHG emissions from various sectors and their trends during the period between 2006 and 2015 are presented in Figure 2.5 where the energy and waste sectors were the dominant contributors to total GHG emissions, while the IPPU sector had the least contribution.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Energy	1,058.79	1,139.11	1,164.18	1,164.65	1,150.14	1,248.41	1,343.16	1,421.46	1,475.12	1,526.37
IPPU	40.26	39.60	39.76	34.94	36.54	38.29	39.47	43.32	49.15	81.68
AFOLU	-7,394.51	-7,125.08	-6,879.36	-6,594.30	-6,276.83	-6,224.55	-6,416.59	-6,364.98	-6,443.97	-6,014.41
Waste	362.26	390.14	415.38	437.22	457.89	477.22	497.26	542.33	589.17	637.27
Total emissions with FOLU	-5,933.19	-5,556.22	-5,260.04	-4,957.49	-4,632.26	-4,460.63	-4,536.70	-4,357.87	-4,330.53	-3,769.09
Total emissions without FOLU	4,795.45	5,242.10	5,608.45	5,981.33	6,337.19	6,640.50	6,682.44	6,897.63	6,987.43	7,590.76

Figure 2.5 Summary and trends in total GHG emissions and removals in Rwanda between 2006 and 2015

For the period between 2006 and 2012, removals from Forestry and Land Use (FOLU) activities had a dominant contribution to total GHG emissions with FOLU, resulting in net GHG emissions sequestration. However, during the period between 2012 and 2015, GHG emissions dominated following the economic development of the country and the modernization of agricultural activities.

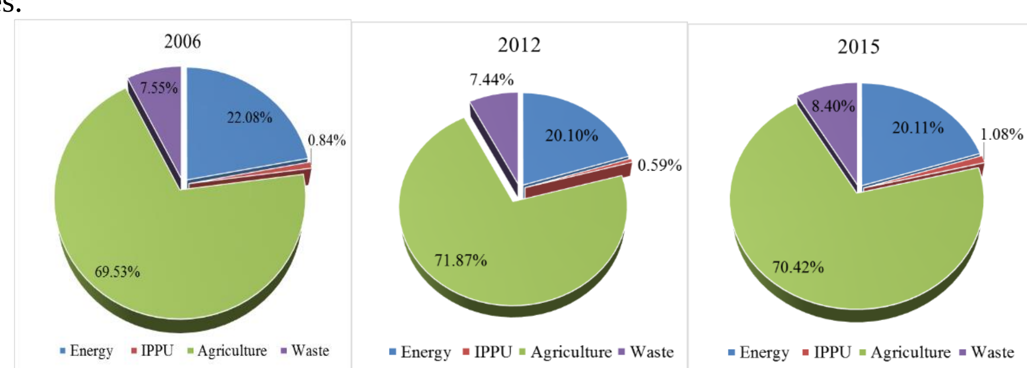
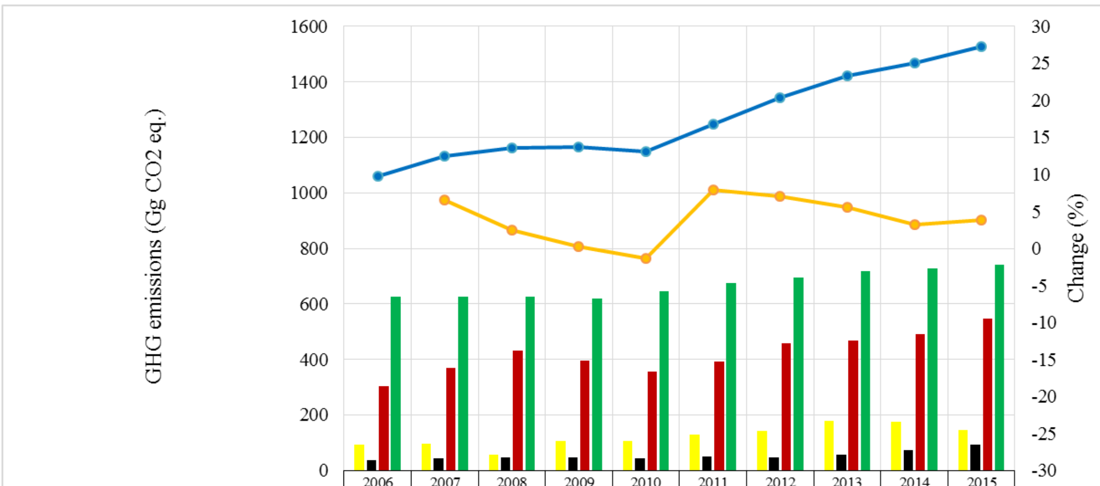


Figure 2.6 Contribution of various sectors to total GHG emissions in 2006, 2012 and 2015

Contributions of various sectors to Rwanda's total GHG emissions without FOLU were analyzed for three years, viz., the base year (2006), the reference year (2012), and the end year (2015) (Figure 2.6).For all the three years agriculture subsector remained at the top of the list with contributions of 69.53 %, 71.87 %, and 70.42 % in 2006, 2012 and 2015, respectively.

2.7.1 Energy sector

Estimated GHG emissions from energy sector between 2006 and 2015 showed increasing trend with an annual increase of 4.2%. Obviously, the increase in GHG emissions followed the trends in both fuels consumption and GDP.

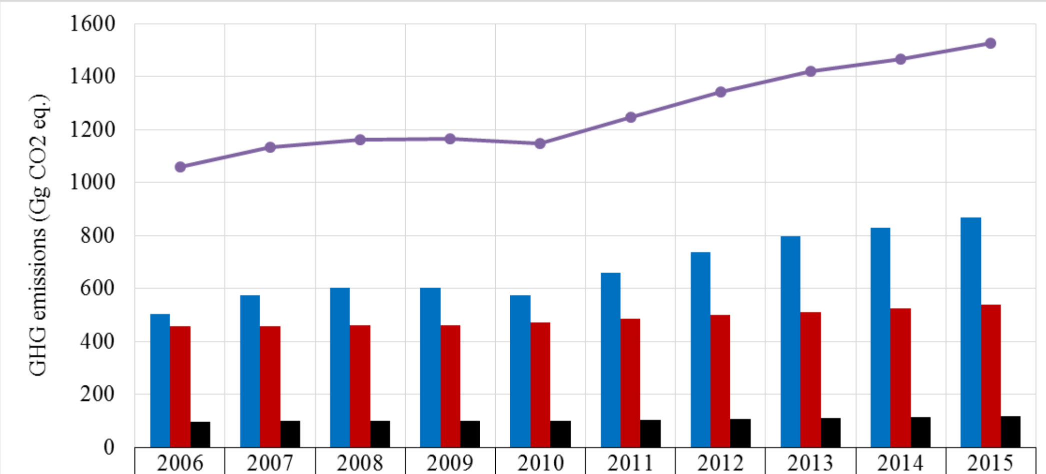


	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Energy industries	91.73	95.94	58.03	104.99	105.67	130.36	143.78	179.54	176.84	144.99
Manufacturing industries and construction	38.34	42.48	46.05	46.55	43.08	48.85	47.33	56.29	73.25	92.59
Transport	301.94	369.4	432.87	394.17	355.5	393.54	458.29	468.53	489.56	547.35
Other sectors	626.77	624.92	624.62	618.94	645.43	675.68	693.78	717.1	728.56	741.44
Total	1,058.78	1,132.74	1,161.57	1,164.65	1,149.68	1,248.43	1,343.18	1,421.46	1,468.21	1,526.37
Change		6.53	2.48	0.26	-1.30	7.91	7.05	5.51	3.18	3.81

Figure 2.7 GHG emissions from energy sector in Rwanda between 2006 and 2015

The results of key category analysis (Table 2.5) showed that other sectors (liquid fuels & biomass), road transportation, manufacturing industries and construction (liquid fuels) energy industries (liquid fuels) to be the top categories. In the second national communication (SNC), only other sector and transportation were the only key categories. The rise of manufacturing industries and construction and energy industries to the list of key sources could be attributed to the recent development in industrial and energy sectors.

A gas per gas analysis revealed that CO_2 was the dominant contributor to energy GHG emissions followed by CH_4, while N_2O had the minute contribution to total GHG emissions from energy sector (Figure 2.8)for the whole period between 2006 and 2015. During the reference year (2012), the shares of various greenhouse gases were 54.85 %, 37.12 %, 8.03 % for CO_2, CH_4, and N_2O, respectively. CO_2 emissions were mainly generated from combustion activities of liquid fuels in transportation and electricity generation, while emissions of CH_4 and N_2O were mainly generated from combustion activities of biomass in households and institutions/commercial activities.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CO2	504.11	575.43	601.95	604.1	575.42	658.32	736.72	799.17	829.57	869.08
CH4	457.75	458.95	460.13	461.3	473.19	485.73	498.62	511.64	524.89	539.86
N2O	96.93	98.37	99.49	99.25	101.08	104.38	107.84	110.65	113.74	117.43
Total	1,058.7	1,132.7	1,161.5	1,164.6	1,149.6	1,248.4	1,343.1	1,421.4	1,468.2	1,526.3

Figure 2.8 Shares of various GHG emissions to total emission from energy sector in Rwanda between 2006 and 2015

The analysis of key gases revealed that other Sectors – Biomass (CH_4), Road Transportation (CO_2), Energy Industries - Liquid Fuels (CO_2), Manufacturing industries and construction-liquid fuel (CO_2), Other Sectors – Biomass (N_2O), Sectors - Liquid Fuels (CO_2) are the top contributors to total GHG emissions from energy sector. In addition, a consistent time series was observed in the estimated GHG emissions and in the comparison with the results of the second national communication.

2.7.1.1 Planned improvement in energy sector

Though a consistent time series was obtained in GHG emissions from energy sector, there are still some data gaps related to reporting system. Data for biomass used in charcoal production are not disaggregated with the data of produced charcoal. In future, these gaps could be filled by improving the reporting system and encourage all the companies and cooperatives involved in this category to keep records of their data activities. Another challenge faced was the possibility to use country specific data, especially for calorific values, densities, emission factors, etc. In future, this challenge could be handled through appropriate research and technical advisory for the companies involved in energy generation. Other areas of improvement related to biomass include the following:

- Conduct survey on biomass fuel consumption in household,
- Considering fugitive emissions from biogas plants
- Conduct surveys on biomass consumption in brick manufacturing industries

In transport sector, they are still some gaps in data, especially on the level of aggregation. The following improvement could help to tackle this problem and contribute to a better estimate of GHG emissions:

- Data collection on the age of vehicles

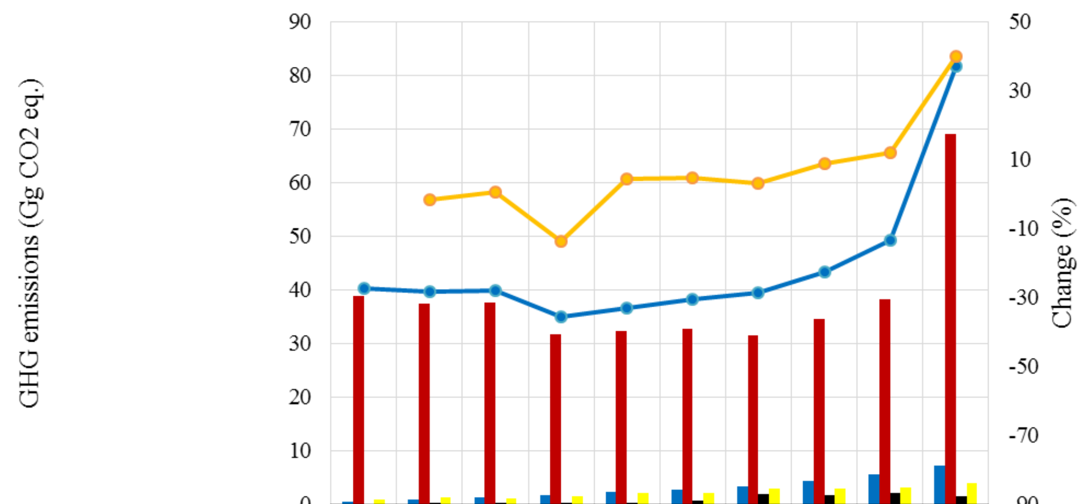
- Data collection on fuel consumption per categories and characteristics of vehicles and airplanes
- Data collection on vehicle travelled kilometres
- Disaggregation between vehicle fuel consumption in transport and other sectors that use petroleum products such as household, industries and institution/commercial activities.

GHG emissions generated by methane gas combustion for electricity generation were not considered in this inventory chiefly due to the lack necessary data to be included in the calculation methodologies. In future inventories, this issue should also be handled through appropriate researches and measurements on physical characteristics and emissions factors of methane gas. In addition, data on Fugitive Emissions from Lake Kivu energy projects should be considered in future inventories.
Further improvement on data collection on various fuels (such as diesel, kerosene, LPG) used in household and institution/commercial activities should also be given special attentions since these activities are the main contributors to Rwanda's total GHG emissions.

2.7.2 IPPU sector

During the period between 2006 and 2015, IPPU sector had the least contribution to total GHG emissions in Rwanda. Estimated GHG emissions were mainly generated from (i) 2A mineral industry, (ii) 2.C metal industry, (iii) 2D Non-Energy Products from Fuels and Solvent Use and, (iv) 2F product use as substitutes of ozone depleting substances. Nevertheless, the sub-sectors that are applicable considering Rwanda circumstances are: (i) 2A mineral industry: 2A1: cement production and 2A2: lime production; (ii) 2.C metal industry: 2C.1 iron and steel production and 2C.2 ferroalloys production; (iii) 2D Non-Energy Products from Fuels and Solvent Use: 2.D.1 Lubricant use and 2.D.2 Paraffin Wax use; and (iv) 2F product use as substitutes of ozone depleting substances: refrigeration and air conditioning.

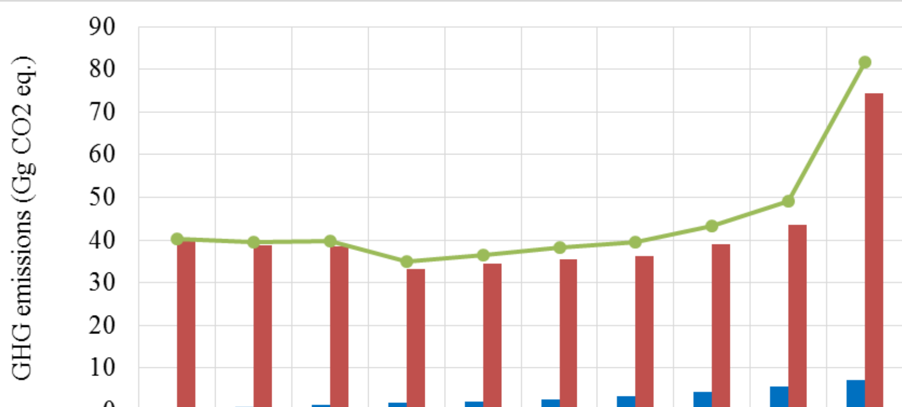
Overall greenhouse gas emissions in IPPU sector gradually increased during the ten years period at an annual growth rate of 8 %. The gas per gas analysis shows that the main gas emissions are from carbon dioxide, which contributed 94% of the total emissions in ten years average. Whereas HFCs are only generated from the product use as substitute for ozone depleting substances, the CO_2 emissions are generated by mineral industries, metal industries, and non-energy products from fuels and solvent use.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Product Usesas Substitutes for ODS	0.42	0.84	1.27	1.72	2.20	2.71	3.26	4.29	5.63	7.18
Mineral Industry	38.88	37.44	37.49	31.70	32.21	32.79	31.51	34.63	38.13	69.11
Metal Industry	0.00	0.00	0.01	0.05	0.07	0.70	1.88	1.59	2.20	1.52
Non-Energy Products from Fuels and Solvent Use	0.96	1.32	0.99	1.47	2.06	2.09	2.81	2.81	3.20	3.88
Total	40.26	39.60	39.76	34.94	36.54	38.29	39.47	43.32	49.15	81.68
Change		-1.67	0.40	-13.81	4.39	4.58	2.97	8.90	11.85	39.83

Figure 2.9 GHG emissions from IPPU sector in Rwanda between 2006 and 2015

On the other hand, HFCs gas contributed 6% of the average total GHGs emissions in IPPU sector. Although the contribution of HFCs is still low, it is growing at a high rate with a peak noticed in 2014 where it represented 11.5% of the total GHGs emissions in the IPPU sector. In addition, it should be noted that the major sector that contribute to CO_2 emission is the cement production, which represent alone 83% of the total emission in IPPU sector.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
HFCs	0.42	0.84	1.27	1.72	2.20	2.71	3.26	4.29	5.63	7.18
CO2	39.84	38.76	38.49	33.21	34.34	35.58	36.20	39.03	43.52	74.50
Total	40.26	39.60	39.76	34.94	36.54	38.29	39.47	43.32	49.15	81.68

Figure 2.10 Shares of various GHG emissions to total emission from IPPU sector in Rwanda between 2006 and 2015

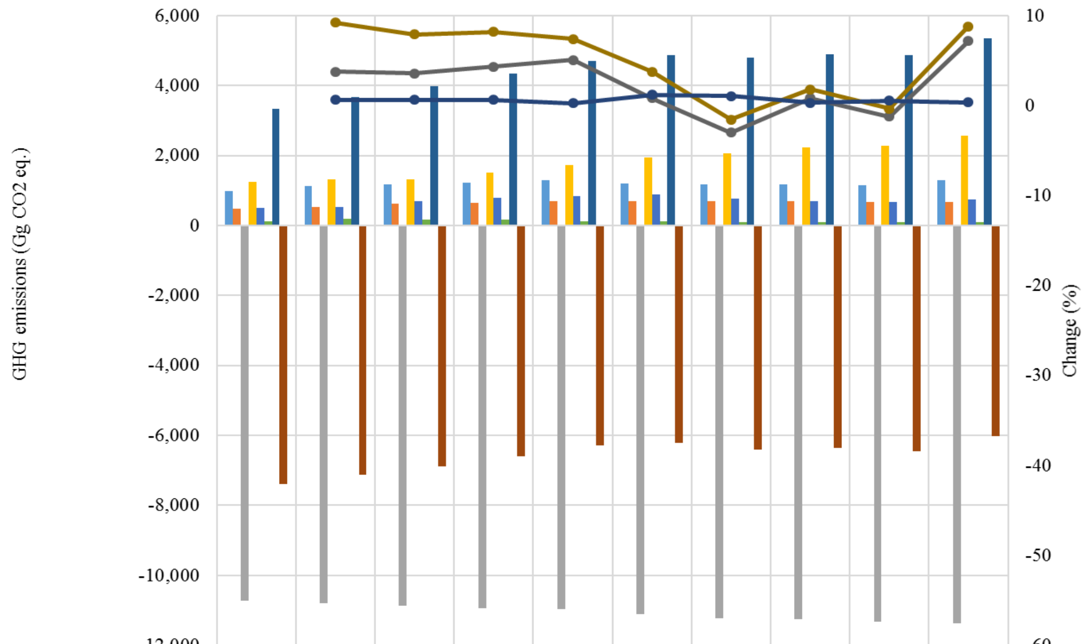
Three IPPU subcategories have been identified to be the key categories in IPPU sector, viz., cement production subcategory of mineral industry, Refrigeration and Air Conditioning subcategory of Products uses as substitutes for Ozone depleting substances and Non-Energy Products from Fuels and Solvent Use.

Planned improvement in IPPU sector

The government through REMA has currently initiated the regular record of import and use of ODS alternatives which will mainly benefit the accuracy in data collection for HFCs. To insure the continuity and integrity of the inventory, formal involvement of Rwanda Revenue Authority (RRA) as the institution that provided diverse data during the inventory should be initiated. In addition, for the inventory improvement, there is a need to prioritize the capacity building in different industries and mainly focus on the rationale of the GHG inventories, the objective on the national communication and the need of data documentation from different industries. Similarly, there is a need to conduct a complete survey of calcinated/burned lime in Rwanda and distinguish the lime used for agriculture purposes with the one used for construction and water treatment purposes.

2.7.3 AFOLU sector

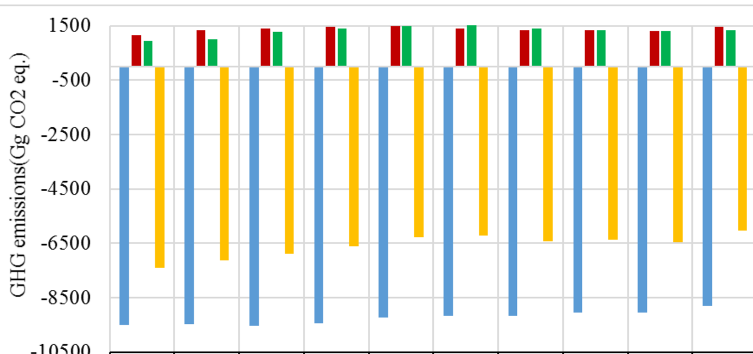
GHG emissions in agriculture and livestock were estimated for enteric fermentation of livestock, manure management, and agricultural practices consisting of rice cultivation and mineral nitrogen fertilizer applications to soil, manure, compost and crop residues applications to soil, nitrogen mineralization in freshly cultivated soil following land use change, organic soils, urine and dung deposited on pastures and paddock, atmospheric volatilization of nitrogen from managed soils and manure management, leaching and runoff. Agriculture burning was excluded from the report. It is evident from **Figure 2.11**that, the AFOLU sector has more carbon sequestered than emitted and forests are the most important carbon sinks. During the period between 2006 and 2015, the dynamic of GHG emissions/removals from AFOLU sector showed fluctuating trend with an annual average increase of 2.37%.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Enteric Fermentation	979.55	1,116.74	1,181.37	1,213.23	1,303.64	1,207.01	1,173.80	1,174.16	1,147.18	1,283.75
Manure management	488.53	524.05	613.31	653.29	690.66	692.42	702.49	698.53	676.56	672.99
Total Removals	-10,728.64	-10,798.32	-10,868.49	-10,938.82	-10,969.46	-11,101.13	-11,219.13	-11,255.49	-11,317.96	-11,359.85
Urea application	1,246.42	1,317.63	1,326.42	1,514.03	1,731.23	1,948.44	2,065.98	2,224.42	2,283.19	2,559.04
Soil	501.10	533.42	701.33	786.32	849.89	897.82	757.17	693.24	676.08	731.34
Rice cultivations	118.54	181.40	166.69	177.66	117.20	130.89	103.11	100.17	90.98	98.33
Total from Agriculture	3,334.14	3,673.24	3,989.13	4,344.52	4,692.63	4,876.58	4,802.54	4,890.52	4,873.99	5,345.44
Total with FOLU	-7,394.51	-7,125.08	-6,879.36	-6,594.30	-6,276.83	-6,224.55	-6,416.59	-6,364.98	-6,443.97	-6,014.41
Change in total with FOLU		3.78	3.57	4.32	5.06	0.84	-2.99	0.81	-1.23	7.14
Change in total from agriculture		9.23	7.92	8.18	7.42	3.77	-1.54	1.80	-0.34	8.82
Change in total removals		0.65	0.65	0.64	0.28	1.19	1.05	0.32	0.55	0.37

Figure 2.11 GHG emissions/removals from AFOLU sector in Rwanda between 2006 and 2015

While FOLU had a modest increase of 0.63%, agriculture subsector showed a fluctuating trend with an annual average in emissions of 5.03 %. The annual average increase 2.37 % was observed for the total GHG emission with FOLU.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CO2	-9482	-9481	-9542	-9425	-9238	-9153	-9153	-9031	-9035	-8801
CH4	1139	1346	1398	1444	1478	1393	1337	1335	1299	1440
N2O	949.1	1010	1264	1386	1483	1535	1399	1331	1292	1346
Total	-7395	-7125	-6879	-6594	-6277	-6225	-6417	-6365	-6444	-6014

Figure 2.12 Summary and trends of GHG emissions/Removals per gas from AFOLU sector between 2006 and 2015

The gas per gas analysis revealed that the CO_2 is the dominant contributor to total GHG emissions from AFOLU sector followed by CH_4, while N_2O had the least contribution (Figure 2.12).

Planned improvement in AFOLU sector

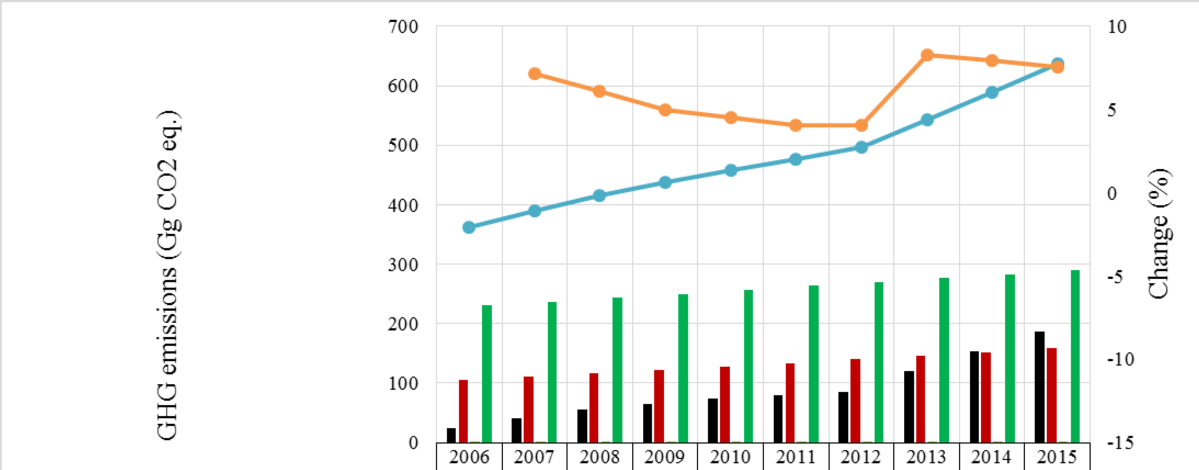
Specific emission factors in AFOLU sector should be researched on at country level to reduce uncertainty in GHG inventory results. Research institutions and universities should be encouraged or facilitated to conduct research on the existing gaps to develop local emission factors to enable Tier 2 computation of GHG emissions. Moreover, all source categories including lime application should be documented and integrated into the GHG inventory in AFOLU.

In preparation of next GHG inventories, there is need to undertake a new forest mapping with high resolution imagery to update forest coverage data in different ecological zones and different forest types. In addition, the following improvements will be needed to have a more complete and comprehensive GHG inventory in AFOLU sector:

- Conduct a survey to get more detailed data on livestock per categories and sub-categories;
- Refine forestry classification in Rwandan context;
- Review and conduct study on use of crop residues to get more specific data on crop residues;
- Review and conduct a survey through agro-dealers on applied chemical fertilizers in agriculture;
- Review and conduct a survey (through lime producers) on burned and non-calcinated lime.

2.7.4 Waste sector

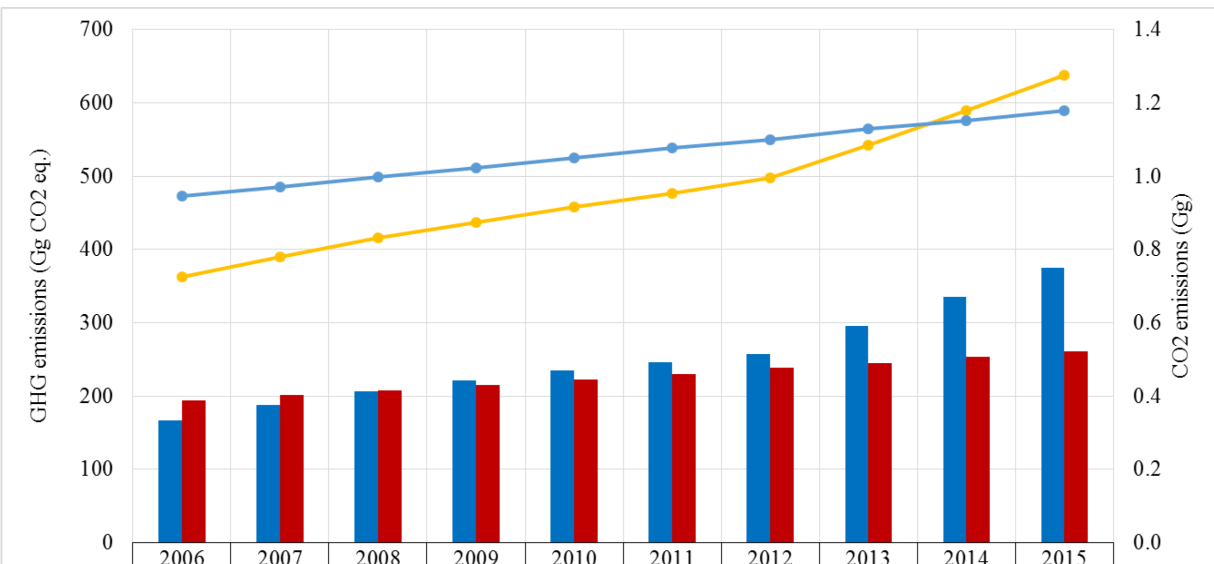
To compute emissions from wastewater sector, two subcategories have been considered, viz., domestic wastewater (4D.1), and industrial wastewater (4D.2) with domestic wastewater emissions being the main contributor to emissions from wastewater source category. Considering the period 2006-2015, the total annual emissions from waste sector have respectively increased from 362.26 Gg CO_2eq to 637.27 Gg CO_2eq.(**Figure 2.13**). Comparing emissions source per subcategory, it has been evidenced that emissions from wastewater treatment and discharge subcategory are the highest with the contribution of 54.29 % to the total GHG emissions from waste sector followed by emissions from biological treatment of solid waste (28.23 %), solid waste disposal (17.23%) and incineration with negligible contribution of 0.25% in 2012. Furthermore, GHG emissions from the wastewater treatment and biological treatment of solid waste subcategories recorded a slow increase: for the period 2006-2015 with the increase rate of 3% and 6%, respectively, while solid waste disposal recorded an increase rate of 75%. The high shift for solid waste disposal is mainly shaped by the involvement of private sector associated with poor waste source separation, which has more than doubled the fraction of solid waste to SWDS from 141,380 tonnes/year to 495,760 tonnes/year from 2006 to 2015, respectively.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Solid Waste Disposal	24.04	41.51	54.68	64.93	73.04	79.82	85.7	119.22	152.82	186.99
Biological Treatment of Solid Waste	105.5	110.44	115.62	121.04	126.71	132.65	140.36	145.38	152.19	159.33
Incineration and Open Burning of Waste	1.06	1.08	1.12	1.14	1.17	1.2	1.23	1.26	1.29	1.32
Wastewater Treatment and Discharge	231.67	237.11	243.97	250.11	256.97	263.54	269.98	276.47	282.88	289.63
Total	362.27	390.14	415.39	437.22	457.89	477.21	497.27	542.33	589.18	637.27
Change		7.14	6.08	4.99	4.51	4.05	4.03	8.31	7.95	7.55

Figure 2.13 GHG emissions from waste sector in Rwanda between 2006 and 2015

A gas per gas analysis revealed that CH_4 emissions had a dominant contribution to total GHG emissions from waste sector for the period between 2008 and 2015. During the reference year (2012), CH_4 emissions contributed 51.84 % to the total emissions from waste disposal, while N_2O emissions contributed 47.94 %. CO_2emissions contributed only 0.22%.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CH4	166.90	188.18	206.58	221.33	234.64	246.35	257.79	296.08	334.86	374.61
N2O	194.42	200.99	207.80	214.87	222.20	229.80	238.37	245.11	253.16	261.48
Total	362.26	390.14	415.38	437.22	457.89	477.22	497.26	542.33	589.17	637.27
CO2	0.95	0.97	1.00	1.02	1.05	1.08	1.10	1.13	1.15	1.18

Figure 2.14 Summary and trends of GHG emissions per gas from waste sector between 2006 and 2015

Planned improvement in Waste sector

The government has initiated the construction of landfills in all cities of district to improve solid waste disposal practices. Many landfills have been constructed and others are under construction in different districts. These include Nduba, Nyamagabe, Nyanza, Ruhango, Huye, Kamonyi, Rwamagana, Nyagatare, Musanze, Rubavu, Rusizi, and Karongi.The effectiveness of these landfills in reducing emissions is not yet known. For Kigali, a project of energy recovery from waste has been initiated by Pivot works. Again, its effectiveness is to be examined. Nevertheless, there is an emergent need to improve waste source separation, which is the main factor shaping current trend in emissions from solid waste disposal by contributing to the amount of organic matter accumulating in Nduba dumpsite. On this issue, Kigali City council has started public awareness and capacity development by providing waste source separation knowledge skills to various stakeholders involved in waste management. These include, but not limited to, waste collection companies, households, and local authorities in charge of hygiene and sanitation at district and sector level.

Furthermore, there is a need to promote statistical accounting of waste generated per capita, industry and per SWDS. This can be done at the district level or by the national institute of statistics or any other research institutional. For instance, an informal study was conducted by Pius NISHIMWE in collaboration with COPED and Rapid Planning Rwanda and UN Habitat on a small scale to determine the specific waste per capita for Kigali and the quantity of waste generated in Kigali. Unpublished report of this study has evidenced that waste per capita for Kigali is smaller (204kg/cap/year) than the default value proposed by 2006 IPCC guideline (290kg/cap/year) which has been used to estimate generated waste in Rwandan cities. The same methodology is recommended to determine the country waste per capita to be used for the Fourth National Communication. Furthermore, as districts are constructing landfills, we recommend them to include weighing system of disposed waste per composition to estimate waste ending into dumpsites.

The amount of solid waste undergoing biological treatment is expected to decrease with the rapid urbanization while contributing to the increase of waste to disposal sites. But this study has failed to provide the trend in decrease for the whole country while the situation of COPED has displayed the proportional decrease in composting in cities and increase of waste to SWDS. The decrease in composting is partly explained by the limited market for compost, which is a disincentive to invest in composting business. With urbanization the fraction of urban population will increase associated with the increasing waste to SWDS while the fraction of rural population will decrease associated with the decreasing waste undergoing biological treatment. It is then imperative to find measures to reduce waste ending into dumpsite in cities as the urbanization process predicts the increase of urban population.

Therefore, as a better record of solid waste undergoing biological treatment is a problem the following are recommended to collect better Activity data in the coming National Communication:

- For cities, it is imperative to identify entities, either households or companies that makes compost and the quantity of composted waste
- For cities with composting activities at dumpsite, it is imperative to develop waste weighing system associated with source waste separation and separate collection to determine the

component of solid waste undergoing biological treatment

- For countryside areas, it is important to crosscheck households undergoing composting activities and the local government to request them to weigh composted materials.
- In general, the National Institute of Statistics need to regularly update the number of households that use compost for waste management through the Integrated Household Living Conditions Survey report.

Also, national emission factors can be obtained by conducting waste generation studies at high learning institutions through sampling at SWDS combined with analysis of the degradable carbon content.

According to the ministry of health in Rwanda, the clinical waste are given more attention since 2012 and this started by the training of health workers on health care waste management and injection safety. In addition, a pyrolytic incinerator with the capacity of incinerating 200 kg/hr is planned to be installed in Kigali City. Similarly, the district hospital incinerators have been acquired in some places and the plans to purchase additional ones are underway (MoH, 2012). However, there is still a need to have an annual report on the quantity of waste incinerated at each hospital in Rwanda and the different reports should be collected and centralised at the ministry of health level and specifically at the health and sanitation department.

In addition, there is a need to have a continuous record of data that could be initiated between REMA and the National Institute of Statistics. The record should mainly focus on (i) quantities of beer production, (ii) production of cosmetics and detergents, and (iii) Sugar production. Similarly, the record of all incinerated clinical wastes and type of wastes should be initiated at the department in charge of sanitation in the Ministry of Health. The quantity of other type of incinerated waste could be regularly collected in each district and submitted to REMA.

2.8 Summary and trend of GHG emission trends per gas

As aforementioned, only direct GHG (i.e., CO_2, CH_4, N_2O and HFCs) emissions were considered in this inventory. During the period between 2006 and 2012, CO_2 removals from FOLU dominated over other GHG emissions from other sectors, resulting in net carbon sequestration. This period was followed by a substantial increase in the GHG emissions in the period between 2012 and 2015. HFCs emissions had a minute contribution to national total emissions (**Figure 2.15**).

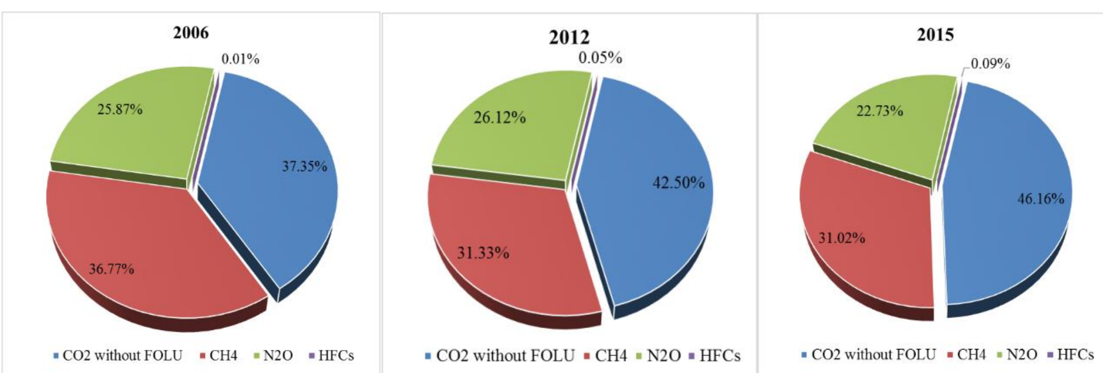
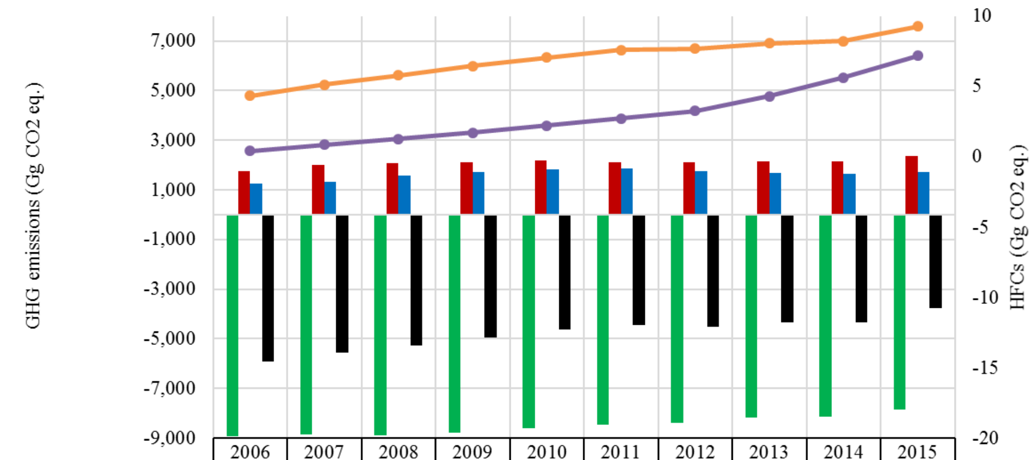


Figure 2.15 Contribution of various greenhouse gases to total GHG emissions in 2006, 2012 and 2015



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Net CO2	-8,937.3	-8,859.1	-8,898.0	-8,786.4	-8,626.9	-8,457.7	-8,379.1	-8,191.7	-8,153.6	-7,856.0
CH4	1,763.29	1,993.05	2,065.09	2,126.89	2,185.93	2,125.35	2,093.65	2,143.10	2,158.37	2,354.76
N2O	1,240.42	1,309.06	1,571.63	1,700.36	1,806.58	1,869.05	1,745.53	1,686.50	1,659.10	1,725.03
Total with FOLU	-5,933.1	-5,556.2	-5,260.0	-4,957.4	-4,632.2	-4,460.6	-4,536.7	-4,357.8	-4,330.5	-3,769.0
Total without FOLU	4,795.45	5,242.10	5,608.45	5,981.33	6,337.19	6,640.50	6,682.44	6,897.63	6,987.43	7,590.76
HFCs	0.42	0.84	1.27	1.72	2.20	2.71	3.26	4.29	5.63	7.18

Figure 2.16 Summary and trends of GHG emissions/Removals per gas in Rwanda between 2006 and 2015

2.8.1 Carbon dioxide

During the period between 2006 and 2015, gross CO_2 emissions (excluding FOLU) estimates showed an increasing trend with 37.35 %, 42.50 % and 46.16 % contributions in 2006, 20012 and 2015, respectively (Figure 2.15). However, these emissions were offset by the removals from FOLU, which decreased from -10,728.64 Gg in 2006 to -11,359.85Gg in 2015. The resulted net CO_2 emissions showed an increasing trend with an annual average increase of 4.54 % (Figure 2.15).

2.8.2 Methane (CH_4) emissions

The methane gas (CH_4) emissions were the second contributor to total GHG emissions with shares of 36.77 %, 31.33 %, and 31.02 % in 2006, 2012 and 1015, respectively. During the period between 2006 and 2015, total CH_4 emissions showed an increasing trend with an annual increase of 3.07% (Figure 2.15). Estimated CH_4 emissions were mainly produced by enteric fermentation, other biomass combustion, and solid waste disposal activities.

2.8.3 Nitrous oxide (N_2O) emission

During the period between 2006 and 2015, Rwanda's N_2O emissions showed an increasing trend with an average increase of 3.34 % (Figure 2.15). The N_2O contributions to total GHG emissions (excluding FOLU) were estimated at 25.8 %, 26.12 %, and 22.73 % in 2006, 2012, and 2015, respectively. The rise in estimated N_2O emissions could be attributed to the increase in agricultural and waste treatment activities including manure management, Indirect N_2O emissions from managed soils, wastewater Treatment, and Discharge activities.

2.8.4 Hydrofluorocarbons (HFCs) emissions

During the period between 2006 and 2015, source category of HFCs had the least contribution to Rwanda's total GHG emissions with 0.01 %, 0.05 % and 0.09 % contributions to total GHG emissions in 2006, 2012, and 2015, respectively. During this period, total CHF emissions increased tremendously with an annual average increase of 26.32 % from 2006. These emissions which are produced by Product Uses as Substitutes for Ozone Depleting Substances showed an increasing trend due to increased use of the gases in air conditioning and refrigeration. It is worth mentioning that, due to data availability and limited time, only Hydrofluorocarbons (HFCs) were considered in the GHG inventory. In future inventories, other emissions such as Perfluorocarbon (PFCs) and Sulphur hexafluoride (SF6) should be considered. The possible use of PFCs in various appliances such as refrigerators, air conditioners would be investigated via national surveys. In addition, a survey at Rwanda Energy Group is needed to provide detailed information on the consumption of Sulphur hexafluoride (SF6) used in electrical equipment as gas insulated switchgear and substations and in gas circuit breakers.

2.9 Quality Assurance and Quality Control procedures (QA/QC)

According to the 2006 IPCC guidelines, the Quality Assurance (QA) and Quality Control (QC) constitute an important part of inventory development cycle and should be conducted at different steps. The QC was conducted at all the steps of the inventory development through data validation and methodology checks from all the working groups. The consistence of data was checked by comparing the total annual consumption figures with the production, import and export data. In addition, the data used were verified during two workshop cessions and with the support of an international consultant. The overall report quality assurance was conducted and checked by an international consultant and validated via various stakeholders meetings.

2.10 General uncertainty assessment

Uncertainty and time series assessments constitute important elements of a complete and transparent GHG emissions inventory. Uncertainty and time series assessments were conducted using the Tier 1 methodology in accordance with the 2006 IPCC guidelines and good practices therein. Taking 2006 as the base year, level and trend uncertainty were estimated using the 2006 IPCC software. Level estimates ranged between ± 0.59 % and ± 29.23 %, while trends uncertainties were in the range between ± 23.69 % and ± 34.69 (Table 2.6). It is evident from **Table 2.6** that for some years, uncertainties are relatively high. The main reason for high uncertainties could be the data gaps, the use of default emission factors and the incomplete understanding on how emissions are generated. Emissions evaluated in this inventory report represent the current best estimates in Rwanda's GHG inventory. However, it is worth mentioning that in some cases estimates were based on extrapolated data, assumptions, and approximation methodologies. These methodological issues also contributed significantly to higher and fluctuating uncertainties. The Rwanda's GHG inventory working group will continue to improve, revise, and recalculate its GHG emission estimates, as new sources of information are available. Another source of uncertainty is the use of default values. It should be recommended that, in future inventories, an effort should be made to develop country specific emission factors to overcome high uncertainties in estimated emissions.

Table 2.6 Estimated national inventory quantitative uncertainties

Period	Indicator	
	Uncertainty in total inventory (%)	Trend uncertainty (%)
2006	± 0.59	-
2007	± 20.08	± 23.69
2008	± 18.04	± 24.07
2009	± 16.37	± 24.66
2010	± 14.41	± 26.42
2011	± 13.41	± 28.00
2012	± 13.3	± 28.85
2013	± 12.50	± 30.62
2014	± 12.41	± 31.98
2015	± 29.23	± 34.69

2.11 General assessment of the completeness

The developed GHG inventory for the Republic of Rwanda between 2006 and 2015 is mostly complete for direct gases including CO_2, CH_4, N_2O and HFCs. In this inventory, an effort was made to estimate all the direct GHG emissions for all the source categories under energy, Industrial process and product use (IPPU), Agriculture, Forestry and Land Use (AFOLU) and waste sectors. Completeness tables of considered categories are provided in details under respective sections of the Rwanda's NIR. Despite the effort made, GHG emissions from some categories and subcategories were not included in this inventory chiefly due to lack of source data. Details on various gaps in the inventory and related data gaps are discussed in the section on planned improvements.

Table 2.7 GHG inventory for the Republic of Rwanda between 2006 and 2015

IPCC Categories	CO_2	CH_4	N_2O	HFCs	PFCs	SF6
Energy sector						
1.A - Fuel Combustion Activities	X	X	X	NA	NA	NA
1.A.1 - Energy Industries	X	X	X	NA	NA	NA
1.A.1.a - Main Activity Electricity and Heat	X	X	X	NA	NA	NA
1.A.1.a.i - Electricity Generation	X	X	X	NA	NA	NA
1.A.1.c.ii - Other Energy Industries[1]	IE	IE	IE	NA	NA	NA
1.A.2 - Manufacturing Industries and Construction	X	X	X	NA	NA	NA
1.A.2.e - Food Processing, Beverages and Tobacco	X	X	X	NA	NA	NA
1.A.2.f - Non-Metallic Minerals	X	X	X	NA	NA	NA
1.A.2.i - Mining (excluding fuels) and Quarrying	X	X	X	NA	NA	NA
1.A.2.k - Construction	X	X	X	NA	NA	NA

[1]Included in Other sectors: Charcoal

1.A.3 - Transport	X	X	X	NA	NA	NA
1.A.3.a - Civil Aviation	X	X	X	NA	NA	NA
1.A.3.a.ii - Domestic Aviation	X	X	X	NA	NA	NA
1.A.3.b - Road Transportation	X	X	X	NA	NA	NA
1.A.3.b.i - Cars	X	X	X	NA	NA	NA
1.A.3.b.i.1 - Passenger cars with 3-way catalysts	X	X	X	NA	NA	NA
1.A.3.b.i.2 - Passenger cars without 3-way catalysts	X	X	X	NA	NA	NA
1.A.3.b.ii - Light-duty trucks	X	X	X	NA	NA	NA
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts	X	X	X	NA	NA	NA
1.A.3.b.ii.2 - Light-duty trucks without 3-way	X	X	X	NA	NA	NA
1.A.3.b.iii - Heavy-duty trucks and buses	X	X	X	NA	NA	NA
1.A.3.b.iv - Motorcycles	X	X	X	NA	NA	NA
1.A.3.d.i - International water-borne navigation	NO	NO	NO	NA	NA	NA
1.A.3.d.ii - Domestic Water-borne Navigation[2]	IE	IE	IE	NA	NA	NA
1.A.4 - Other Sectors	X	X	X	NA	NA	NA
1.A.4.a - Commercial/Institutional	X	X	X	NA	NA	NA
1.A.4.b - Residential	X	X	X	NA	NA	NA
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms [3]	IE	IE	IE	NA	NA	NA
1.B - Fugitive emissions from fuels	NE	NE	NE	NA	NA	NA
1.C - Carbon Dioxide Transport and Storage	NO	NO	NO	NA	NA	NA
IPPU sector						
2A1: Cement Production	X	NO	NO	NO	NO	NO
2A2: Lime Production	X	NO	NO	NO	NO	NO
2C1: Iron and Steel Production	X	E	NO	NO	NO	NO
2C2: Ferroalloys Production	X	NO	NO	NO	NO	NO
2D1: Lubricant Use	X	NO	NO	NO	NO	NO
2D2: Paraffin Wax Use	X	NO	NO	NO	NO	NO
2F1: Refrigeration and Air Conditioning	NO	NO	NO	X	NO	NO
2F1a: Refrigeration and Stationary Air Conditioning	NO	NO	NO	X	NO	NO
2F1b: Mobile Air Conditioning	NO	NO	NO	X	NO	NO
IPCC Categories	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF6**
AFOLU sector						
3.A.1 Enteric Fermentation	NO	X	NO	NA	NA	NA
3.A.2 Manure Management	NO	X	NA	NA	NA	NA
3. B.1. Forest Land	X	X	X	NA	NA	NA
3.B.2 Cropland	X	NA	NA	NA	NA	NA
3.B.3 Grassland	NE	NA	NA	NA	NA	NA
3.B.4 Wetlands	NE	NA	NA	NA	NA	NA
3.B.5 Settlements	NE	NA	NA	NA	NA	NA
3.B.6 Other Land	NE	NA	NA	NA	NA	NA
3.C.2 Lime application	NE	NE	NE	NA	NA	NA
3.C.3 Mineral N applied to soil	X	NA	X	NA	NA	NA
3.C.4 Direct N_2O emissions from managed soils	NA	NA	X	NA	NA	NA
3.C.5 Indirect N_2O emissions from managed soils	NA	NA	X	NA	NA	NA

[2]Included in road transportation: Liquid fuel

[3]Included in road transportation: Liquid fuel

3.C.7 Rice cultivation	NA	X	NA	NA	NA	NA
Waste sector						
4A-Solid waste disposal	X	NO	NO	NA	NA	NA
4B-Biological Treatment of Solid waste	X	X	NO	NA	NA	NA
4C1-Incineration	X	X	X	NA	NA	NA
4C2-Open Burning	NE	NE	NE	NA	NA	NA
4D1-Domestic wastewater	X	X	NO	NA	NA	NA
4D1-Industrial wastewater	X	NA	NA	NA	NA	NA

NA: Not Applicable, NO: Not Occurring, X: Estimated, NE: Not Estimated, IE: Included Elsewhere

Though, reporting on precursors and indirect emissions is not mandatory for Non Annex I countries, there is a need to consider these gases in future reports of national communication since they are linked with national air pollution management which is a priority for the GoR. GHG emissions and their analysis were conducted using the 2006 IPCC guidelines. Tier 1 methodology was mainly used with some country specific physical characteristics of fuels.

2.12 Planned improvements

Emissions evaluated in this inventory report represent the current best estimates in Rwanda's GHG inventory. Despite the effort made to make the Rwanda's GHG inventory as complete and comprehensive as possible, it is worth mentioning that in some cases estimates were based on extrapolated data, assumptions, and approximation methodologies. These methodological issues also contributed significantly to higher and fluctuating uncertainties. The Rwanda's GHG inventory working group will continue to improve, revise, and recalculate its GHG emission estimates, as new sources of information are available. As discussed in subsequent sections, planned improvements in various sectors will encompasses improvement on methodology (including QA/QC and uncertainty assessment and completeness at sectoral level), improvement on capacity building and information sharing and Strategies for long-term improvement.

2.13 Conclusion

In this chapter, Rwanda's GHG emissions and removals were estimated and analysed for a period between 2006 and 2015. Estimates on GHG were produced on a gas-by gas basis considering direct GHGs including CO_2, CH_4 and N_2O. Estimates of the key sources, sensitivity analysis and uncertainty level were provided. Estimates of aggregated GHG emissions and removals expressed in CO_2 equivalent were also reported. In general, default emission factors provided by 2006 IPCC Revised Guidelines were used with country specific physical characteristics (Net calorific values, densities) of fuels where available. In addition, the approach used during Rwanda Second National Communication and during NAMA study for identification of appropriate emission factor were considered, especially in transportation GHG emissions estimations. The key category analysis was conducted both for sources and GHG gases according to 2006 IPCC guidelines.

The results showed that, during the period between 2006 and 2015, GHG removals dominated over emissions for the period between 2006 and 2012. During the period between 2006 and 2012, GHG emissions from AFOLU had a dominant contribution to the total GHG emissions without FOLU, resulting in a net carbon sequestration. However, following the increase in the Rwanda economy, the change in lifestyle, and the application of urea in agricultural activities, Rwanda recorded a rapid increase in GHG emissions during the period between 2013 and 2015. The GHG intensity (i.e., the amount of GHG emitted per GDP) decreased from 22.28 Gg/USD in 2006 to 18.73 Gg/USD. This decrease could be explained by the rapid increase in Rwanda economy. During the same period the GDP increased from USD 333 to USD 720. The increase in GDP was estimated at 53.75 % between 2006 and 2015, while that of GHG emissions was only 44.98% In addition, the GHG emissions per capita increased from 823.79 kg per capita to 1,201.38 kg per capita with an annual increase of 3.98%.

Analysis of the contribution of various gases to the total energy emissions showed that CO_2 was the dominant contributor to the total GHG emissions followed by CH_4 and N_2O, while CHFs were the least contributors to the total GHG emissions. The increases in GHG emissions were related to fuel consumption and economic growth of Rwanda during the period between 2006 and 2015 and a time series consistency with previous results was observed.

CHAPTER 3

NATIONAL CLIMATE CHANGE MITIGATION ASSESSMENT

CHAPTER III: NATIONAL CLIMATE CHANGE MITIGATION ASSESSMENT

3.1. Introduction

This chapter provides details about mitigation assessment and abatement measures (mitigation scenarios) for Rwanda in energy sector (electric power generation, industries, buildings and transport) and non-energy sector (waste, industrial processes and product use (IPPU), agriculture, and Forestry and other Land use). Mitigation scenarios have been informed and aligned to existing Government sectoral policies, strategies and programmes. In order to ensure consistency, the level of emission reductions has been also aligned with the national targets outlined in the NDCs set for 2030 (REMA, 2017) but goes beyond year 2050.

The mitigation scenarios are presented by explaining the underlying assumptions and the methodology used to develop mitigation options.

3.2. Approaches used for mitigation assessment

Mitigation assessments were based on a combination of three alternative approaches namely (i) activity-based approach, (ii) an outcome-based approach, or (iii) a combination of the two approaches (WRI&UNDP, 2015). These types of mitigation activities (contribution types)are illustrated in Figure 3.1.

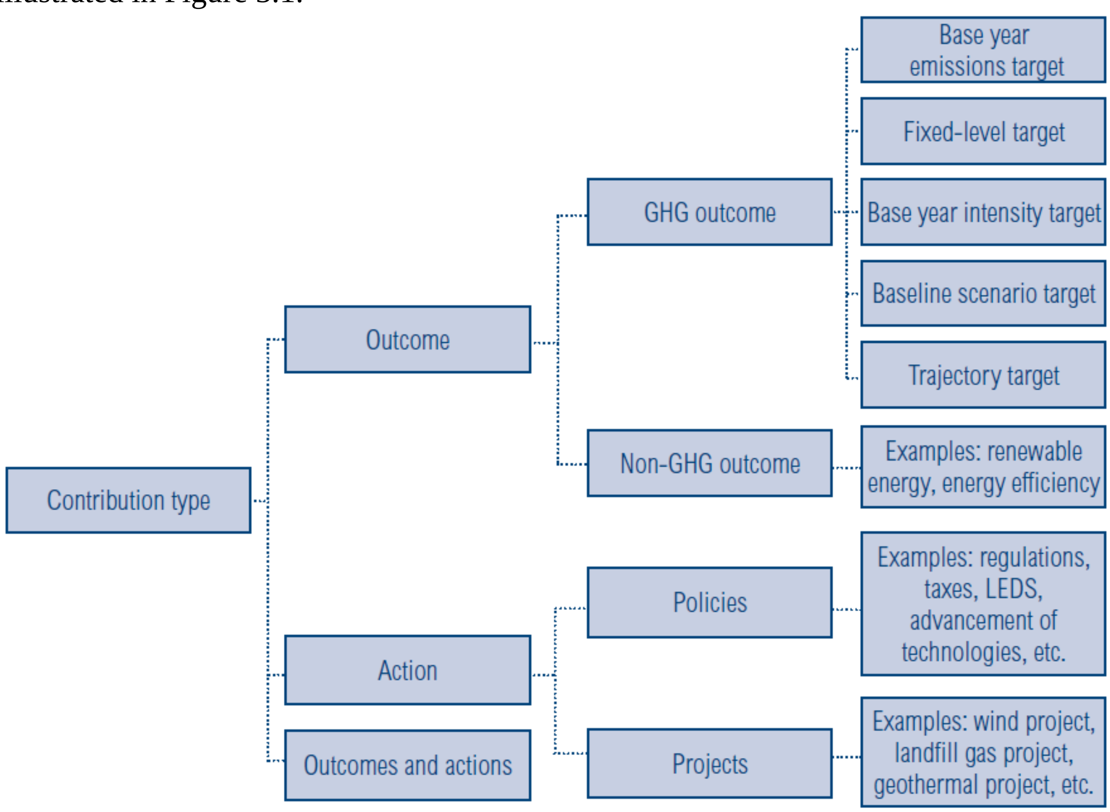


Figure 3.1 Types of mitigation contributions (WRI & UNDP, 2015)

The total GHG emission reductions or removals have been calculated by developing business-as-usual sectoral baseline scenarios and alternatives scenarios based on various policy implementation assumptions. In the energy sectors, the transformation module of LEAP software was used to model baseline and mitigation scenarios. The use of baseline scenarios to compute emission reduction resulting from mitigation actions is illustrated in WRI & UNDP (2015) as shown in Figure 3.2.

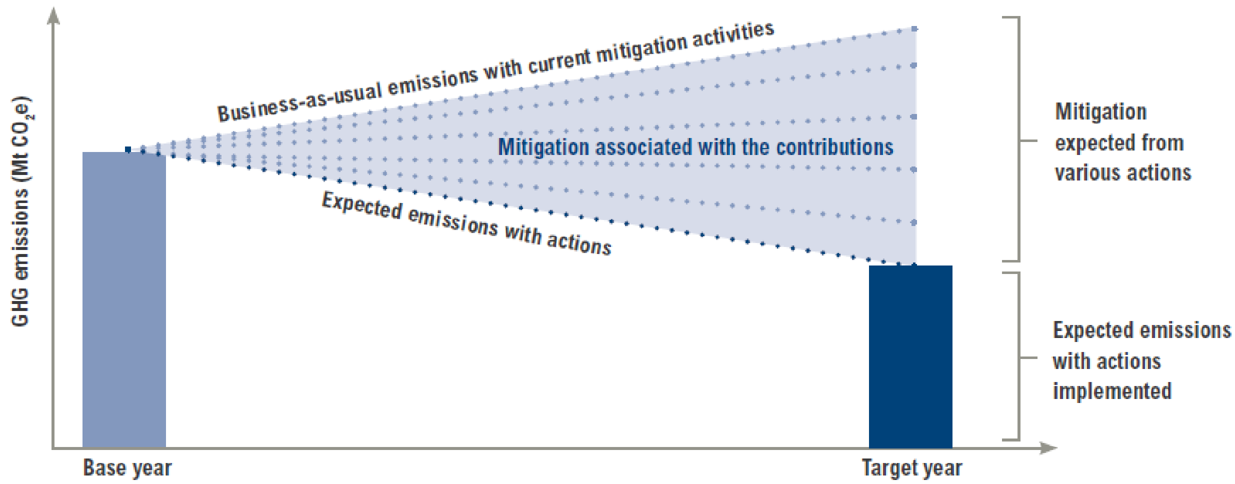


Figure 3.2 Determining expected emissions in a future year if the mitigation actions are implemented (WRI & UNDP, 2015).

3.3. Mitigation assessment and abatement measures in the energy sector

3.3.1. Electric power generation

In order to model the electricity generation GHG emission mitigation, a number of assumptions were formulated guided by the recent NAMA report as follows:

- The storyline was developed using the transformation module of LEAP software, taking into consideration the population and the GDP growths.
- The process efficiencies of the diesel, peat were assumed to be 39% and 30%, respectively, while that of renewable energy resources (i.e. hydro, biomass and solar) were chosen to be 100%.
- The Merit Order Dispatch was chosen as dispatch rule.
- The exogenous capacity (i.e.current and future committed capacity) are 82.27 MW, 51.8 MW, and 8.75 MW for hydro, diesel and solar electricity generation in 2015.
- The exogenous capacity (i.e. current and future committed capacity) are 138.27 MW, 67.8 MW, and 28.75 MW, and 145 MW for hydro, diesel and solar and peat, respectively in 2018.
- Following the trend in the GDP, an addition of 150 MW of electricity generated from peat will be added to the grid.
- The share of biomass in the electricity generation will grow at 10% from 2017.

- Based on the projections conducted by the JICA team, the electricity transmission and distribution losses will decrease from 21% in 2012 to 10.2% in 2032 (which was extended to the year 2050).

Based on these assumptions, the evolution of major fuels simulated in the transformation module of LEAP software shows thatthe electric generation will be dominated by peat and hydropower plants with 43.48% and 42.01%, respectively in 2050. The biomass will be the least contributor to total generation with only 0.24% (Figure 3.3).

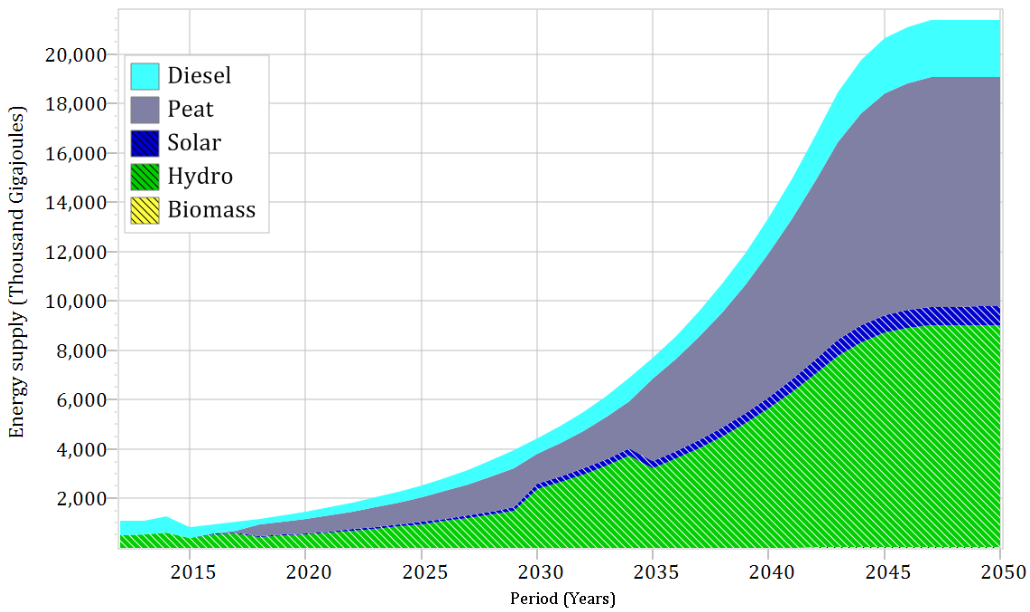


Figure 3.3 Contributions of various fuels to energy supply between 2012 and 2050

The baseline electricity generation (business as usual) modelled through the transformation module of LEAP software is projected to grow substantially from 1,089,800 GJ in 2012 to 21,394,800 GJ in 2050. GHG emissions in the BAU scenario will increase from 106.12 Gg CO_2eq. to 3,346.27 Gg CO_2eq.(Figure 3.4).

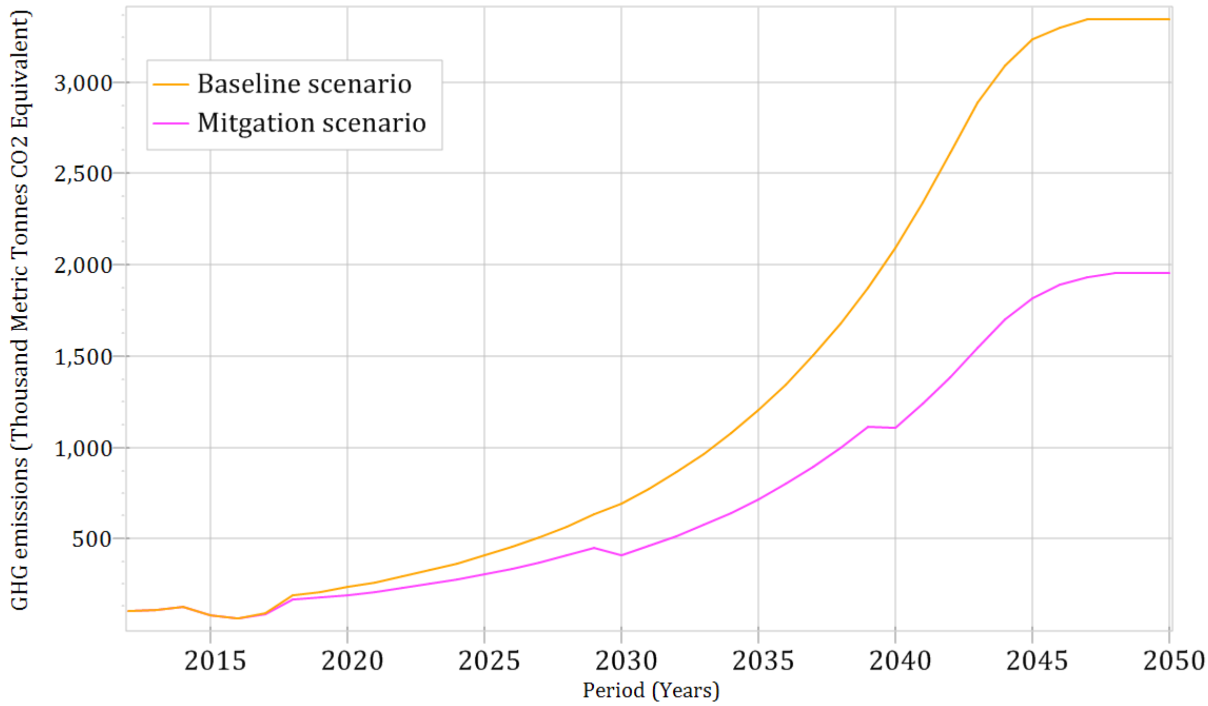


Figure 3.4 Simulated GHG emissions under baseline and mitigation scenarios (2012-2050)

The mitigation scenarios for electricity generation based on Government targets to increase the renewable energy power generation while reducing the liquid fuels for power generation. The liquid fuels are expected to reduce from 26.76% in 2017 to 6% in 2024, i.e.an annual reduction of around 3% (RoR, 2017). In addition, the country is planning to install various on-grid and off-grid hydropower and solar power plants to increase the installed capacity while reducing the GHG emissions associated with the nonrenewable energy generation. As detailed in the sustainable energy for all (MININFRA, 2015b), the shares of renewable energy generation (including solar, hydro, geothermal, imports, and off-grid generation) contributions to installed capacity and generation capacity are expected to increase to 65% and 55%, respectively.

Considering the expected economic growth from upper middle-income country with a GDP of USD 4,035 in 2035 to high-income country with a GDP of USD 12,476 in 2050, an additional on grid capacities would be estimated at 604.5 MW and 200 MW solar PV generation capacity, respectively. This additional capacity would replace the diesel and some peat-fueled power plants. The 604.5 MW are suggested to be implemented in three batches: 304.5 MW between 2015 and 2030, 100 MW between 2030 and 2040 and 200 MW between 2040 and 2050. The large solar PV capacity is suggested to be implemented in two phases: 100 MW between 2015 and 2030 and the remaining 100 MW between 2030 and 2050.

The solar plants would have an efficiency of 100%, an expected availability of 40% and an expected lifetime of 30 years. Due to low availability of solar power, the 200 MW of solar would only replace about 70 MW of diesel plant. The diesel plant would have a thermal efficiency of 30%, an expected availability of 80%, and an expected lifetime of 35 years. In addition, generation from renewable energy will be accompanied by replacing 50 MW from peat by 50 MW from biomass. Biomass would have an efficiency of 100% and a maximum availability of 80%.Under the mitigation scenario, the GHG emissions for electricity supply will increase 106.100 Gg CO_2 eq. to 1,300.90 Gg CO_2 eq. (Figure 3.4).The mitigation scenario for energy generation simulated in the transformation module of LEAP software is projected to generate a cumulative emissions reduction of 20,377.80 Gg CO_2 eq. by 2050 (Figure 3.4). The main mitigation scenario is the use of large renewable energies (Large hydro and solar PV plants) scenario

3.3.2. Energy use in industries

The following key assumptions were used to model both the energy consumption and the corresponding GHG emissions from industries:

- The manufacturing sector in Rwanda is still small but steadily growing at an annual rate of 7%. The non-metallic industry, which is the main contributor to GHG emissions, will grow at the same rate through the year 2050.
- Based on historical data, the GHG emissions in food industries are expected to grow at an annual rate of 4%.
- Considering the recent increase in the Mining industry, it is assumed that the future energy consumption and thus the related GHG emissions will grow at the same rate as the manufacturing industries.
- The growth in the liquid fuel use in construction industry are expected to grow as the GDP grows (GDP is projected to increase from USD 4,035 in 2035 to USD 12,476 in 2050) (RoR, 2017).
- The biomass consumption in the construction industries will grow following the historical growth rate, which is estimated at 4%.

The baseline scenario (BAU) was developed for each individual industry based on the historical data as detailed in the Rwanda National GHG inventory and the national plans. The modelled baseline GHG emissions from industrial sector are expected to increase from 50.19 GgCO_2 eq. to 1,170.82 GgCO_2 eq. in 2050 (Figure 3.5). The non-metallic mineral industries will remain the main contributor to GHG emissions through the year 2050 and the food industries will be the least contributor. During the first period between 2012 and 2030 the GHG emissions are expected to increase slowly, but between 2030 and 2050 is characterized by a substantive increase in GHG emissions mainly due to the expected GDP growth, which is the main driver for industry growth (Figure3. 5).

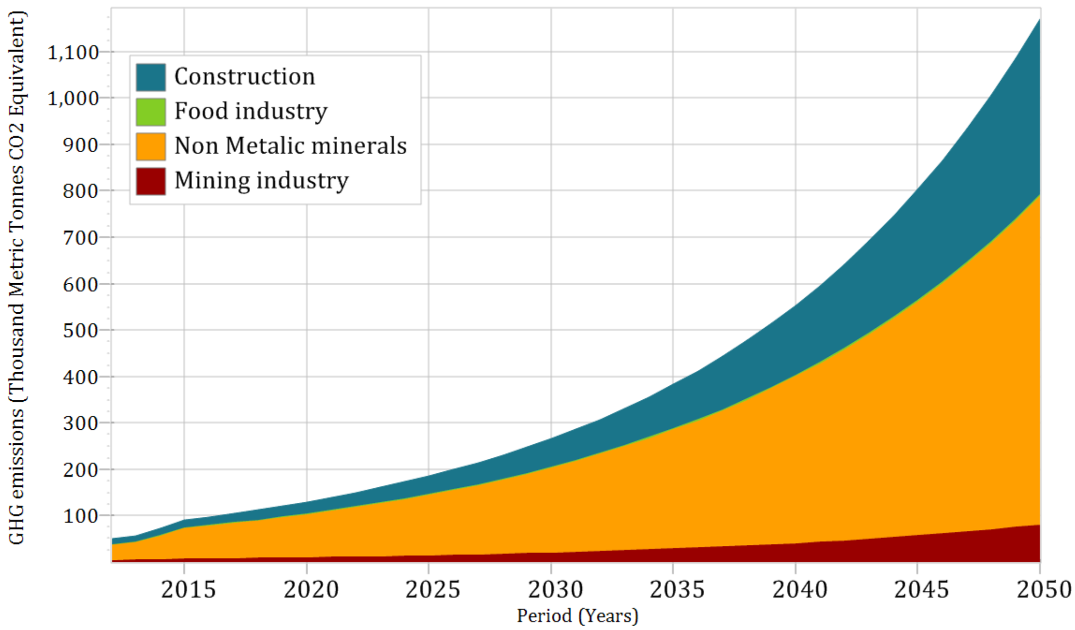


Figure 3.5 Baseline GHG emissions from energy use in major industries in Rwanda (2012–2050)

The mitigation scenario was developed and simulated based on mitigation options outlined in **Table 3.1.** The options were developed based on the expert judgment, the mitigation scenarios developed in the NAMA report (REMA, 2015a) and the NDCs (REMA, 2017).

Table 3.1 Proposed mitigation scenarios and emissions reduction potentials

Scenario options (Energy efficient improvements)	GHG emission reduction potentials
Food industries: Efficiency improvement in drying and roasting tea and coffee: Increase efficiency by 5% per year up to at least 30% in 2021.	The GHG emissions from Food industries will follow the same trend and the reduction in GHG emissions from these industries will be reduced gradually at a rate of 5%.
Non-metallic industries: The nonmetallic industry considered is the cement industry. According to NAMA report, two main options could be proposed for mitigations, namely, the heat recovery from clicker production through co-generation and use of rice husk as replacement of peat and/oil.	Considering the rice husk option, the use of about 50,000 tons of rice husk has a potential of reducing the energy consumption to about half the current level. The average energy use per tons of clinker is about 6 GJ/ton in wet kilns and 4.5 GJ/ton in dry kilns. Therefore, the potential savings could be 150-200,000 GJ, which if produced by peat at 30% efficiency would correspond to 45,000-60,000 tCO_2eq. per year of emissions reduction. An average of 52.50 Gg CO_2 eq. per year was applied to residual fuel oil.
Mining industries: According to REMA (2017), 80% of total mines are expected to phase out fossil fuel use, through electricity by 2018. Based on this target, it can be inferred that by 2050, all the mining industries will be using onsite-generated electricity and/or grid connected electricity.	Considering this restriction, the mitigation scenario assumed a reduction in GHG emission of up to 80%. The remaining 20% could be generated by on-site fuel combustion activities in the thermal generators.

Construction: Considering the projected GDP growth, the number of construction machinery will continue to grow through 2050. The main mitigation option could be sought from efficient brick kilns. The implementation of efficient brick kilns could reduce significantly the fuel consumption the construction sector.	Due to lack of appropriate data for kiln efficiencies and considering the government plan to reduce considerably the dependence on wood fuels, an annual reduction in GHG emissions of 4.13% was applied to GHG emissions from wood and wood wastes. The diesel combustion was considered as in business as usual (baseline) scenario.

The results of the simulated mitigation scenario and the baseline scenario are shown on **Figure 3.6.**The implementation of mitigation measures will decrease the GHG emissions from various industries from 1,170.82 Gg CO_2 eq. in 2012 to 1,087.56 GgCO_2 eq. in 2050 (a cumulative reduction of 884.75 Gg CO_2 eq.)

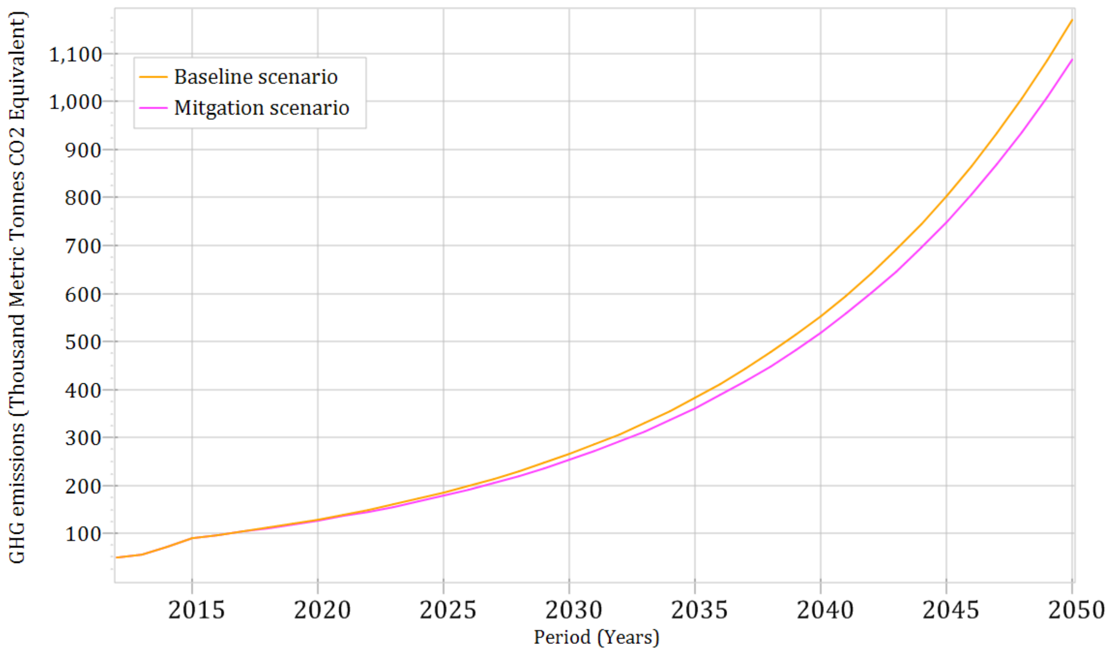


Figure 3.6 Simulated GHG emissions under baseline and mitigation scenarios (2012-2050)

3.3.3. Buildings

The energy in buildings encompasses the energy consumption for cooking, heating (room heating, water heating), cooling (air-conditioning), lighting and operating electrical appliances. The baseline GHG emissions from buildings were modeled in the LEAP software based on the projected energy consumptions and the key assumptions are listed below:

- The population will grow from 10.5 million in 2012 to 23.2 million in 2050
- The GDP will increase from USD 756 in 2017 to USD 1,493 in 2024; USD 4,035 in 2035 and USD 12,476 in 2050.
- The urbanization rate of up to 30% in the Provinces and 100% in Kigali.
- The biogas was assumed to grow at 26%, while the wood and wood wastes and LPG are assumed to grow as the population. The kerosene consumption is expected to continue decreasing at 12%.

- Due to the lack of disaggregated data, the electricity consumption in industry, commercial buildings and public buildings (including public lighting) was considered in the commercial and public building sector.
- Based on historical data, the demand in residential buildings was assumed to grow at 11.7%.
- The wood and wood waste consumption in the commercial and building sector was assumed to grow as the GDP.
- Based on historical data, diesel and electricity demand were assumed to grow at 12% and 10 %, respectively.

The baseline GHG emissions are expected to increase from 2,183.00 Gg CO_2 eq.in 2012 to 6,145.40 Gg CO_2 eq. in 2050 (**Figure 3.7**). During the first period between 2012 and 2038, the projected GHG emissions from residential buildings are projected to dominate over those from the commercial and public buildings, while the situation will reverse over the remaining period. The contribution of commercial and public building to total GHG emissions from buildings will increase from 49% in 2038to 72% in 2050 (Figure 3.7).

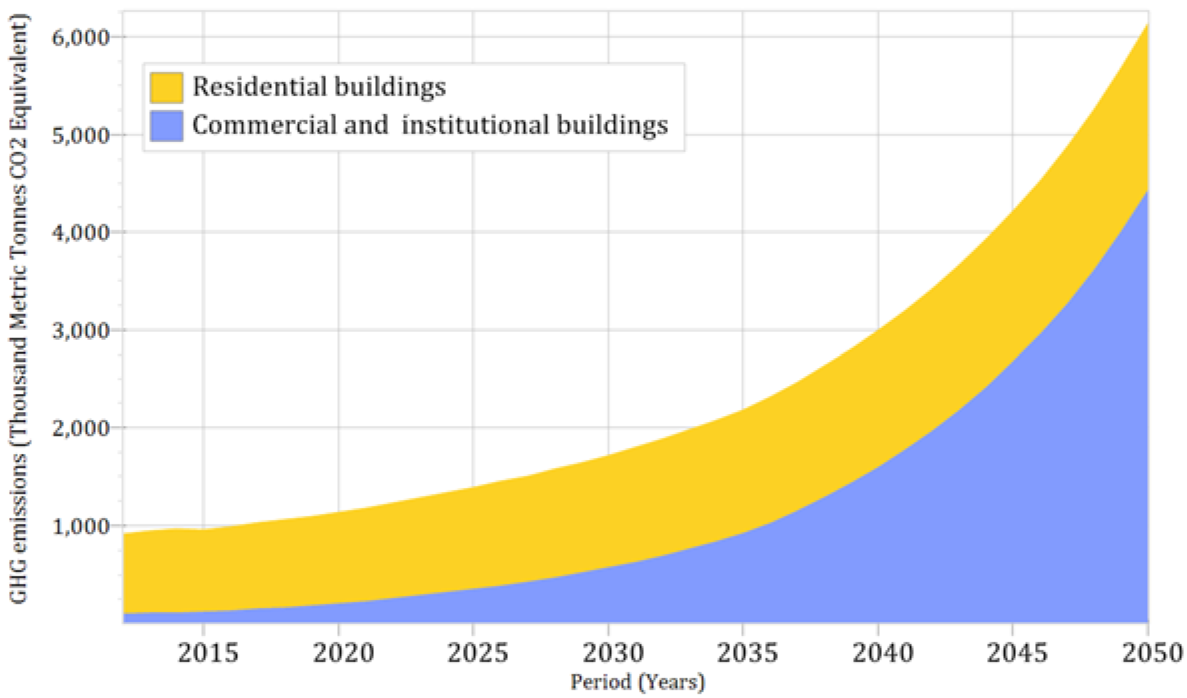


Figure 3.7 Baseline GHG emissions in buildings between 2012 and 2050

The projected baseline GHG emissions will be generated by combustion activities of various fuel including wood and wood wastes, kerosene, LPG, diesel, and biogas. The analysis of the baseline GHG emissions per fuel shows that the wood and wood waste is the main contributor to total GHG emissions for the period between 2012 and 2045 (Figure 3.8). However, for the remaining period, the GHG emissions from diesel are predominant due to rapid growth in service sector stimulated by the high GDP growth expected over this period.

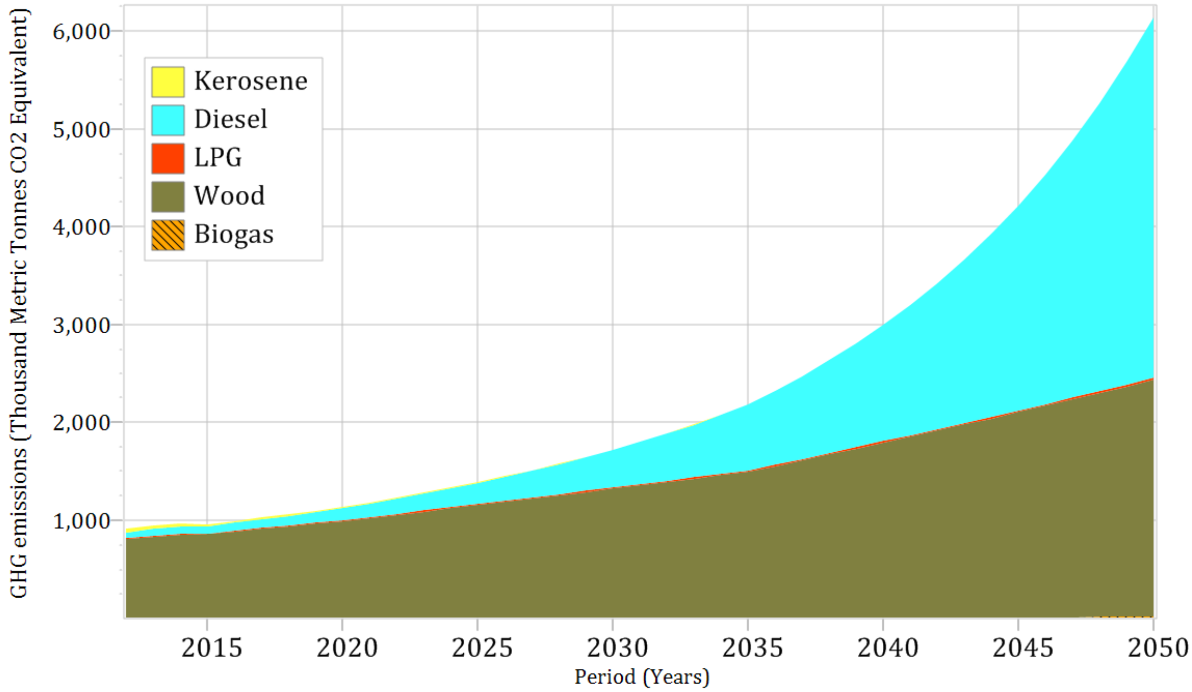


Figure 3.8 Baseline GHG emissions per fuel between 2012 and 2050

The proposed mitigation scenario also referred to as efficient building consists of the efficient and sustainable use in residential and commercial buildings, the use of the efficient lighting and the use of solar heaters for hot water in buildings. Besides the environmental benefit, the adoption and/or strengthening of the latter options will provide some other socioeconomic benefits such as the indoor clean air, etc. The mitigation options summarized in Table 3.2 were combined and simulated in the LEAP software.

Table 3.2 Scenario options and GHG emission potentials for mitigation in buildings

Scenario options	GHG emission reduction potential
Residential buildings	
Efficient cooking, LPG and biogas use	The GHG emissions reduced in efficient cooking can vary according to fuel type, cookstove efficiency, non-renewable biomass content and cooking practice. Based on the UNFCCC CDM PoA 'PoA9956' model as described in the NAMA report (REMA, 2017), the GHG emission reduction potential for one cookstove was estimated at 2 MT CO_2 eq. per year. Combining this with the LPG and biogas use, we assumed an annual decrease in biomass consumption of 4.13 % and the increase in LPG use at the same rate from the year 2022. To balance the wood and wood waste use, the biogas demand was set at the same increase rate as in the baseline scenario. The 7-year government program (2017-2024) targets to reduce the wood and wood waste consumption from 83.3% in 2014 to 42% by 2024 (i.e.an annual reduction of 4.13%) (RoR, 2017).
Efficient lighting	The proposed efficient lighting consists of the use of LED lights powered, hence the emission reduction 100%. Thus, assuming a grid emission factor of 0.537 metric tonnes CO_2equivalent/MWh, the emission reduction is estimated at 0.537 MT CO_2 eq. for every MWh of electricity consumed for lighting.

Efficient refrigerators	Efficient refrigerators to replace standard refrigerators in three million households. Efficient fridges will use 400 kWh per year, while standard fridges consume 800 kWh per year. Efficient fridges cost 500 USD and have a lifetime of 10 years. Standard fridges cost 300 USD and last 8 years. One fridge per household is assumed.
Solar Water heaters	The GHG emission reduction potential for solar water heater is estimated at 1 tCO_2 equivalent per year for every solar thermal water heater installed. The emission reduction potential considers all urban households in Kigali classified as premium housing and 25% of households classified as mid-range housing.
Commercial and institutional buildings	
Hybrid diesel-solar PV power systems	The combination of the diesel generators and solar PV system offers a good alternative for GHG emission mitigation. An annual reduction in the GHG emission from diesel combustion in the generators was applied from 2020.
Efficient lighting	The replacement of lighting systems by efficient lightings such as LED. A reduction of 86% was assumed from 2020.

The GHG emissions simulated in the LEAP software under the mitigation scenarios with the baseline scenario are shown in in

. By the year 2050, the GHG emissions are projected to reduce from 6,145.42 Gg CO_2 eq. to 3,463.04 Gg CO_2 eq. (a cumulative GHG emissions reduction of 38,993.79 Gg CO_2 eq.) (Figure 3.9).

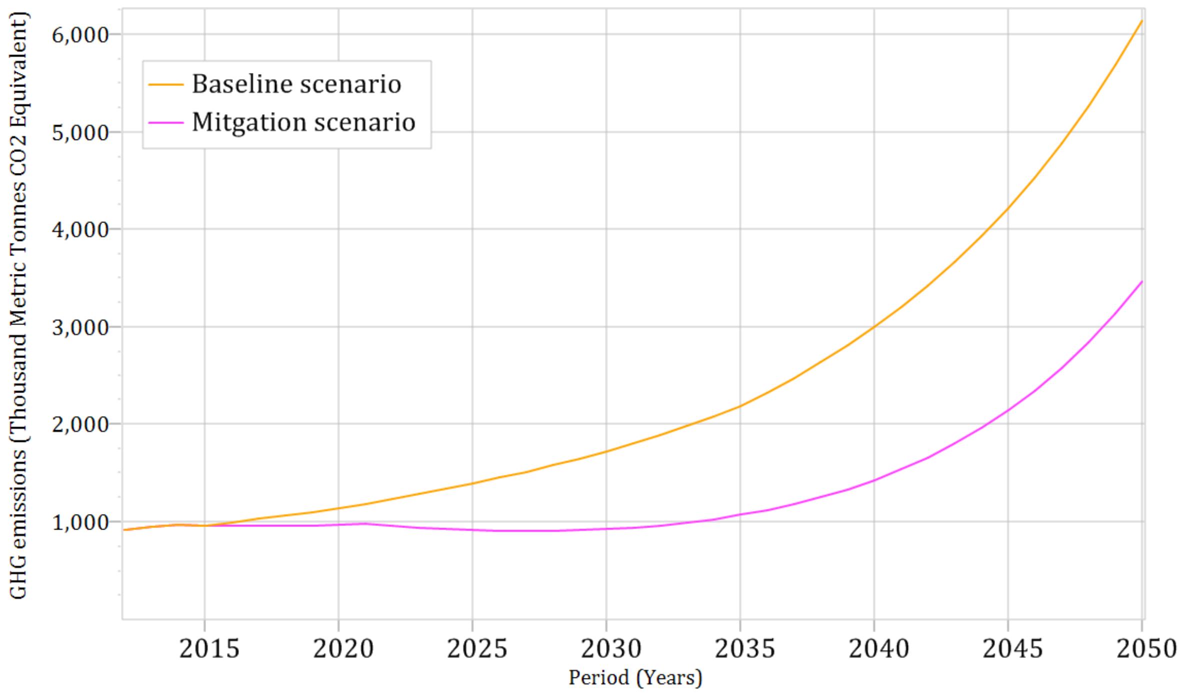


Figure 3.9 Simulated GHG emissions from buildings under baseline and mitigation scenarios (2012-2050)

3.3.4. Transportation

GHG emissions from the transportation sector are mainly generated from fuel combustion activities in various categories of vehicles. According to IPCC guidelines and the situation of the country, the GHG emissions from air transportation in Rwanda are mainly counted as international bunker and were not considered in this assessment. However, following the expected GDP growth and the construction of Bugesera airport, the situation may change and this should be carefully assessed in future national reports. The baseline scenario was developed in the LEAP software based on the historical trends and considering the government plans and the following key assumptions:

- Population and GDP growth rates as for buildings scenarios
- A steady annual increase of 2% and 3% were assumed respectively for gasoline and diesel consumption in all sub-categories of transportation sector except for motorcycles and heavy-duty trucks and buses.
- A steady growth rate of 5% in GHG emissions from motorcycles category was assumed for the whole period of the assessment.
- Based on the historical data, the annual growth rates of 2% and 6% were assumed for gasoline and diesel consumption, respectively for heavy-duty trucks and buses.

The baseline scenario developed in the LEAP software shows that GHG emissions will increase from 447.57Gg CO_2 eq. in 2012 to 1,678.25 Gg CO_2 eq. in 2050 (Figure 3.10). GHG emissions from motorcycles are expected to be the dominant contributor to total GHG emissions from transport (Figure 3.10).

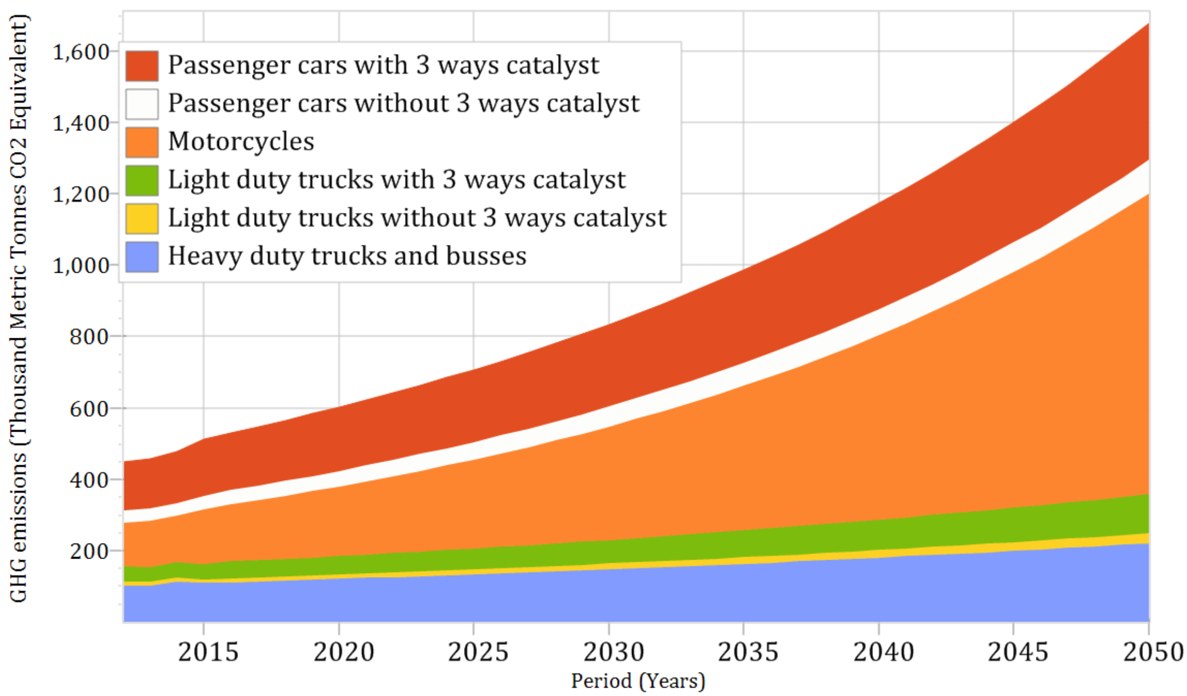


Figure 3.10 GHG emissions under baseline scenario between 2012 and 2050

The proposed mitigation options consist of an integration of various options including the adoption of electric cars combined with the fuel efficiency and the implementation of the recently signed agreement to construct an electric rail between Isaka and Kigali. It is evident that the implementation of the electric railway will reduce significantly the diesel and gasoline consumption by heavy-duty trucks and buses and the related GHG emissions. The future rail demand is well documented in the strategic transport master plan for Rwanda[4]. According to this report, a significant change in mode should rail be introduced to the network is predicted. Around 11,300 tons per day could shift from road-based transport to rail freight by 2020. This will be largely due to a shift of 80 per cent of imports and exports to rail. This will be largely due to a shift of 80 % of imports and exports to rail. The same report suggest that by 2020, there will be passenger rail demand of 23,000 passengers per day for the entire rail network including the northern extension. On the link between Tanzania to Kigali there will be passenger rail demand of 5 500 passenger per day. This was calculated as part of the modal split in the demand model as discussed earlier in the document. It is important to note however, that due to the lack of data related to all rail projects, which are still under studies, the related GHG emissions reduction was not completely quantified in this report. Considering the importance of the projects and their possible impact on the GHG emissions from transportation, this quantification should be among the priorities in future reports. Diesel fuelled cars will be partially replaced by electric cars starting from 2020. This mitigation option was proposed following the Volkswagen plans to install a car assembling plant in Rwanda. It is planned to produce 5,000 cars annually from 2020. Electric cars are expected to replace 150,000 passenger cars by 2050. The electric cars will require an average of 30 kWh per 100 km.

The mitigation options were integrated in a single mitigation option and modelled in the LEAP software (Figure 3.11). The simulated GHG emissions under mitigation scenario are expected to increase from 447.60 Gg CO_2 eq. in 2012 to 1,169.40 GgCO_2 eq. in 2050 (a cumulative GHG emission reduction of 8,690.40 Gg CO_2 eq. between 2012 and 2050) (Figure 3.11).

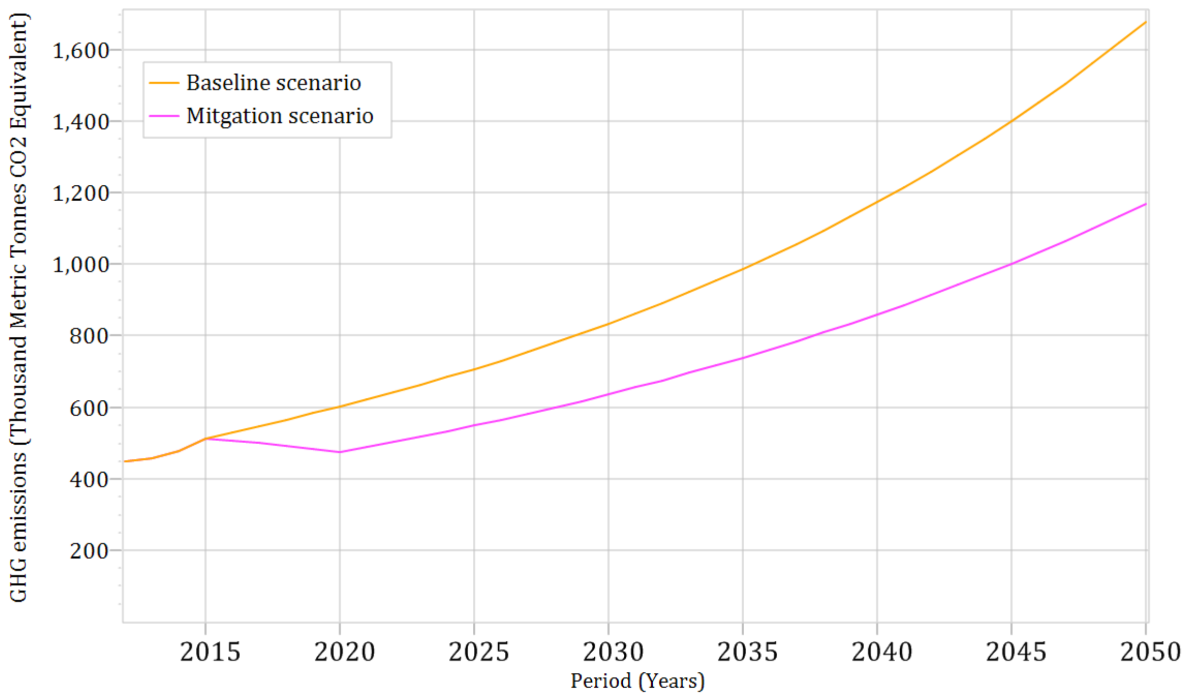


Figure 3.11 Simulated emissions from transportation under baseline and mitigation scenarios (2012-2050)

[4]Government of Rwanda, strategic transport master plan for Rwanda, 2012, Kigali-Rwanda

The electric cars will require an average of 30 kWh per 100 km. Another important option is the integration of the bicycles with with the Bus/BRT system in Kigali and secondary cities. However, this option should be implemented after ensuring safe parking at convenient locations.

The mitigation options were integrated in a single mitigation option and modelled in the LEAP software (Figure 3.11). The simulated GHG emissions under mitigation scenario are expected to increase from 447.60 Gg CO_2 eq. in 2012 to 1,169.40 GgCO_2 eq. in 2050 (a cumulative GHG emission reduction of 8,690.40 Gg CO_2 eq. between 2012 and 2050) (Figure 3.11).

3.4. Mitigation assessment and abatement measures in IPPU sector

The Industrial Processes and Product Use (IPPU) sector comprises GHG emissions generated directly from the non-energy-related industrial activities. The GHG emissions from fuel combustion are considered in the energy sector. In Rwanda, the GHG emissions from the IPPU sector represent the emission generated from the following categories: (i) 2A mineral industry, (ii) 2.C metal industry, (iii) 2D Non- Energy Products from Fuels and Solvent Use and, (iv) 2F product use as substitutes of ozone depleting substances. Sub-categories that are applicable considering Rwanda circumstances are: (i) 2A mineral industry: 2A1: cement production and 2A2: lime production; (ii) 2.C metal industry: 2C.1 iron and steel and 2C.2 ferroalloys production; (iii) 2D Non-Energy Products from Fuels and Solvent Use: 2.D.1 Lubricant use and 2.D.2 Paraffin Wax use; and (iv) 2F product use as substitutes of ozone depleting substances: refrigeration and air conditioning.

The Business-as-usual scenario is based on actual IPPU emissions for the year 2015 and projected to include the future until 2050. In the long run, an annual growth rate of 8% was adopted based on the emissions growth rate of previous five years, i.e. from 2009 to 2014, GDP growth rate in the future and the predicted macroeconomic growth for the industry sector until 2050. Based on the 2015 share of IPPU emissions, the mineral industry will contribute the large share of around 85%, the metal industry with 2%, the Non-Energy Products from Fuels and Solvent Use with 5% and 8% for the products uses as substitutes for Ozone depleting substances. In fact, the mineral industry is predicted to keep on rising in the coming years based on the infrastructure gaps in the country and the population projected to double to around 23 million during the forecasted period from 2015 to 2050. For instance, the renovated cement production plant at CIMERWA has since 2015 expanded its capacity six times from 100,000 tonnes of cement a year to 600,000 tonnes a year. The baseline scenario of IPPU emissions shows a gradual increase from 81.68 Gg CO_2eq in 2015 and 259.10 Gg CO_2eq in 2030 to 1207.66 Gg CO_2eq in 2050 (Figure 3.12).

Two mitigation options are proposed in the IPPU sector:

- **Increased proportions of Pozzolana in cement:**

The emissions in cement production arise from fuel combustion around 40% of the total and from the calcination reaction approximately 50% and the remaining 10% of CO_2 emissions arise from grinding and transport. The emissions from fuel combustion can be reduced by energy efficiency methods and changing the type of fuel while the process emissions are reported unavoidable and can be reduced only by reducing demand as well as improved material efficiency (Fischedick et al., 2014).In Rwanda, the cement manufacturing process is the first largest cause of non-energy related GHG emissions in mineral industry due to clinker production, the key ingredient in cement. Thus, the proposed mitigation considers to increase the share of non-clinker additives in the cement production beyond current cement-to-clinker ratio of 0.7 in the country. A rational 2% substitution of clinker with pozzolana from 2025 to 2029 and 5% (i.e. 0.65 cement-to-clinker ratios) substitution from 2030 to 2050 was assumed and a corresponding 2% and 5% reduction of CO_2 emissions was also assumed. The implementation of this mitigation will result in a slight reduction of total baseline IPPU emissions from 2.86 Gg CO_2 eq. in 2025 to 48.97 Gg CO_2 eq. in 2050 (Figure 3.12).

- **Gradual substitution of F-gases by less polluting substitutes:**

Rwanda neither produces nor export substitutes for ozone depleting substances "F-gases" but they are being imported mainly for refrigeration, stationary air conditioning and mobile air conditioning. Among the ODS alternatives surveyed in Rwanda includes the controlled substances as per the annex F of the Montreal Protocol such as HFC-134a, HFC-125, HFC-143a and HFC-32(UN, 2016).Mitigation measures for category 2F emissions considered the gradual substitution of F-gases by less polluting substitutes. The controlled substances in 2F category are projected to decrease significantly by considering the future effects of Kigali amendment of the Montreal Protocol on substances that deplete the ozone layer(UN, 2016). Thus, bearing in mind that the 2F gases imported for refrigeration and servicing sector are under the controlled substances, the calculated level of their consumption expressed in CO_2 eq. was set to gradually decrease and not to exceed the following percentages: (a) 2020 to 2024: 95%; (b) 2025 to 2028: 65%; (c) 2029 to 2033: 30%; (d) 2034 to 2035: 20%; (e) 2036 to 2050: 15%.Gradual substitution of F-gases by less polluting substitutes (ODS) will contribute to the decrease of total baseline IPPU emissions from 0.51 Gg CO_2 eq. in 2020 to 86.46 Gg CO_2 eq. in 2050 (Figure 3.12).

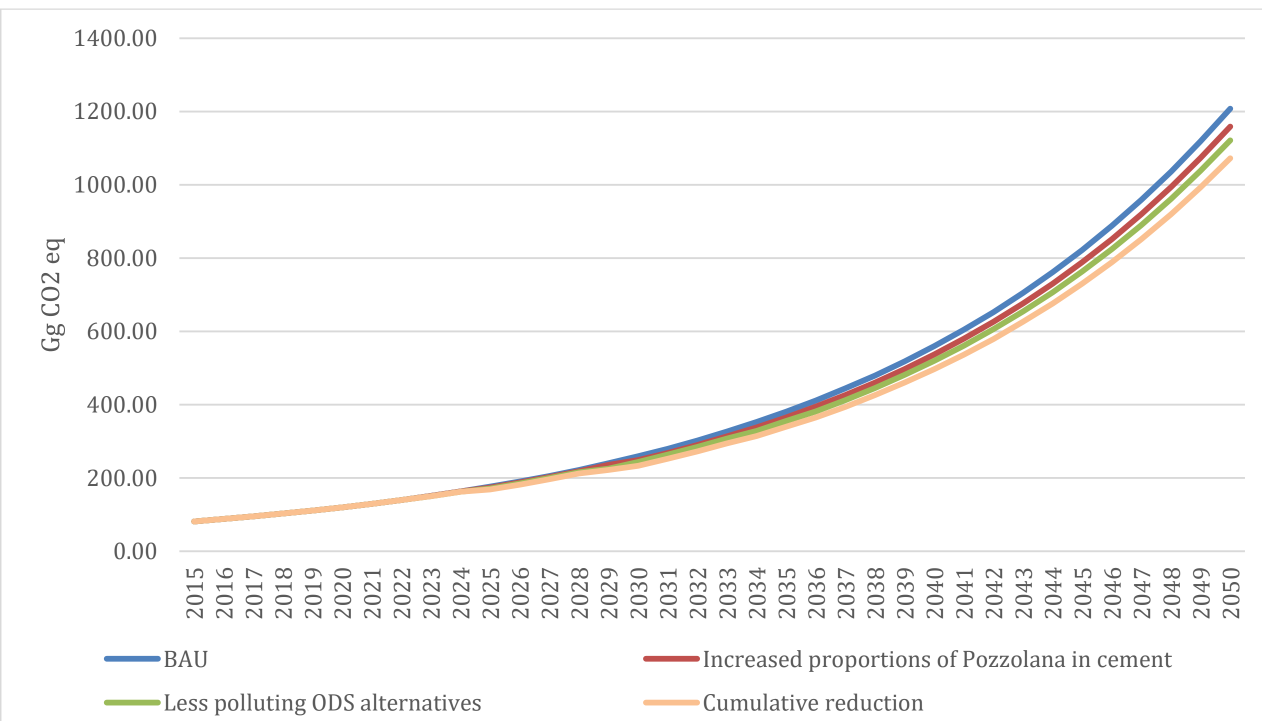


Figure 3.12 BAU and mitigation alternatives for the IPPU sector (2015 – 2050)

However, it is obvious that the process emissions for cement and lime production will keep on rising due to the country development and the climate change adaptation measures that need cement among other requirements. In fact, while Rwanda standout worldwide among the very lowest level of CO_2 emissions with around 0.1 ton per capita in 2014 (WB, 2015), it could be foreseen that further national economic growth will be challenging to accomplish without increasing the level of GHG emissions among other things. Therefore, other GHG mitigation measures should be considered in the mineral industry sector such as to reduce the demand in cement trough cleaner production measures and the construction of green building as well as the improved material efficiency in cement production. This improved material efficiency in cement-to-clinker fractions will require further national and international research and development actions to evaluate substitution materials and to assess their regional availability.

3.5. Mitigation assessment and abatement measures in waste sector

3.5.1. Solid waste

The business-as-usual scenario for the GHG emissions from solid waste sector considered the emission from (i) solid waste disposal site; (ii) biological treatment of solid waste; and (iii) waste incineration. The development of baseline emissions scenario was based on the following key assumptions:

- Demographic projections have considered the medium scenario of the Population Projection from 2015 to 2030 reported in the 4th population and housing census 2012 (NISR, 2012).
- Considering that population projections from 2030 to 2050 were given for 20 years period (RoR, 2017), linear interpolation has been used to derive midway levels of population. Thus a 1.98% year-on-year increase of population was calculated for that period.
- An annual increase of 3% from 2012 in urban population was assumed and the results correlate with the percentage of urban population projection of Rwanda sectoral analysis in NAMA report (REMA, 2015a).
- The default value of waste generation of 290kg/cap/year as proposed by IPCC 2006 guidelines has been used for rural waste generation, i.e. waste that undergoes biological treatment (IPCC, 2006).
- No methane recovery from waste management is assumed as it is the case for 2015.
- The waste generation per capita per year considered the economic growth of Rwanda, i.e. the GDP by using the data generated by Rwanda NAMA waste model, from which the annual waste generation in urban area is expected to grow from 338 kg/c/yr in 2016 to 478 kg/c/yr in 2050 (REMA, 2015a).
- The waste composition has been kept constant as the percentage used in the solid waste national inventory report.
- Considering the population increase, creation of secondary cities and the increase of recycling, the current 65% of waste to SWDS was kept constant.
- Population making compost at rural household level was estimated at 78.9% of rural population, based on the national inventory report and considering the year 2015 as the baseline year.

- Waste generation rate in rural area is considered constant and the African region default value of 0.29 tonnes/cap/year has been used to estimate total waste for composting (IPCC, 2006).
- The type of waste composted, and for the case of Rwanda, food waste has been considered as more than 67% of biodegradable waste is food waste from kitchen waste.
- There is no methane recovery, i.e. the total generated methane is released to the environment.
- The quantity of waste incinerated was derived from the number of the population, based on the quantity of waste incinerated in 2014 estimated at 0.265 kg per person per year.
- Mainly clinical wastes are incinerated in Rwanda where each health facility is supposed to have the incinerator

The BAU scenario for the solid waste sector shows an increase from 347.64 Gg CO_2eq in 2015 to 2,269.17 Gg CO_2eq in 2050 (Figure 3.13). This high increase of more than 6 times will be dominated by the increase of urban population from 2.6 to 12.1 million respectively in 2015 and 2050.

Two mitigation scenarios were considered in for GHG mitigation in solid waste: (a) Utilization of Landfill Gases (LFG) for power generation and (b) Use of solid waste for energy generation. The utilization of Landfill Gases requires the development of semi- or fully- controlled landfills, and the establishment of Landfill Gas (LFG) plants for power generation. The assumption used in the NAMA report (REMA, 2015a) was considerd and it assumes an increase of LFG extraction from 30% in 2020 to 60% in 2050. This scenario assumes the LFG capture increasing from 30% in 2020-2029 to 40% in 2030-2039 and to 50% from 2040 to 2050. The reduced emissions from utilization of Landfill Gases for power generation will increase from 94.52 Gg CO_2 eq in 2020 to 1030.41 Gg CO_2 eq in 2050 (Figure 3.13). Other co-benefit that results from this mitigation scenario include but not limited to job creation opportunities for stakeholders involved in the waste management process chain; improved air, water and soil quality; reduction of leachate and improved cleanness of the environment (RoR, 2017).

The second alternative for GHG emissions mitigation scenario for solid waste sector is the development and implementation of Waste-to-Energy (WtE) plants servicing the Kigali and other urban area (REMA, 2015a). TheWtE scenario consist in recovering energy from waste by the conversion of non-recyclable waste materials into useable heat, electricity or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion and landfill gas recovery (RoR, 2016). Thus, the WtE scenario considers the conversion of non-recyclable waste materials from urban area into usable electricity. The first WtE plant in Kigali City would have a capacity to process up to 800 tonnes of solid waste per day (or 292 Gg solid waste per year), and an electricity generation capacity of up to 15 MW per hour by 2021 which will increse to 30 MW and 45 MW respectively in 2030 and 2040. A second and a third WtE plants with the same capacity will be introduced respectively in 2030 and 2040.The reduced emissions from WtE plants will increase from 153.11 Gg CO_2eq or 29% in 2021 to 637.6 Gg CO_2eq or 28% in 2050 (Figure 3.13). In addition the WtE alternative will generate much other environmental co-benefit such as: saving space otherwise occupied by wastes, electricity generation, avoid groundwater pollution, and reduction of methane GHG usually released from SWDS.

Figure 3.13 Baseline (BAU) and mitigation scenarios for solid waste (2015 – 2050)

3.5.2. Wastewater

The wastewater sub-sector in Rwanda is still developing in terms of practices and technology use and is not currently serviced by centralized systems and utilities in either urban or rural areas. Thus, today the sanitation infrastructures in Rwanda mainly include the following: (i) individual small wastewater treatment unit specific to a building or a semi collective sewer network and which release uncontrolled treated effluent, (ii) sceptic tanks for individual houses and small building which are emptied regularly with the faecal sludge disposed in dumping sites, (iii) individual latrines which are emptied regularly with the faecal sludge disposed in dumping sites. But currently, the government is committed to implement the sanitation policy which is evidenced by the plan to develop a centralized wastewater treatment plant for Kigali city and other waste management facilities that are being constructed in secondary cities. The sanitation policy has the main mission to promote, plan, build and operate services in a sustainable, efficient and equitable manner (RoR, 2016).

Emissions from wastewater were modelled using the 5 year trend of emissions prior to 2015, which is 2.3% annual increment.Under the BAU scenario, emissions will increase from 289.63 Gg CO_2eq in 2015 to 641.94 Gg CO_2eq in 2050 (Figure 3.14).

The mitigation scenario for wastewater treatment assumes the introduction of centralised wastewater treatment plants and the reuse of wastewater in particular for irrigation purposes. Based on ongoing projects (e.g. The Kigali central wastewater treatment plant in Nyarugenge, Feasibility Study and Detailed Engineering Designs for a Centralized Sewerage System for Kibagabaga and Kinyinya Catchments in Gasabo District) for wastewater treatment in Rwanda and the requirement of the national sanitation policy, the population connected to the centralised wastewater treatment in urban area was projected to gradually increase from 12% to 70% respectively by 2022 and 2050.Another proposed mitigation option is the use of wastewater sludge to generate biogas (REMA, 2015a). This process requires the collection of sludge from pit latrines and small treatment systems, and a central biogas plant. This mitigation option has a medium mitigation potential and a high level of challenge as it requires new methods and practices at the source such as collection of wastewater, and can likely face issues of lower participation and motivation from households. This option also requires a novel system for the collection of sludge, which does not exist yet in Rwanda.

The results of the mitigation scenario from wastewater treatment and reuse analyses show that GHG emissions are projected to increase from 296.30 Gg CO_2eq in 2016 to reach 421.33 Gg CO_2eq in 2050 (Figure 3.14). The avoided emission for wastewater treatment and reuse measures without considering other several co-benefits is around 220 Gg CO_2eq by 2050.

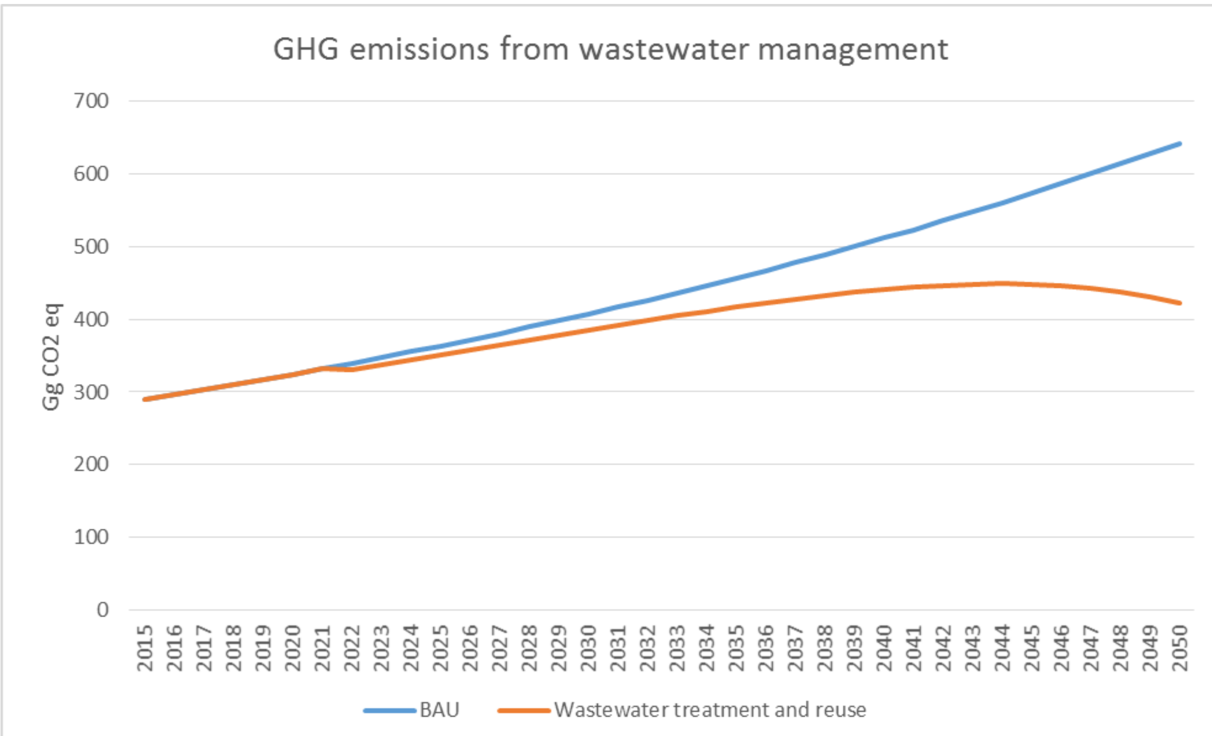


Figure 3.14 Baseline (BAU) and mitigation scenarios for wastewater (2015-2050)

3.6. Mitigation assessment and abatement measures in agriculture sector

3.6.1 Crop sub-sector

The projections in crop sub-sector assume strong increase in GHG emissions, mainly because of strong policy support for expansion of use of mineral fertilizers (urea) and crop intensification. The crop sub-sector, accounting for more than 67% GHG emissions in 2015, is projected to grow at the rate of 5% for business as usual. The major source of GHG emissions in the crop sub-sector is mineral fertilizer use through urea application.

Major mitigation options in the crop sub-sector include replacement of urea by less volatile N fertilizers, more judicious use of fertilizers based on soil maps and specific crop requirements, and development of large quantity and high quality compost production, farmer training and compost quality control system to largely reduce N losses. The two proposed mitigation options and the Business as usual (BAU) are described in Table 3.3.

Table 3.3 Description of mitigation scenarios in the Crop sub-sector

Mitigation Scenarios	**Description of mitigation scenarios**
Business as usual (BAU)	The baseline mitigation scenario (BAU) reflects a future in which there are no additional policies or programs designed to encourage or require actions that reduce GHG emissions or enhance carbon sinks. Thus, the business as usual scenario assumes implementation of current policies and current GHG trend. Emissions are projected using the 5 year trend prior to 2015, which is about 5% annual increase in GHG emissions (Figure 3.15).
Option A (medium mitigation strategy)	This mitigation scenario forestalls 7.6% annual increase in emissions, 10% reduction in urea use through its replacement by more environmental friendly fertilizers and 4% through expansion of enriched compost production by 20% of farmers. Total mitigation potential for mitigation option A is 14% reduction in total GHG emissions by 2050 as compared to BAU total emissions (Figure 3.15).
Option B (maximum mitigation strategy)	This mitigation scenario projects 6% annual growth in emissions with 20% reduction of BAU total emissions (12% reduction in GHG emissions from replacement of urea by more environment friendly fertilizers, and 8% of BAU emissions by focusing more on enriched compost production [using high quality manure and mineral fertilizers] and having at least 40% of farmers adopting it to cover their needs) (Figure 3.15).

Key indicators for mitigation options implementation in the crop sub-sector include the quantity of less emitting N fertilizers, the proportion of urea fertilizer replaced/reduced, the quantity of compost produced, increased yield and food security, number of farmers trained and using environmental friendly fertilizers. The baseline and mitigation scenarios for the crop sub-sector from 2006 to 2050 are illustrated in Figure 15.Under the BAU scenario the GHG emissions from crop sub-sector will increase from 2,066.0 Gg CO_2eq.in 2012 to 8,354.00 Gg CO_2eq. in 2050, while under the medium mitigation option A, the GHG emissions from the crop sub-sector will increase from 2,066.0 Gg CO_2eq in 2012 to 7,194.0 Gg CO_2eq in 2050 (Figure 3.15).

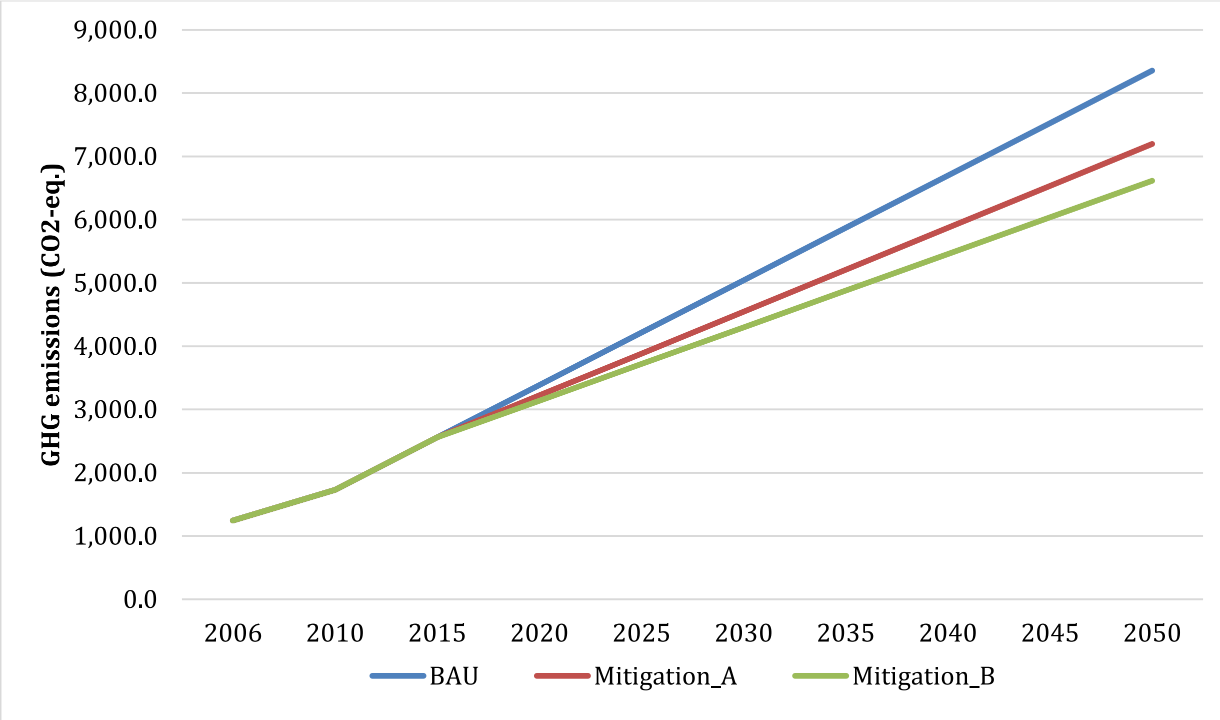


Figure 3.15 Mitigation scenarios for Crop sub-sector (2006-2050)

In Rwanda, the main barriers for the crop sub-sector include limited resource base (land) for biomass production and high cost of mineral fertilizers, as well as their narrow range at the local market, quasi-un-existent guidelines in terms of precise requirements of crops according to specific soils, quasi-unavailability of micro-nutrient fertilizers and lack of clear information of the extent of site-specific micronutrient deficiencies and the potential of micronutrient fertilizers to improve crop yield beyond the application of the standard NPK 17:17:17 or urea.

However, to achieve both mitigation scenarios (option A & B), the current agricultural policy (mainly CIP) should be explained more thoroughly to farmers. This should include appropriate crop combinations (for both, intercropping ad rotations) for more efficient mineral fertilizer use, as well as to clarify how the required doses may be applied in more splits to reduce its leaching from soil. More judicious use of mineral fertilizers should be technically supported by the Crop Intensification Program and research should monitor the impact of the change. In case of financial constraints to introduce more expensive but less volatile N fertilizers, focus in the policy and its implementation should be on expansion of compost use and dissemination of technical knowledge for compost production. Emphasis could be also on enforcement of existing policies (e.g. support to private sector, SMEs, facilitation of access to agricultural loans, incentives for high employment enterprises, etc.). Other options are to support diversified import of types of fertilizers to include micronutrient fertilizers, liquid foliar fertilizer sprays etc. and/or to support research to study the potential of micronutrient fertilizers to improve yields and to map the occurrence of micro-nutrient deficient soils.

In the field of technical knowledge, there is a need to expand training program and make it nationwide through targeting all village-based farmer promoters, disease diagnostic and surveillance, and provision of technical support in terms of introduction of manure management standards, follow up and quality control for the implemented programs (e.g. inspection of manure quality). Moreover, dissemination of technical knowledge on more diversified and more environment friendly fertilizer use should be promoted, while research should initiate studies to develop more nutrient efficient varieties which are more responsive to soil symbionts. A technical knowledge on production of quality compost manure with combined use of mineral fertilizer enriched compost should be promoted and its quality inspected by research.

3.6.2 Livestock sub-sector

Livestock, which was contributing less than 36% of the total Agriculture emissions in 2015, will most probably grow slowly due to limited resources for its further expansion, especially, large stock. Major mitigation options in the livestock sub-sector include replacement of local cows with improved ones and reducing their number, promotion of biogas and collective farm holdings, as well as building manure storage facilities and training in improved cow and manure management. Two mitigation scenarios are proposed: (a) Option A with Girinka scheme to medium levels (improved cow, better feed and biogas plants) and Option B with Girinka scheme to maximum levels with higher adoption and out scale of the technologies (more improved cow, better feed and biogas plants). The two mitigation options and the Business as usual (BAU) are described in Table 3.4.

Table 3.4 Description of mitigation scenarios in the livestock sub-sector

Mitigation Scenarios	Description of mitigation scenarios
Business as usual (BAU)	The baseline mitigation scenario (BAU) assumes implementation of current policies and current GHG emissions trend. Emissions are projected using the 10 year trend prior to 2015, which is 3.3% annual increase in emissions from livestock.
Option A (medium mitigation strategy)	The sources of Emissions from livestock are mainly enteric fermentation and manure management. The enteric fermentation emissions are projected to increase by 2.7% annually. Promotion of better livestock feed (especially legume fodder species) along with replacement of 10% local cows by 10% improved cows, creation of collective farm holdings and farmer training in better livestock management – will give 23% decrease in the projected BAU GHG emissions (10% from improved cows; 10% from biogas and 5% from farmer trainings and resulting improved cow productivity). Emissions from manure management are projected to increase by 2.6% annually. The projected reduction is 20% of BAU emissions (8.4% with building collective farms for 10% cow population and by 11.6% with building appropriate manure storage facilities). This scenario projects 62% increase in GHG emissions by 2050 as compared to 2015 (Figure 3.16).
Option B (maximum mitigation strategy)	In this mitigation scenario, the emissions from enteric fermentation are projected to increase by 2% annually. The projected reduction is 24% of BAU emissions (14% through building collective farms; 6 % through building of biogas digester and 4% from farmer training in improved cow and manure management). Replacement of 30% of local cows by 10% improved cows, and better livestock management in collective farm holdings + farmer training in better management – will lead to 20% decrease in GHG emissions. The mitigation option B projects emissions from manure management to increase by 2% annually. This scenario is expected to reduce the projected BAU GHG emissions by 49% (25% reduction from building of collective farms for 20% livestock and 24% from building manure storage facilities for 200,000 farms). This scenario projects 26% increase in GHG emissions by 2050 as compared to 2015 (Figure 3.16).

Key indicators for implementation of proposed mitigation scenarios include among others the proportion or number of cattle population of local cows replaced by improved cows, number of biogas units installed, and number of manure storage facilities built.The baseline and mitigation scenarios for the livestock sub-sector from 2006 to 2050, as illustrated in Figure 3.16 show that under the BAU scenario, the GHG emissions from livestock will increase from 1,876.0 Gg CO_2eq.in 2012 to 3,780.00 Gg CO_2eq.in 2050, while under the medium mitigation option A, the GHG emissions from livestock will increase from 1,876.0Gg CO_2eq. in 2012 to 2,466.0 Gg CO_2eq. in 2050.

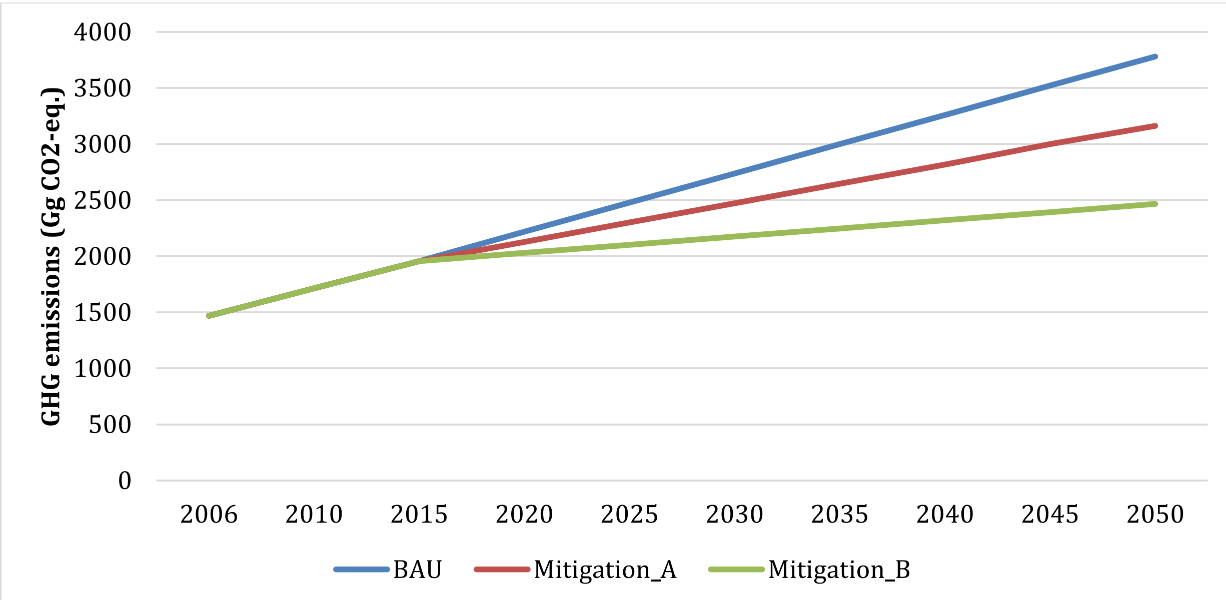


Figure 3.16 Mitigation scenarios for livestock sub-sector (2006-2050)

Although Livestock accounts for about 20% of the current GHG emissions from agriculture sector, it will be important to implement the suggested mitigation measures, notably, by reducing large stock population through replacement of local cows by more productive improved breeds, promote collective farms, expand biogas use and build appropriate manure storage facility. The common barriers in Livestock sub-sector in Rwanda are limited land for pasture and fodder production, occurrence or resurgence of endemic livestock diseases, limited knowledge on quality manure production and management on farm. Other limitations include undefined policy in terms of the population size and composition of the large stock herds, focus on individual cattle holding, little attention/guidelines for high quality manure production, lack of manure production standards, limited capacity to invest in biogas technology at individual farm level, lack of incentives for feed industries and importation of some feed ingredients that are missing locally, limited support to research to develop local feed formula and support its industrial production.

Most of the mitigation options in Livestock sub-sector (replacement of local cows, investment in good manure storage facility, expansion of feed industries, and disease surveillance/prevention) require heavy financial support. However, these initial investments will pay back not only with the projected reductions in GHG emission growth trend, but also with creation of additional jobs and economically beneficial enterprises in the livestock subsector, safer and greener energy production through biogas, etc.

3.7. Mitigation assessment and abatement measures in FOLU sector

The Government of Rwanda recognizes the importance of forestry resources for providing various ecosystems services including carbon sequestration, water flow regulation and many other provisioning, cultural and supporting services. In this regards, the Government has elaborated several policies and programs that describe relevant interventions that support restoration and sustainable management of forest resources and agro-forestry with the aim of ensuring optimum contribution to climate change adaptation and impact mitigation. Some of the policy and program documents include the Green Growth and Climate Resilience – National Strategy for Climate Change and Low Carbon Development (GGCRS) (RoR, 2011), Assessment of Sectoral Opportunities for the Development of Nationally Appropriate Mitigation Actions (NAMAs) in Rwanda (REMA, 2015a), the Detailed implementation plan for the nationally determined contributions (NDCs) of Rwanda (REMA, 2017), the National Strategy for Transformation (NST 1)/Seven year government program (2017-2024) (RoR, 2017), the updated National forestry policy of 2018 (MINILAF, 2018a), the Forestry Sector strategic plan (FSSP, 2018-2024) (MINILAF, 2018b), and others. Basing on strategies outlined in these policy and program documents, major mitigation actions in Forestry and other land use should include:

- **Development of agro-forestry for sustainable agriculture:** Agro-ecology technologies must be mainstreamed in the agriculture intensification programme and other natural resource-based livelihood programmes. This will enable increasing the number of trees on farm per hectare. Multipurpose tree species, both indigenous and exotic should be raised in the nursery and distributed to farmers in different agro-ecological zones.

- **Promotion of afforestation and reforestation of designated areas through improved germplasm and technical practices in planting and effective post-planting operations (maintenance/tending activities):** More efforts are to be put in using quality germplasm, planting trees at the right time (rain season) and improving post-planting care (maintenance operations) in replanting harvested areas and planting new available forest areas such as on steep slopes, buffer zones around water bodies, wetlands, protected areas, roads and settlements. Mixed-species approaches which contribute greatly to the achievement of both mitigation objectives and adaptation benefits of ecosystem resilience and biodiversity must be promoted. Thus more indigenous species planting materials are to be produced, disseminated and planted to reduce the current dominance of Eucalyptus. While the national target remain to reach and maintain an overall 30% sustained forest cover of the total national land surface, planting of remaining potential area for afforestation and areas stipulated by the environmental law such as buffer and riparian areas as well as very steep slopes as priority, may bring the forest cover to well beyond the famous 30%.

- **Rehabilitation and improved forest management of degraded forest resources:** The National forestry inventory carried in 2015 reported that most forest plantations are understocked (DFS et al. 2016). There is need to maximize the productivity of the degraded forest plantations which present an opportunity to increase biomass supply without converting additional land. Public private partnerships to sustainably manage all public forest plantations through multi-year contracts with forests operators (in cooperatives) who would plant and maintain young plantations until they reach commercial size should be promoted as proposed in the FSSP (2018-2024).

- **Efficient wood conversion and sustainable biomass energy:** There is considerable waste that occurs due to conversion of wood into products (Timber, charcoal, biomass energy etc.) and the wood value chain is poorly organized making wood products lowly valued. Poor wood conversion efficiency implies that more trees are cut to meet wood demand which leads to over exploitation. Wastages from wood conversions should be reduced by increasing efficiency of the conversion process and improving the value of wood products to make them more profitable. Reducing waste of biomass through development of an efficient and professional improved charcoal value chain; increased use of wood pellet with high efficient gasifier stoves, especially in urban area; increased fuelwood use efficiency by providing improved stoves to every household and increased salvage and reuse of timber and service wood products can bring about considerable reduction in biomass energy demand. The FSSP (2018-2024) reported that it is possible to get 9.5% reduction in demand by conversion to only "green" charcoal production technologies; 14.5% reduction in demand – from use of alternative energy sources (LPG, wood pellets, etc.) and 9% reduction in demand from increased use of improved cooking stoves.

Two mitigation options (option A & B) together with the business-as-usual mitigation scenarios are proposed for the period running from 2015 to 2050. Option A is the medium mitigation scenario while option B is the maximum mitigation scenario. These mitigation scenarios are described in Table 3.5.

Table 3.5 Mitigation scenarios for Forestry and Other Land Use

Mitigation Scenarios	Description of the scenarios
Business as usual (BAU)	The baseline mitigation scenario (BAU) reflects a future in which there are no additional policies or programs designed to encourage or require actions that reduce GHG emissions or enhance carbon sinks. Thus the business as usual scenario assume implementation of current policies and current GHG trend. Emission removals are projected using the 5 year trend prior to 2015, which is 0.6% annual increment until 30% forest cover is reached (Figure 3.17).
Option A (medium mitigation strategy)	Agro-forestry development, afforestation/reforestation and improved tending operations, rehabilitation and improved management of existing forests, efficient wood conversion and sustainable biomass energy- 0.6% annual increment plus raising Mean Annual Increment from current 8 m^3/ha/year to 13 m^3/ha/year due to improved forest management; increase number of trees in Agro-forestry from current 25 to 50 trees per ha. The implementation of this option may increase removals by 92% compared to BAU removals (Figure 3.17).
Option B (maximum mitigation strategy)	Agro-forestry development, afforestation/reforestation and improved tending operations, rehabilitation and improved management of existing forests, efficient wood conversion and sustainable biomass energy - 0.6 % annual increment plus raising Mean Annual Increment from current 8 m^3/ha/year to 15 m^3/ha/year due to improved forest management; increase number of trees in Agro-forestry from current 25 to 75 trees per ha. The implementation of this option may increase removals by 144% compared to BAU removals (Figure 3.17).

Key indicators for the implementation of the mitigation scenarios in Forestry and Other Land Use include among others increased forest productivity (average annual increment in m^3/ha/year) and forest products harvested/supplied (m^3), agro-forestry coverage (number of farms with agro-forestry and number of trees on farm per ha), number of forest actors trained and certified (e.g. green charcoal producers), afforested/reforested areas (ha), number of jobs created in the sector, wood conversion efficiency (%), etc. The baseline and mitigation scenarios for forestry and other land use from 2015 to 2050 are illustrated in Figure 17.Under the BAU scenario, the GHG emission removals from Forestry and Other Land Use will increase from -11,219.10 Gg CO_2eq. in 2012 to -13,594.80 Gg CO_2eq. in 2050. But under the medium mitigation option A, the GHG emission removals from Forestry and Other Land Use will increase from -11,219.1 Gg CO_2eq in 2012 to -26,150.3 Gg CO_2eq in 2050 (Figure 3.17).

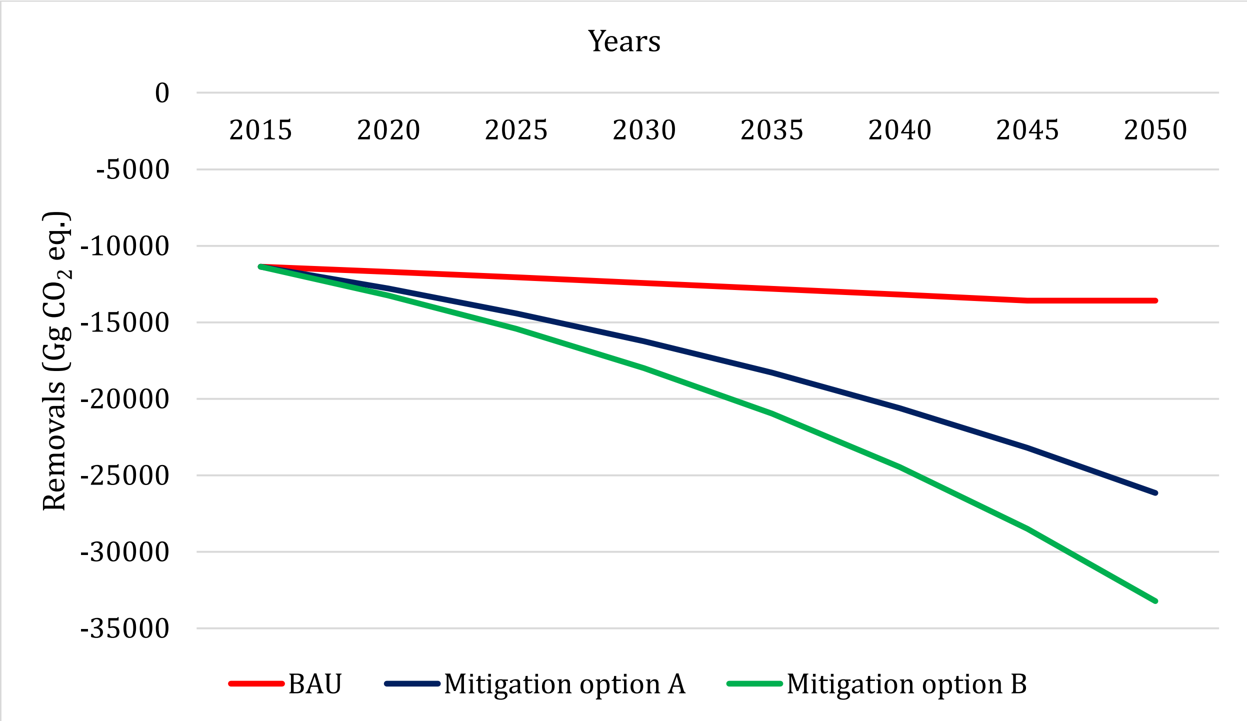


Figure 3.17 Emission removals trend under different mitigation scenarios (2015-2050)

Major barriers for implementing mitigation options in the forestry and other land use include among others limited land for afforestation, limited availability of quality and diversified planting materials, poor accessibility for some forests, limited human resource capacity, high cost of improved kilns, stoves and efficient wood processors and high cost of alternatives sources of energy. To overcome these barriers more efforts (and thus more investment) should be directed towards improving forest productivity (so that less area of forest would be needed to produce the same amount of forest products), improve the quality of germplasm of tree planting materials, capacity building for farmers and extension officers and incentivize forest activities as well as most efficient use of wood including improved cook stoves, wood processors, charcoal kilns and alternative energies such as liquefied gases, briquettes, wood pellets, etc.

Furthermore, limited land being the major constraint for Forestry and other land use, the land use master plan and the environment law should be enforced in order to claim lands that are either underutilized or non-matching land uses (e.g. steep slopes, and buffer of water bodies, roads and wetlands. In addition, adequate regulations of woodfuels (firewood and charcoal) production and transportation systems will need to be in devised in order to promote green or certified charcoal production and use. The national agro-forestry strategy which is being elaborated under the support of FAO should be well implemented by responsible institutions (mainly the MINAGRI, RAB, MINILAF and RWFA) in order to achieve targeted agro-forestry coverage. Moreover, forest and agro-forestry research must be adequately supported to produce improved germplasms of tree planting materials.

3.8. Summarized emission simulation in business as usual and mitigation scenarios

3.8.1 Summarized emission simulation in business as usual (baseline) scenarios

The summary of emission simulation for the business as usual (BAU) scenarios from 2012 to 2050 in all sectors is provided in Table 3.6 while Figure 3.18 illustrates the simulation trends of BAU emissions from all sectors between 2012 and 2050.

Table 3.6 Summarized emission simulation (Gg CO2 eq.) in business as usual scenarios

BUSINESS AS USUAL										
Sector	**Subsector**	2012	2015	2020	2025	2030	2035	2040	2045	2050
Energy	Electric power generation	106.1	82.0	234.2	407.2	692.8	1204.4	2093.5	3231.8	3346.3
	Energy Industries	50.2	91.2	129.8	185.4	265.8	382.7	553.1	803.0	1170.8
	Buildings	912.5	955.2	1133.3	1386.9	1718.5	2183.0	2995.8	4215.4	6145.4
	Transportation	447.6	510.4	601.5	706.5	833.1	986.5	1172.8	1400.1	1678.3
	Total energy	1516.4	1638.7	2098.7	2686.0	3510.3	4756.5	6815.3	9650.3	12340.8
Waste Sector	Solid waste	227.3	347.6	500.7	640.0	809.8	1025.3	1313.8	1709.2	2269.2
	Wastewater	270.0	289.6	324.5	363.6	407.4	456.4	511.4	573.0	641.9
	Total Waste	497.3	637.3	825.3	1003.6	1217.2	1481.8	1825.1	2282.2	2911.1
IPPU	Total IPPU	39.5	81.7	120.0	176.3	259.1	380.7	559.4	821.9	1207.7
AFOLU	Crop	2066.0	2559.0	3387.0	4215.0	5042.0	5870.0	6698.0	7526.0	8354.0
	Livestock	1876.0	1957.0	2217.0	2477.0	2738.0	2999.0	3259.0	3520.0	3780.0
	Forestry and other land use	-11219.1	-11359.9	-11704.8	-12060.2	-12426.4	-12803.7	-13192.4	-13593.0	-13594.8
National total		**-5224.0**	**-4486.2**	**-3056.8**	**-1502.3**	**340.2**	**2684.3**	**5964.4**	**10207.4**	**14998.7**

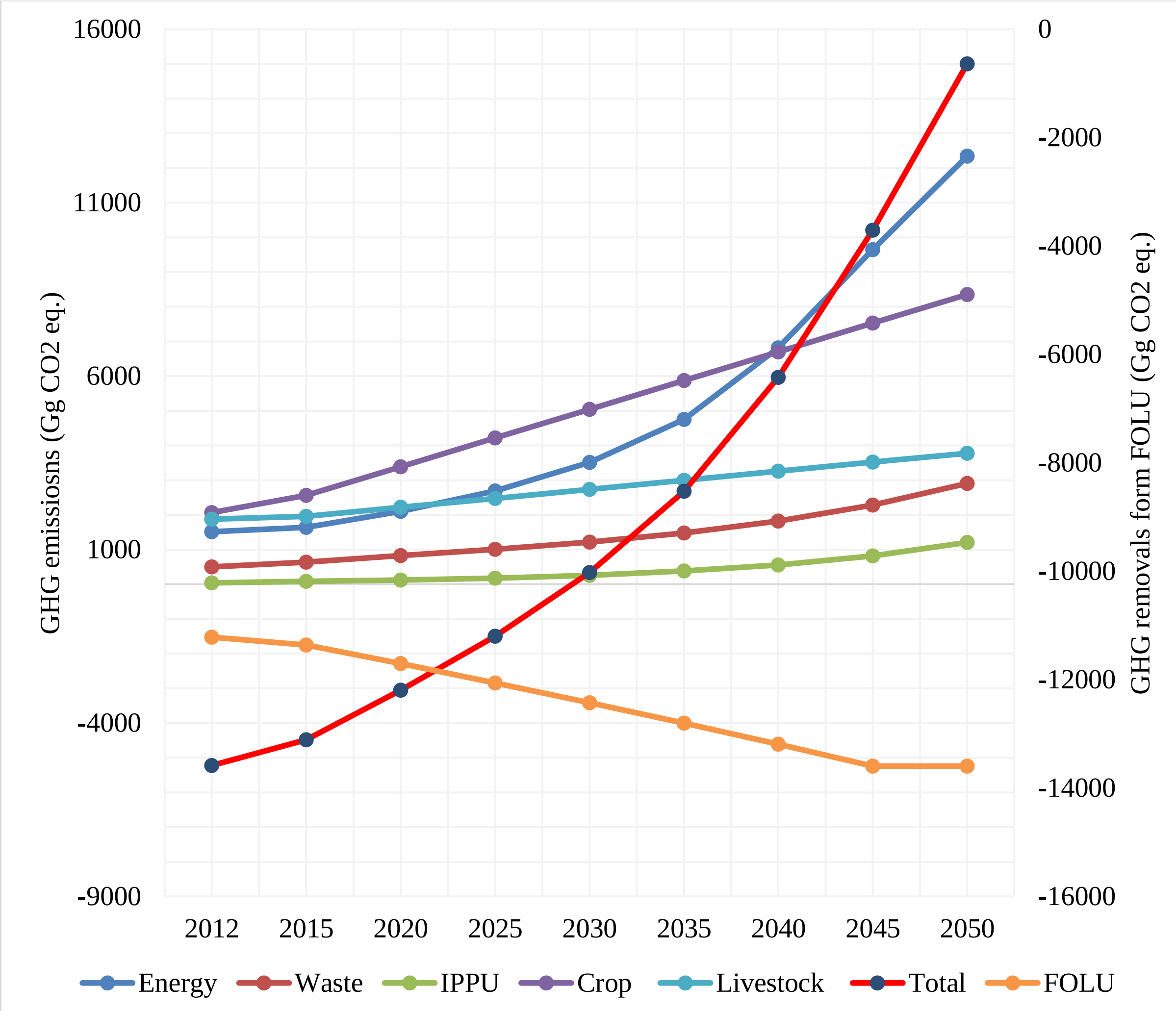


Figure 3.18 Emission simulation trends for BAU (Baseline) scenarios in different sectors

3.8.2 Summarized emission simulation mitigation scenarios

The summary of emission simulation for mitigation scenarios from 2012 to 2050 is provided in Table 3.7 while Figure 3.19shows the trends of emissions in mitigation scenarios for all sectors from 2012 and 2050.

Table 3.7 Summarized emission simulation (Gg CO2 eq.) in mitigation scenarios

MITIGATION SCENARIOS										
Sector	**Subsector**	2012	2015	2020	2025	2030	2035	2040	2045	2050
Energy	Electric power generation	106.1	82.0	191.5	306.4	412.1	716.3	1109.3	1817.4	1954.6
	Energy Industries	50.2	91.2	127.6	179.1	253.5	361.6	519.0	749.3	1087.6
	Buildings	912.5	955.2	960.2	910.4	919.9	1064.5	1422.3	2136.2	3463.0
	Transportation	447.6	510.4	474.0	548.4	635.8	738.6	859.4	1001.7	1169.4
	Total energy	1516.4	1638.7	1753.2	1944.3	2221.3	2880.9	3910.0	5704.6	7674.6
	Solid waste	227.3	347.6	406.2	349.4	407.7	375.3	115.5	317.2	601.1

Waste Sector	Wastewater	270.0	289.6	324.5	350.9	384.9	416.6	440.9	448.3	421.3
	Total Waste	497.3	637.3	730.7	700.3	792.6	791.9	556.4	765.5	1022.5
IPPU	Total IPPU	39.5	81.7	119.5	168.3	233.3	339.6	496.7	729.8	1072.3
AFOLU	Crop	2066.0	2559.0	3139.0	3718.0	4298.0	4877.0	5457.0	6532.0	7194.0
	Livestock	1876.0	1957.0	2029.0	2102.0	2175.0	2247.0	2320.0	2393.0	2466.0
	Forestry and other land use	-11219.1	-11359.9	-12796.9	-14415.6	-16239.1	-18293.2	-20607.2	-23213.9	-26150.3
National total		-5224.0	-4486.2	-5025.4	-5782.8	-6518.9	-7156.8	-7867.1	-7089.0	-6720.9

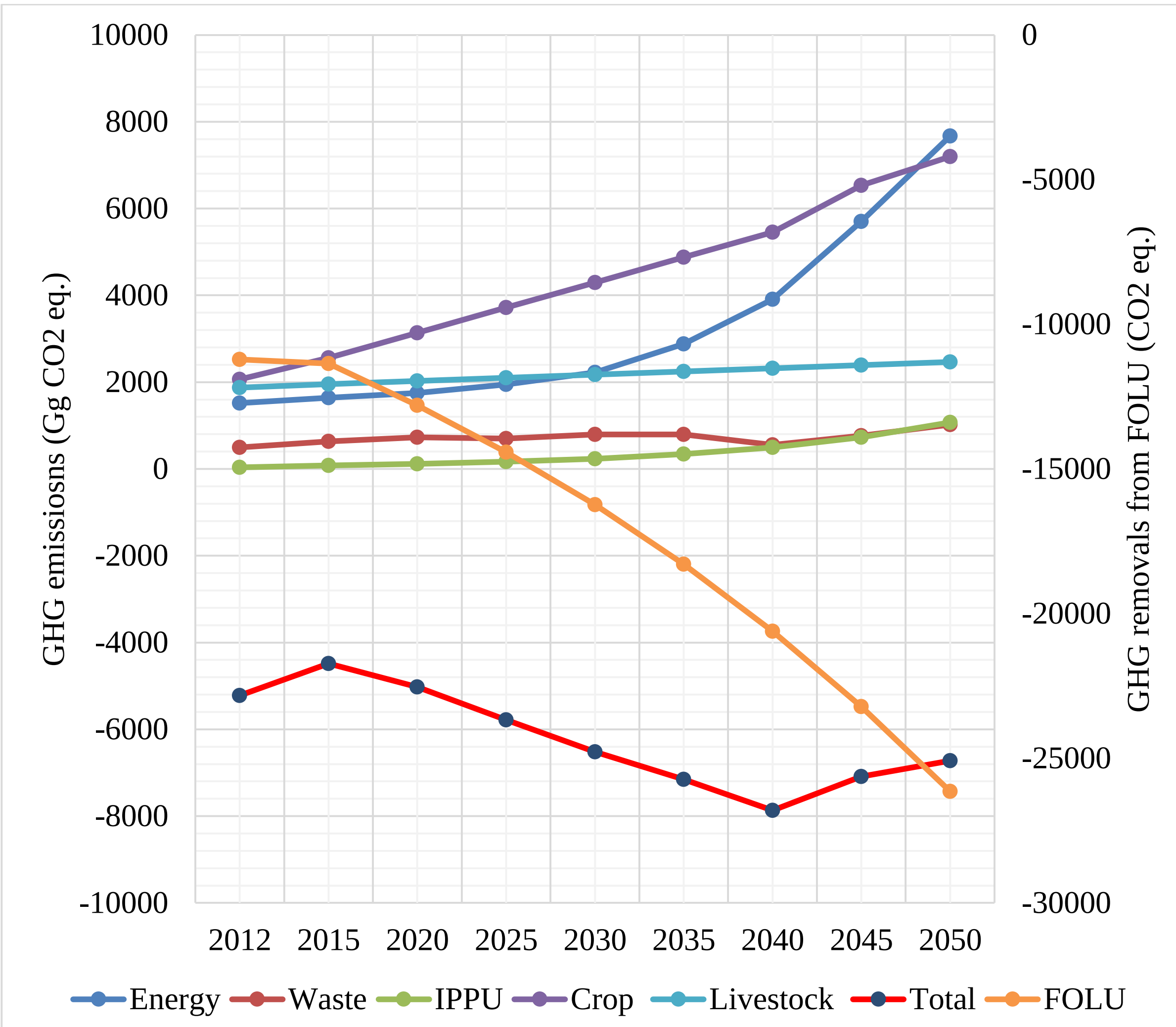


Figure 3.19 Emission simulation trends for mitigation scenarios in different sectors

3.8.3 Summarized emission simulation reduced or removed in mitigation scenarios

The summary of emission simulation for reduced or removed emissions in mitigation scenarios from 2012 to 2050 is provided in Table 3.8. The trends of total emissions reduced or removed in baseline and mitigation scenarios are shown in Figure 3.20.

Table 3.8 Summarized emission simulation (Gg CO2 eq.) reduced in mitigation scenarios

EMISSION REDUCED/REMOVED										
Sector	**Subsector**	2012	2015	2020	2025	2030	2035	2040	2045	2050
Energy	Electric power generation	0	0	42.7	100.8	280.8	488.1	984.2	1414.4	1391.7
	Energy Industries	0	0	2.2	6.3	12.3	21.1	34.1	53.7	83.3
	Buildings	0	0	173.1	476.6	798.6	1118.5	1573.6	2079.2	2682.4
	Transportation	0	0	127.5	158.1	197.3	247.9	313.4	398.3	508.8
	Total energy	0	0	345.5	741.7	1289.0	1875.6	2905.2	3945.7	4666.1
Waste Sector	Solid waste	0	0	94.5	290.6	402.1	650.1	1198.2	1392.0	1668.0
	Wastewater	0	0	0.0	12.7	22.5	39.8	70.5	124.7	220.6
	Total Waste	0	0	94.5	303.3	424.6	689.9	1268.7	1516.7	1888.7
IPPU	Total IPPU	0	0	0.5	8.1	25.8	41.1	62.7	92.2	135.4
AFOLU	Crop	0	0	248.0	497.0	744.0	993.0	1242.0	994.0	1160.0
	Livestock	0	0	188.0	375.0	563.0	752.0	939.0	1127.0	1314.0
	Forestry and other land use	0	0	1092.1	2355.4	3812.7	5489.5	7414.8	9620.9	12555.5
National total		0	0	1968.6	4280.5	6859.1	9841.1	13832.4	17296.5	21719.7

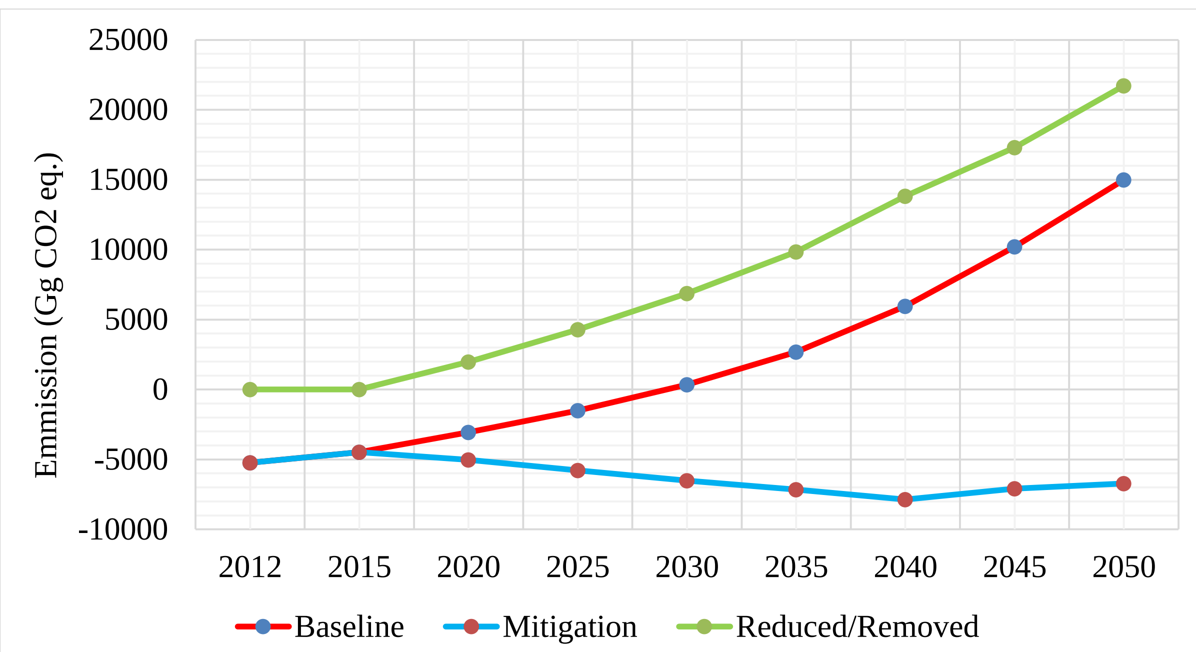


Figure 3.20 Trends of total emissions reduced or removed in baseline and mitigation scenarios

3.9. Justification of selected mitigation options

Table 3.9 below provides the options selected to reduce GHG emissions, their justifications and their potential mitigation impacts.

Table 3.9 Justification of selected mitigation options of GHG

Mitigation option	Justification	Potential impact
A. Energy		
1. The use of large renewable energies (Large hydro and solar PV plants)	The Government targets to increase the renewable energy power generation while reducing the liquid fuels for power generation. The liquid fuels are expected to reduce from 26.76% in 2017 to 6% in 2024, i.e. an annual reduction of around 3% (RoR, 2017). In addition, the country is planning to install various on-grid and off-grid hydropower and solar power plants to increase the installed capacity while reducing the GHG emissions associated with the nonrenewable energy generation. As detailed in the sustainable energy for all (MININFRA, 2015b), the shares of renewable energy generation (including solar, hydro, geothermal, imports, and off-grid generation) contributions to installed capacity and generation capacity are expected to increase to 65% and 55%, respectively by 2030.	The use of renewable energy sources is projected to generate a cumulative emissions reduction of 20,377.80 Gg CO_2 eq. by 2050
2. Increasing efficiency in manufacturing processes in different industries	In the food industries, there is need to improve efficiency in drying and roasting tea and coffee. According to NAMA (REMA, 2015a), the heat recovery from clicker production in the cement industry through co-generation and use of rice husk as replacement of peat and/or oil can lead to 45,000-60,000 tCO_2 eq. per year of emissions reduction. According to REMA (2017), 80% of total mines are expected to phase out fossil fuel use, through electricity by 2018. Based on this target, it can be inferred that by 2050 all the mining industries will be using onsite-generated electricity and/or grid connected electricity. Considering the projected GDP growth, the number of construction machinery will continue to grow through 2050. The implementation of efficient brick kilns could reduce significantly the fuel consumption the construction sector.	These mitigation measures will result in a cumulative reduction of 884.75 Gg CO_2 eq. by 2050
3. The use of the efficient lighting, cooking, refrigeration and use of solar heaters for hot water in buildings	These mitigation measures also referred to as efficient building consists of the efficient and sustainable use in residential and commercial buildings, the use of the efficient lighting and the use of solar heaters for hot water in buildings. Besides the environmental benefits, the adoption and/or strengthening of the latter options will provide some other socioeconomic benefits such as the indoor clean air, etc.	These mitigation measures are projected to generate a cumulative GHG emissions reduction of 38,993.79 Gg CO_2 eq. by 2050
4. Adoption of electric cars combined with fuel efficiency	These mitigation options consist of an integration of various options including the adoption of electric cars combined with the fuel efficiency and the implementation of the recently signed agreement to construct an electric rail between Isaka and Kigali. The implementation of the electric railway will reduce significantly the diesel and gasoline consumption by heavy-duty trucks and buses to 0% and by 80%, respectively from 2020. This reduction in fuel consumption will be followed by a substantive reduction in GHG emissions. Diesel fuelled cars will be partially replaced by electric cars starting from 2020. The Volkswagen plans to install a car	These mitigation measures are expected to generate a cumulative GHG emission reduction of 8,690.40 Gg CO_2 eq. between 2012 and 2050.

Mitigation option	Justification	Potential impact
	assembling plant in Rwanda. It is planned to produce 5,000 cars annually from 2020. Electric cars are expected to replace 150,000 passenger cars by 2050.	
B. Waste		
5. Utilization of Landfill Gases (LFG) for power generation and the use of solid waste for energy generation	The utilization of Landfill Gases requires the development of semi- or fully- controlled landfills, and the establishment of Landfill Gas (LFG) plants for power generation. The utilization of Landfill Gases for power generation will considerably decrease GHG emissions.Other co-benefits that will result from this mitigation option include but not limited to job creation opportunities for stakeholders involved in the waste management process chain; improved air, water and soil quality; reduction of leachate and improved cleanness of the environment (RoR, 2017).	The reduced emissions from utilization of Landfill Gases for power generation will increase from 94.52 Gg CO_2 eq in 2020 to 1030.41 Gg CO_2 eq in 2050.
6. Waste-to-Energy (WtE) plants servicing the Kigali and other urban area.	There are plans to develop and implement Waste-to-Energy (WtE) plants servicing the Kigali and other urban area (REMA, 2015a). The WtE option consist in recovering energy from waste by the conversion of non-recyclable waste materials into useable heat, electricity or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion and landfill gas recovery (RoR, 2016). Thus, the WtE scenario considers the conversion of non-recyclable waste materials from urban area into usable electricity. In addition to reducing GHG emissions, the WtE option will generate many other environmental co-benefit such as saving space otherwise occupied by wastes, electricity generation, avoid groundwater pollution, and reduction of methane GHG usually released from SWDS.	Under the WtE mitigation scenario, the reduced GHG emissions from WtE plants would increase from 153.11 Gg CO_2eq. in 2021 to 637.6 Gg CO_2eq. in 2050
7. The introduction of centralised wastewater treatment plants and the reuse of wastewater in particular for irrigation purposes.	The introduction of centralised wastewater treatment plants and the reuse of wastewater in particular for irrigation purposes is planned in Kigali city. Other waste management facilities are also being constructed in secondary cities in accordance with the sanitation policy. The main mission of the sanitation policy is to promote, plan, build and operate services in a sustainable, efficient and equitable manner (RoR, 2016).Based on ongoing projects for wastewater treatment in Rwanda and the requirement of the national sanitation policy, the population connected to the centralised wastewater treatment in urban area is projected to gradually increase from 12% to 70% respectively by 2022 and 2050.	Under this mitigation scenario, the avoided GHG emission for wastewater treatment and reuse measures without considering other several co-benefits is around 220 Gg CO_2eq. by 2050.
C. IPPU		
8. Increased proportions of Pozzolana in cement	The emissions in cement production arise from fuel combustion around 40% of the total and from the calcination reaction approximately 50% and the remaining 10% of CO_2 emissions arise from grinding and transport. The emissions from fuel combustion can be reduced by energy efficiency methods and changing the type of fuel while the process emissions are reported unavoidable and can be reduced only by reducing demand as well as improved material efficiency (Fischedick et al., 2014). In Rwanda, the cement manufacturing process is the first largest cause of non-energy related GHG emissions in mineral industry due to clinker production, the key ingredient in cement. Therefore, in addition to improving energy combustion efficiency methods, a progressive increase of Pozzolana	This mitigation measure will result in a reduction of total baseline IPPU emissions from 2.86 Gg CO_2 eq. in 2025 to 48.97 Gg CO_2 eq. in 2050

Mitigation option	Justification	Potential impact
	in cement by substituting clinker with Pozzolana will contribute to reducing GHG emissions.	
9. Gradual substitution of F-gases by less polluting substitutes.	Rwanda neither produces nor export substitutes for ozone depleting substances “F-gases” but they are being imported mainly for refrigeration, stationary air conditioning and mobile air conditioning. Among the ODS alternatives surveyed in Rwanda includes the controlled substances as per the annex F of the Montreal Protocol such as HFC-134a, HFC-125, HFC-143a and HFC-32 (UN, 2016). The controlled substances in 2F category are projected to decrease significantly by considering the future effects of Kigali amendment of the Montreal Protocol on substances that deplete the ozone layer (UN, 2016). Thus, bearing in mind that the 2F gases imported for refrigeration and servicing sector are under the controlled substances, the calculated level of their consumption expressed in CO_2 eq. is set to gradually decrease.	Under this mitigation scenario, the IPPU emission reduction will increase from 0.51 Gg CO_2 eq. in 2020 to 86.46 Gg CO_2 eq. in 2050.
D. AFOLU		
10. Replacement of urea by less volatile N fertilizers, more judicious use of fertilizers based on soil maps and specific crop requirements, training of farmers and development of large quantity and high quality compost production	The main barriers for the crop sub-sector in Rwanda include limited resource base (land) for biomass production and high cost of mineral fertilizers, as well as their narrow range at the local market, quasi-inexistent guidelines in terms of precise requirements of crops according to specific soils, quasi-unavailability of micro-nutrient fertilizers and lack of clear information of the extent of site-specific micronutrient deficiencies and the potential of micronutrient fertilizers to improve crop yield beyond the application of the standard NPK 17:17:17 or urea. There is need for dissemination of technical knowledge to farmers on more diversified and more environment friendly fertilizer use while research should initiate studies to develop more nutrient efficient varieties which are more responsive to soil symbionts.	Under the medium mitigation option, the GHG emissions from the crop sub-sector will increase from 2,066.0 Gg CO_2eq in 2012 to 7,194.0 Gg CO_2eq in 2050 against the baseline increase to 8,354.0 Gg CO2eq.by 2050.
11. Replacement of local cows with improved ones, better feed, promotion of biogas plants and collective farm holdings and improved manure management.	The sources of Emissions from livestock are mainly enteric fermentation and manure management. Promotion of better livestock feed (especially legume fodder species) along with replacement of 10% local cows by 10% improved cows, creation of collective farm holdings and farmer training in better livestock management – will give 23% decrease in the projected baseline GHG emissions (10% from improved cows; 10% from biogas and 5% from farmer trainings and resulting improved cow productivity).	Under the medium mitigation option, emissions will increase from 1876 Gg CO_2eq. in 2012 to 2466 Gg CO_2eq. in 2050 against the baseline increase to 3,780.0 Gg CO2eq.by 2050.
12. Development of agro-forestry for sustainable agriculture increasing the number of multi-purpose trees on farm per hectare	Agro-ecology technologies must be mainstreamed in the agriculture intensification programme and other natural resource-based livelihood programmes. This will enable increasing the number of trees on farm per hectare. Multipurpose tree species, both indigenous and exotic should be raised in the nursery and distributed to farmers in different agro-ecological zones.	Under the medium option, the GHG emission removals from Forestry and Other Land Use will increase from -11,219.1 Gg CO_2eq in 2012 to -26,150.3 Gg CO_2eq in 2050.
13. Promotion of afforestation and reforestation with improved germplasm and effective post-planting operations	Using quality germplasm, planting trees at the right time (rain season) and improving post-planting care (maintenance operations) in replanting harvested areas and planting new available forest areas such as on steep slopes, buffer zones around water bodies, wetlands, protected areas, roads and settlements can increase forest cover (even beyond the 30% target) and forest productivity and	

Mitigation option	Justification	Potential impact
(maintenance/tending activities)	subsequently increased carbon sequestration. Mixed-species approaches which contribute greatly to the achievement of both mitigation objectives and adaptation benefits of ecosystem resilience and biodiversity must be promoted. Thus more indigenous species planting materials are to be produced, disseminated and planted to reduce the current dominance of Eucalyptus.	
14. Rehabilitation and improved forest management of degraded forest resources	The National forestry inventory carried in 2015 reported that most forest plantations are understocked (DFS et al. 2016). There is need to maximize the productivity of the degraded forest plantations which present an opportunity to increase biomass supply without converting additional land. Public-private partnerships to sustainably manage all public forest plantations through multi-year contracts with forests operators (in cooperatives) should be promoted as proposed in the FSSP (2018-2024).	
15. Efficient wood conversion and sustainable biomass energy.	There is considerable waste that occurs due to conversion of wood into products (Timber, charcoal, biomass energy etc.) and the wood value chain is poorly organized making wood products lowly valued. Reducing waste of biomass through development of an efficient and professional improved charcoal value chain; increased use of wood pellet with high efficient gasifier stoves, especially in urban area; increased fuelwood use efficiency by providing improved stoves to every household and increased salvage and reuse of timber and service wood products can bring about considerable reduction in biomass energy demand. According to the FSSP (2018-2024), it is possible to get 9.5% reduction in demand by conversion to only "green" charcoal production technologies; 14.5% reduction in demand – from use of alternative energy sources (LPG, wood pellets, etc.) and 9% reduction in demand from increased use of improved cooking stoves.	

CHAPTER 4

VULNERABILITY ASSESSMENT AND ADAPTATION TO CLIMATE CHANGE




CHAPTER IV. VULNERABILITY ASSESSMENT AND ADAPTATION TO CLIMATE CHANGE

4.1. Introduction

Climate trend analysis over the periods 1961-1990 and 1991-2016 shows a significant trend of an increase in temperature and a decrease in rainfall amount with extreme weather events that are increasingly happening in Rwanda. In addition to the current situation, the vulnerability of Rwanda's sectors is projected to increase with the projected impacts of climate change. To get a deep insight into Rwanda's vulnerability to climate change impacts, a vulnerability assessment and adaptation exercise was conducted with the aim of establishing where and how Rwanda is vulnerable to climate change impacts and identifying potential adaptation measures to be undertaken in order to address the impacts of climate change to various sectors.

To assess the vulnerabilities of various sectors in Rwanda, different methodological approaches such as qualitative and quantitative methods were used to define the levels of exposure, sensitivity and adaptive capacity. This has involved at some extent the use of models to analyze the correlation between the impacts of climate change and the vulnerabilities in sectors as well as to make projections for future vulnerabilities with regards to climate change scenarios. The identification of adaptation measures involved the prioritization of potential measures through multi-criteria approach as recommended by IPCC guidelines.

The chapter three discusses the status of climate change and projected climate change scenarios as well as the vulnerability and adaptation within the sectors of energy, agriculture and forestry, water resources, infrastructure, biodiversity, tourism and health based on the results from the trends analysis of climate scenarios.

4.2. Climate change trends and projections

4.2.1. Observed climate trends

A trend analysis in climate change revealed a dominant increased trend in mean temperatures for the period 1961-2016. The highest increase varying between 1.4 °C and 2. 56°C was added on annual mean temperature over the south-west and eastern regions of Rwanda for the period of 46 years since 1971 to 2016. The northern highlands were warmed at the lowest rate of between 0. 11°C and 1.7°C by 2016. The following table shows the change in temperature for the period 1971-2016.

Table 4.1 Magnitude of changes in temperatures (0C) after 46 years (since 1971 to 2016)

Key: Min.= Minimum; Max.= Maximum; Av.= Average

Stations / Months/seasons	Gisenyi			Kamembe			Kigali			Ruhengeri		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
January	1.19	0.46	0.83	1.15	2.02	1.56	2.57	2.57	2.58	2.16	0.69	1.43
February	1.01	0.46	0.74	0.87	2.21	1.7	2.48	2.48	2.48	1.47	0.59	1.06
March	0.73	-0.004	0.32	0.74	1.79	1.43	2.21	1.61	1.93	1.24	0.32	0.78
April	0.27	0.23	0.27	0.69	1.70	1.84	2.16	1.33	1.75	0.74	-0.27	0.23
May	0.96	0.64	0.83	0.87	2.16	1.66	2.16	1.7	1.93	0.55	-0.37	0.09
June	0.82	0.009	0.41	0.78	1.79	1.47	2.3	1.56	1.93	0.96	0.05	1.43
July	0.78	0.69	0.72	1.15	2.16	1.84	1.38	2.21	1.79	0.64	0.83	0.74
August	0.87	0.64	0.78	1.06	1.93	1.66	2.35	1.56	1.93	0.83	0.23	0.51
September	0.87	0.05	0.46	1.43	1.84	1.79	2.48	1.47	1.98	1.15	-0.32	0.41
October	0.73	0.09	0.41	0.78	1.93	1.33	2.21	1.47	1.84	1.75	-0.41	0.64
November	0.96	1.06	1.01	0.64	1.47	1.104	2.12	1.33	1.75	1.24	-0.18	0.51
December	1.15	0.32	0.74	0.69	1.43	1.43	2.48	1.978	2.21	1.52	0.0644	0.78
Short dry season	1.19	0.51	0.87	0.92	1.88	1.84	2.53	2.34	2.44	1.47	0.414	1.06
Long rainy season	0.64	0.27	0.46	0.74	1.88	1.61	2.16	1.56	1.88	0.87	-0.138	0.37
Long dry season	0.87	0.51	0.69	1.01	1.98	1.66	2.02	1.75	1.88	0.78	0.414	0.92
Short rainy season	0.83	0.41	0.64	0.96	1.75	1.43	2.25	1.43	1.84	1.43	-0.24	0.55
Annual average	0.96	0.46	0.69	0.96	1.88	1.61	2.25	1.75	2.02	1.24	0.092	0.74

The highest rise in annual mean temperature of 2.58 °C was observed in the eastern region for the period between 1971 and 2016. However the highest decrease of 0.24 °C was observed in annual maximum temperature over the north-west region.

The western and eastern regions which already registered the highest annual temperatures (between 20 °C and 22 °C) have continued to present the highest increase in annual temperatures.

Furthermore, the same eastern region has showed a highest decreasing trend in rainfall intensity and frequency. These changes in temperatures were alongside a steady decline in the frequency of rainfall of between 35-45days for 1961-2016. This resulted into a reduction of between 54 and 250 mm in mean rainfall across the country and a decline in aridity index especially in central plateau and eastern lowlands of the country. This reduction in aridity index implies a continuous warming up of the mentioned areas. However, some isolated areas of north-western highlands and south-west region continued to receive enough water at a rising trend of between 30 and 100 mm especially for 1961-1990. On the other hand, the south-eastern lowlands and the central plateau continued to get warmer at the rate of between 0 and 6.75 per year for 1961-1990 and between 0-10.22 mm/year for 1991-2016.The cumulative changes in the total annual rainfall since 1961 to 2016 are presented in the table below.

Table 4.2 Magnitude of changes in mean rainfall (mm) since 1961 to 2016

Stations / Months/seasons/year	Byumba	Kamembe	Kigali	Rubona
January	- 26.88	- 4.895	14	- 8.4
February	- 58.8	- 32.45	- 29.12	- 36.96
March	- 15.12	36.3	7.28	1.848
April	- 110.88	- 66.275	- 59.36	- 43.68
May	- 54.32	- 25.3	- 19.04	- 40.32
June	- 4.48	13.75	- 4.256	1.288
July	- 16.8	2.2	5.656	0.504
August	24.64	4.95	4.984	- 0.952
September	5.768	7.04	2.8	- 23.184
October	- 50.96	- 11.22	33.6	- 33.936
November	64.96	- 23.65	1.008	- 36.4
December	- 42	- 22.385	- 9.52	22.568
Short dry season	- 127.68	- 59.4	- 24.08	- 34.16
Long rainy season	- 180.88	- 55.55	- 90.72	- 98
Long dry season	20.16	21.45	4.032	- 4.144
Short rainy season	110.88	- 28.05	37.52	- 106.68
Annual totals	- 249.76	- 122.1	- 54.32	- 243.6

The highest decline in mean rainfall oscillating around 250 mm was registered in northern and central regions for a period of 56 years (1961-2016). The remaining regions also lost more than 50 mm from annual total rainfalls. This decline in mean rainfall was alongside with the reduction of the number of rainy days which were maybe the main cause of the recent reduction of water storage especially in central and eastern regions

Table 4.3 Magnitude of changes in number of rainy days in 56 years from 1961 to 2016

Stations / Months/seasons/year	Byumba	Kamembe	Kigali	Rubona
January	- 1.064	- 1.76	- 3.25	- 3.25
February	1.008	- 3.72	- 3.81	- 6.05
March	1.79	0.336	0.224	- 4.82
April	- 0.36	- 4.44	- 5.21	- 6.66
May	- 2.29	- 4.52	- 6.16	- 5.71
June	0.84	- 2.92	- 2.02	- 2.13
July	- 0.11	- 1.9	- 4.59	- 2.02
August	3.17	- 0.89	- 1.57	- 0.39
September	4.42	- 0.62	- 4.09	- 5.43
October	1.9	- 0.67	- 1.4	- 4.59
November	0.95	- 2.46	- 2.69	- 2.63
December	2.18	- 2.85	- 2.52	- 2.74
Short dry season	- 0.17	- 12.32	- 9.52	- 12.32
Long rainy season	- 1.34	-10.53	- 11.2	- 17.25
Long dry season	2.91	- 5.76	- 6.16	- 1.68
Short rainy season	7.28	- 3.86	- 7.8	- 12.32
Annual totals	5.6	- 35.8	- 35.8	- 44.2

A decline in number of rainy days oscillating between 35 and 45 days was observed over Rwanda for a period of 56 years (1961-2016) except in northern region where a rise of 5.6 days was registered. This decline in number of rainy days is obviously the main cause frequent dry spells observed recently across the country especially in central and eastern region. Therefore, there is a call to appropriate adaptation measures to deal with this reduction of rainfall frequency.

4.2.2. Dynamic downscaling and Climate scenarios

The new version of the stochastic weather generator-LARS-WG (version 3.0 for Windows 9x/NT/2000/XP) incorporating predictions from 15 GCMs used in the IPCC AR4 (IPCC, 2007; Solomon *et al.*, 2007) was used to project precipitation and temperature data for 1991-2050. These projected data were derived from precipitation and temperature datasets of 1961-1990. The projections of observed precipitation/temperature data (1961-1991) were made with help of four GCMs used in the IPCC AR4 named as BCM2.0, CSMK3.0, and MPEH5 (ECHAM5-OM)for the SRES emissions scenarios SRB1 and CNCM3for the SRES emissions scenario SRA2. These were selected due to the fact that they have the lowest spatial resolution with a grid of 1.9°x1.9° (Nakicenovic and Swart 2000; Mikhail and Stratonovitch, 2010). SRES emissions scenarios SRB1 and SRA2 were chosen in projecting data from the assumptions that Rwanda is one of the countries characterized by high population growth with rapid changes in economic structures and improved equity and environmental concern (Nakicenovic and Swart 2000; MINIRENA, 2010; NISR, 2012c). The CO_2 concentration for the baseline scenario (2011-2030) was preferred as it falls within the study period.

Furthermore the model output data (predictors) obtained from the data portal of Lawrence Livermore National Laboratory, Department of Energy USA was also used. The model outputs of MIROC_4h were chosen to provide a historical run for the period of 1961-1990 and Representative Concentration Pathways (RCP) future scenario 4.5 was also selected (Wilby *et al.*, 2004). This model was selected because of its high spatial resolution (1.0°x1.0°) resulting into a high number of grid points over Rwanda hence it predicts better monthly rainfall and temperature.

The mean standardized anomaly indices for each year, j(X_j), for representative weather stations were calculated as follows: $X_j = \frac{R_{ij} - \overline{R}_i}{\sigma_i}$ Where: R_{ij} is the annual rainfall in mm/number of rainy days/annual mean temperatures and; $\overline{R}_i$ is the mean annual rainfall/mean number of rainy days/annual mean temperatures over the study period (2017-2050); σ_i is the standard deviation of annual rainfall totals/annual number of rainy days totals/annual mean temperatures over the study period (2017-2050). These mean standardized anomaly indices were calculated to explore the temporal variability of projected mean rainfall/ number of rainy days/ mean temperatures (2017-2050) of selected weather stations.

4.2.2.1. Trend analysis of projected precipitation data over Rwanda

The spatial representation of magnitude and direction of rainfall trends at monthly timescale predicts an increase of between 0.1 and 0.64 mm per year (1 to 6.4 mm per decade) in the south-west, the north and the north-east regions of the country in all months except in June, September, October, November. In the same view, Hudson and Jones, in 2002 projected also an increase in rainfall up to 2099 in December-February while Ruosteenoja *et al.* in 2003 projected higher levels of warming for the period 2070-2099 in September to November over East Africa.

However, June and November are the only months which are expected to present a decline in mean rainfall in the south west region of Rwanda. The highest increase of 0.88 mm per year (8.8 mm per decade) and decrease of 1.31 mm (13.1 mm per decade) are expected in May in the central and the south eastern lowlands regions respectively. The south-central and the south-eastern lowlands are expected to experience a decreasing trend of between 0.1 and 0.85 mm per year except at the isolated small pockets. The following maps (**Figure 4.1**) show spatial-temporal variation trends from the predicted mean rainfall over the country for the period of 2017-2050.

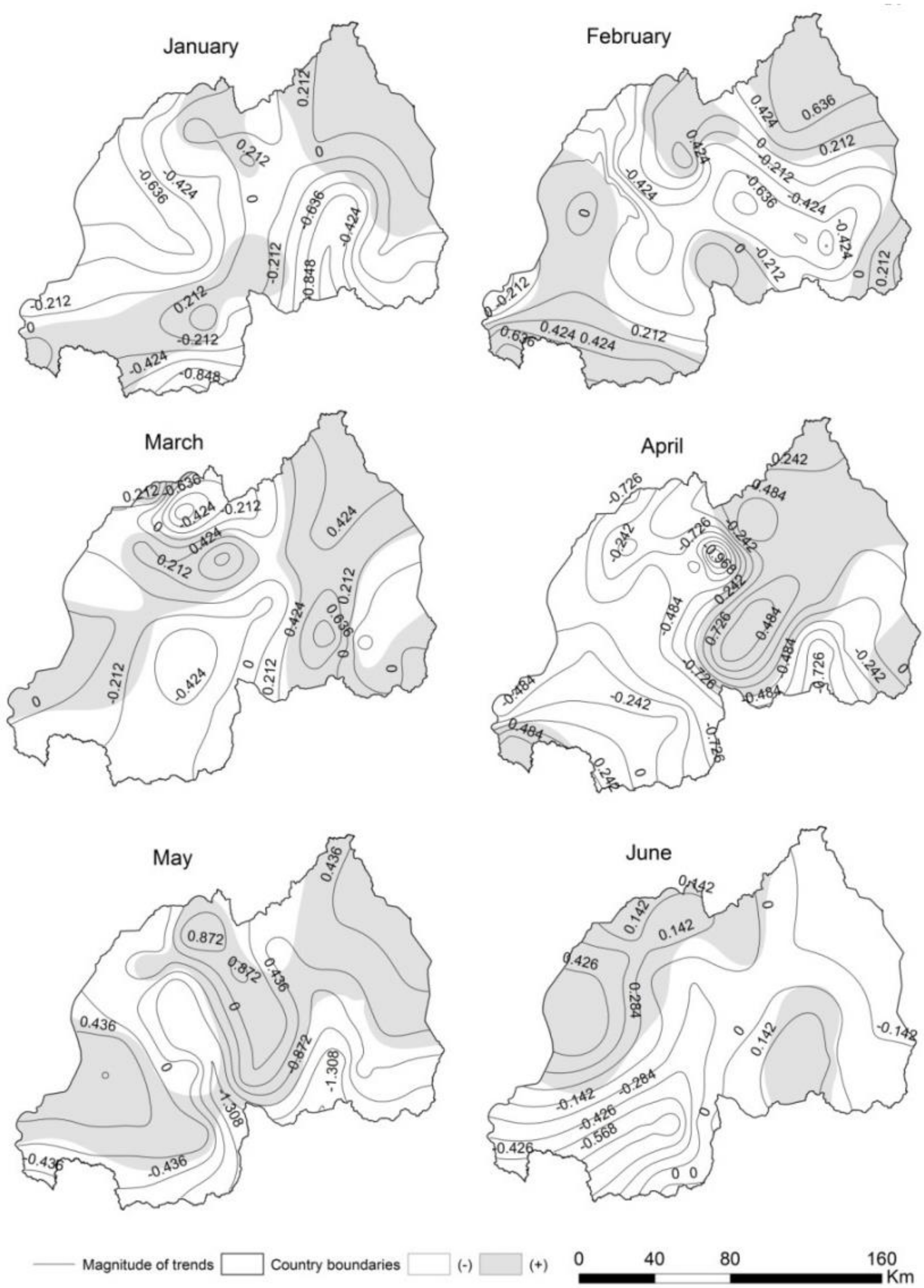


Figure 4.1 Trend magnitudes (in mm) of projected mean rainfall (January-June) for 2017-2050

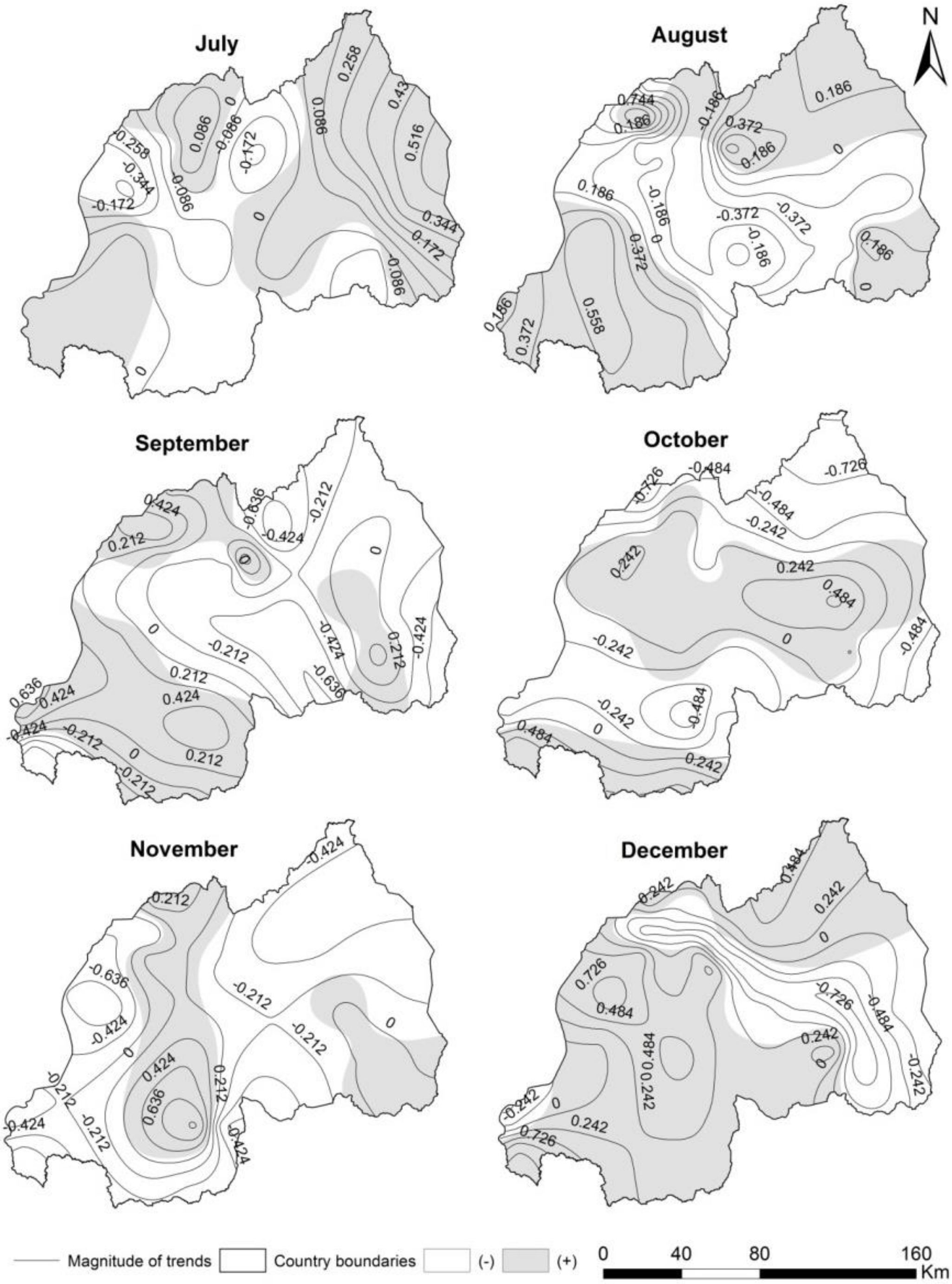


Figure 4.2 Trend magnitudes (in mm) of projected mean rainfall (July-December) for 2017-2050

At seasonal resolution, a steady decline in mean rainfall is predicted in large parts of the country with a rise during the long dry season except in the central plateau (**Figure 4.2).** However, this rise will not add much to the annual mean rainfall as long as the long dry season contributes less than 10% of the rains received over Rwanda (Ilunga *et al.*, 2004).

The mean rainfall is predicted to increase by between 0.1 and 1.24 mm and 0.1 and 0.82 mm per year in the north-east and the south-west regions of the country respectively except during the short rainy season (Mid-September-October-November-Mid-December), showing a marked decline of between 0.412 and 1.65 mm per year in the north-east region of the country.

This is an indicator that the north-east already under low amount of rainfall is bound to experience water deficit for various activities in coming years.

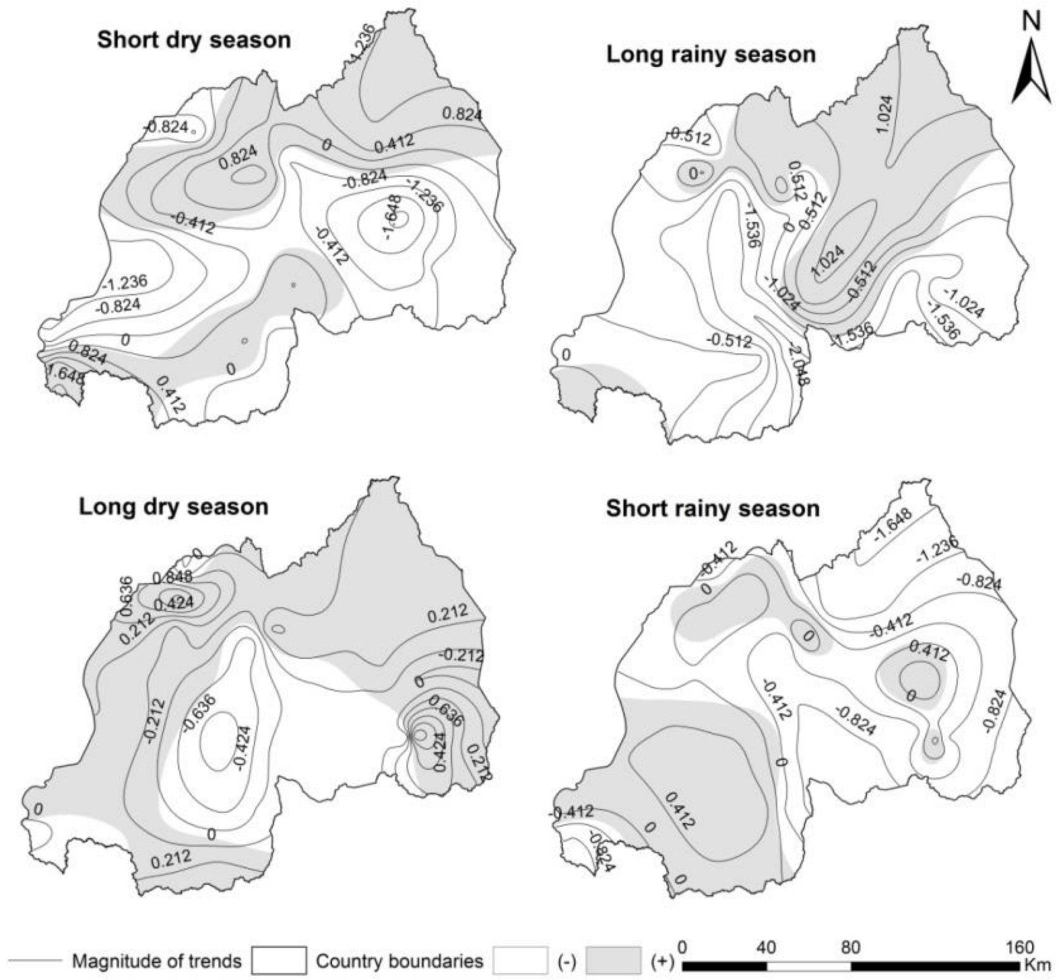


Figure 4.3 Seasonal and annual trend magnitudes (in mm) of projected mean rainfall for 2017-2050

At annual resolution, a positive trend is anticipated over the south-west, the north-east region and the north highlands at a rate of between 0.01 and 1.22 mm per year (0.1 to 12.2 mm per decade), with the remaining regions (central, south-east and western regions) having a decline in mean rainfall (**Figure 4.3).** This shows the degree to which Rwanda may face the challenge of water supply for various activities like agriculture; livestock which are major source of income for more than 85% of Rwandan population. However, this situation may help in reducing the frequent flooding episodes which have been registered in the western highlands of the country.

Moreover recent studies are not very clear about the predicted precipitations over East Africa (EA); some suggest that local circulation effects could result in a general decreased precipitation (Brown and Funk, 2008) while others predict an increase in rainfall (by 5%-20% from December to February, and decreased rainfall by 5%-10% from June to August by 2050) in relation to the projected increase in temperatures (Hulme, 2001; WWF, 2006; IPCC, 2007; Eriksen *et al.*, 2008). The expected changes in mean rainfall by 2050 are presented in the table below.

Table 4.4 Expected magnitudes changes in mean rainfall (mm) in 2050

Stations / Months/seasons/year	Byumba	Kamembe	Kigali	Rubona
January	- 1.85	-7.16	-0.33	12.1
February	2.31	-6.2	-23.39	-7.8
March	-5.15	3.73	-7.99	-12.21
April	18.45	-20.29	27.39	-9.77
May	-0.099	10.66	23.19	5.97
June	3.3	-5.38	-1.91	-22.97
July	-4.19	1.12	1.52	-0.56
August	5.32	5.02	-9.4	9.1
September	-24.35	19.12	-19.14	18.7
October	-9.07	8.48	11.38	-27.8
November	-6.3	5.81	-6.99	-1.48
December	12.1	-10.66	-4.78	9.6
Short rainy season	12.57	0.43	-28.54	-13.9
Long rainy season	13.2	-5.94	42.9	-16.1
long dry season	4.42	0.79	-0.97	-14.5
Short dry season	-9.83	4.82	-14.85	18.9
Annual	-4.91	8.59	-0.37	-0.53

A general decreasing trend in mean rainfall is expected across the country by 2050. Between 0 and 5 mm are expected to be deducted from the annual total rainfall of 2016 for most of regions except the western region which expect to receive an additional 8.59 mm on annual mean rainfall by 2050. This low decreasing rate may result into expected increase in temperatures which may increase the amount of water from evapo-transpiration to yield some rainfall across the country. This reveals that the central and eastern regions will continue to be exposed to more dry spells more than before (**Figure 4.3).**

4.2.2.2. Anomalies analysis of projected precipitation data over Rwanda

Figure 4.4 shows the projected annual mean rainfall variability for the selected four weather stations representing each of the climatic regions of Rwanda. Kamembe, Kigali, Kinigi and Rubona weather stations represent western, eastern lowlands, highlands and central plateau regions respectively.

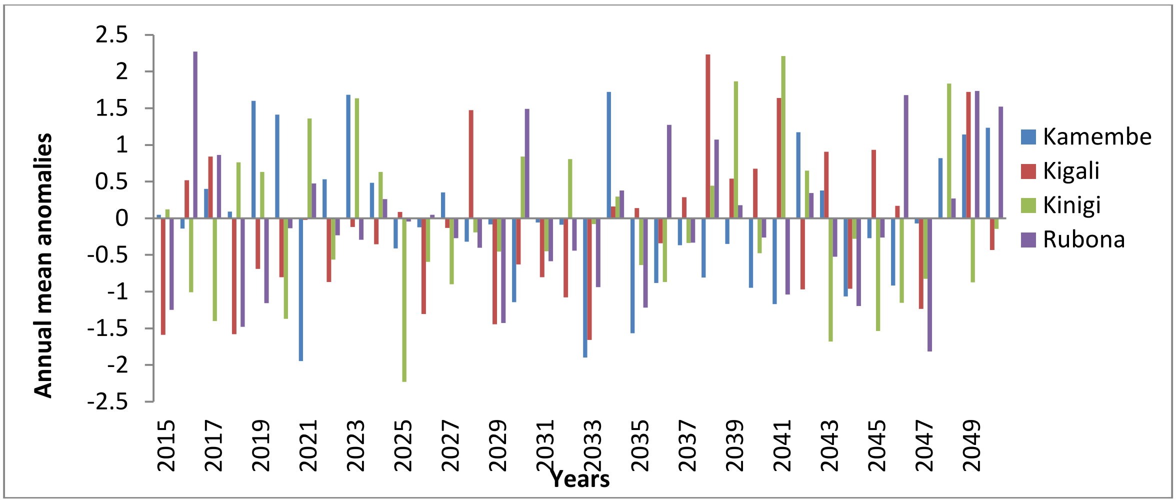
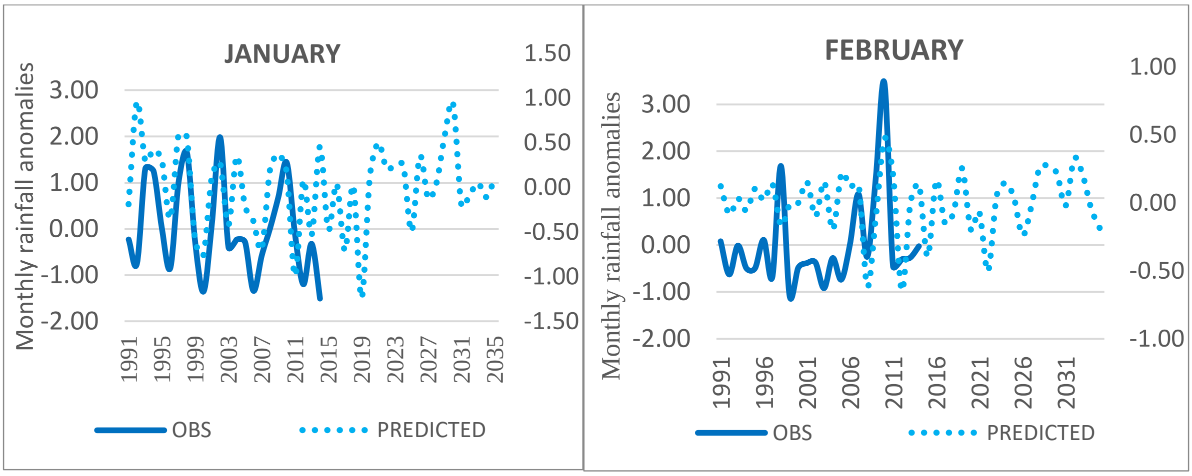


Figure 4.4 Variations of annual mean standardized rainfall anomalies for selected weather stations (2015-2050)

It emerges that the period 2015-2050 is generally expected to have a general decreasing trend at all four representative weather stations. It is predicted that the periods 2015-2038 and 2043-2047 will experience a decreasing trend particularly in eastern region represented by Kanombe weather station, while the periods 2039-2042 and 2048-2050 will have an increasing pattern (Fig. 4.4). High variability in mean rainfall with a tendency to decrease is expected especially in 2015-2023 and 2033-2042. Hence, more occurrences of extreme weather events (flooding and droughts episodes) might be also predicted from the fact that a number of positive and negative rainfall anomalies (above -1 and 1) are projected in the period of study.

The projected precipitations with help of MIROC4h model predict high monthly fluctuations for the period of 2015-2035.



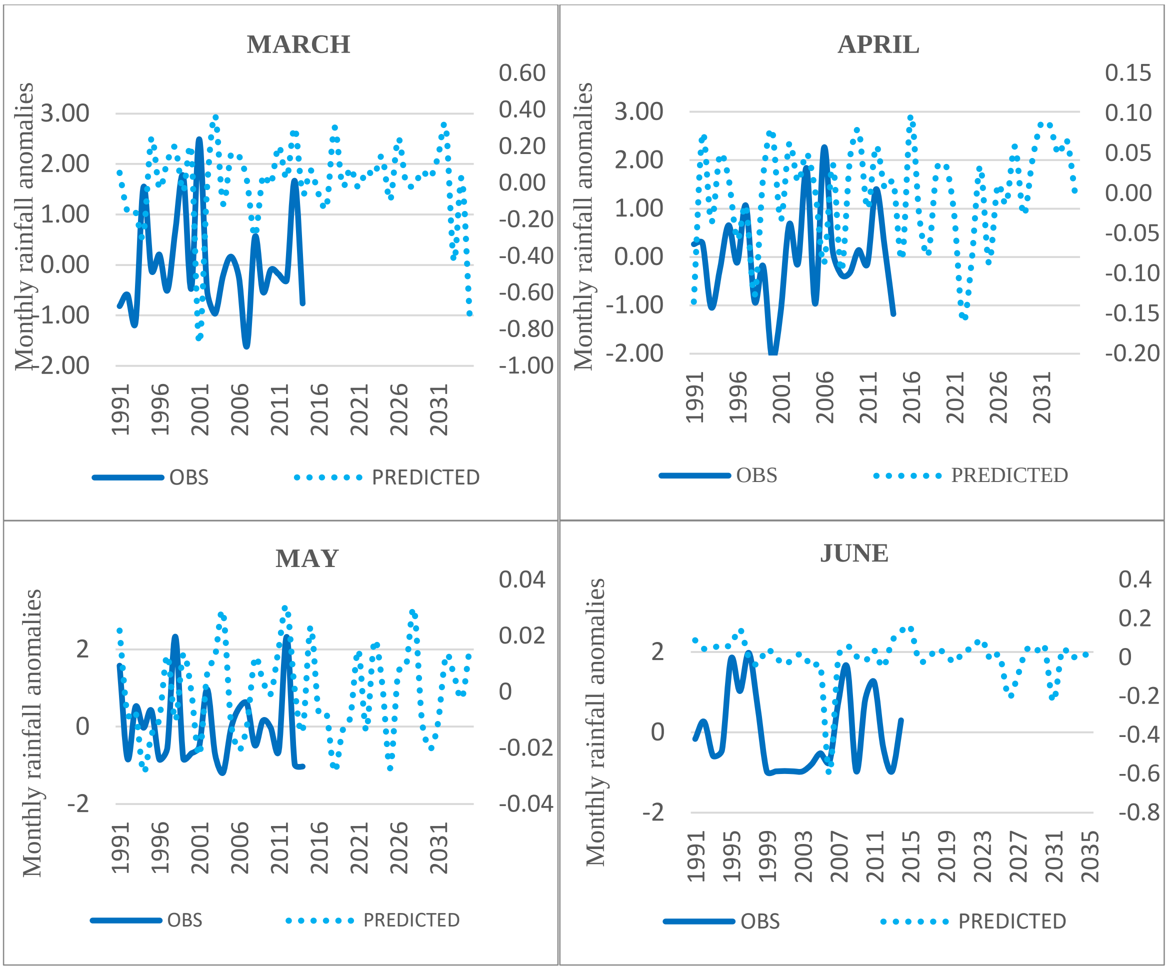
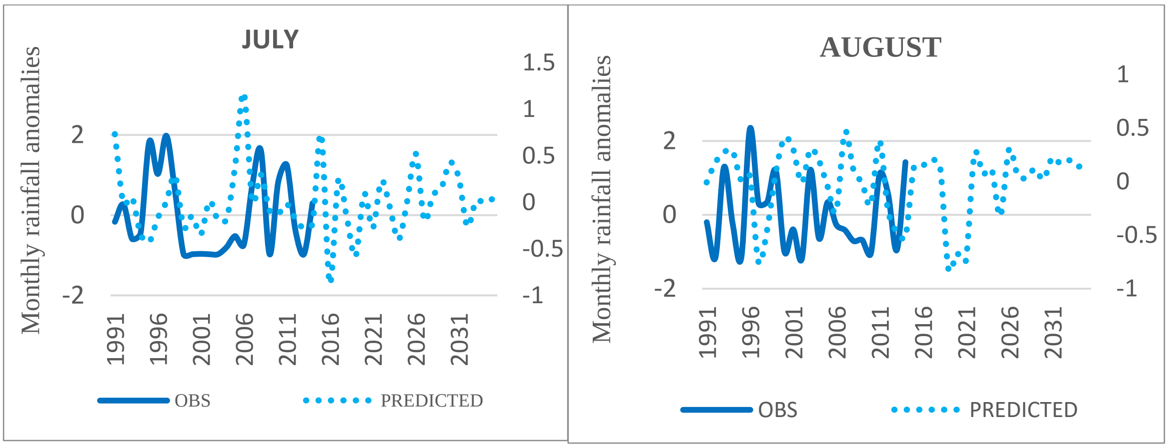


Figure 4.5 Projected monthly precipitation anormalies at Kigali for January to June (2015-2035)



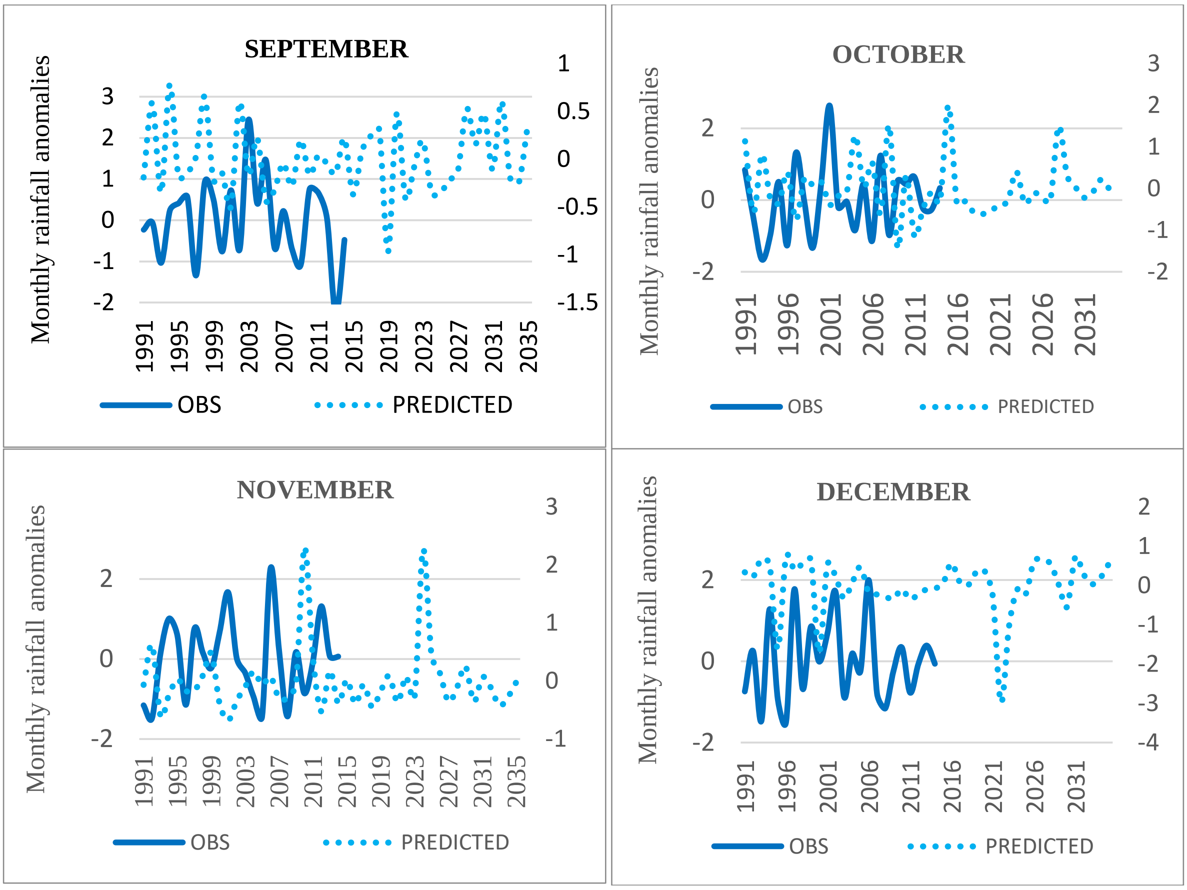


Figure 4.6 Projected monthly precipitation anormalies at Kigali for July to December (2015-2035)

Apart from January, March, June and November which are expected to have a decreasing trend in mean rainfall other months are predicted to have a general increasing trend. However, more fluctuations in mean rainfall are expected throughout the years for the period of 2015-2035.

The above presented figures depict an increasing trend during short rainy season (September-October-November) season and a slight rise in mean rainfall during the usually dry months of January-February and July-August. The table below shows the magnitude of monthly changes in projected mean rainfall for 2015-2035.

The above presented figures depict an increasing trend during short rainy season (Mid-September-October-November-Mid-December) season and a slight rise in mean rainfall during the usually dry months of January-February and July-August. The table below shows the magnitude of monthly changes in projected mean rainfall for 2015-2035.

Table 4.5 Magnitude of monthly changes of projected mean rainfall with help of MIROC4h for 2015-2035 at Kigali weather station

Months	Percentage change (%)
January	- 17.0
February	18.0
March	- 9.0
April	3.0
May	0.5
June	-13.0
July	42.0

August	56.0
September	23.0
October	2.0
November	-1.0
December	18.0

The table above reveals that a decreasing trend of between 1 and 17 mm in mean rainfall is expected in January, March, June and November over eastern region represented by Kigali weather station. This trend fits with the finding put out by Shongwe et al., in 2010.

4.2.2.3. Trend analysis of projected temperatures

The trend analysis of projected minimum, maximum and mean temperatures were undertaken to evaluate the extent of expected warming/cooling over Rwanda. The figure shows the expected trends in minimum temperature.

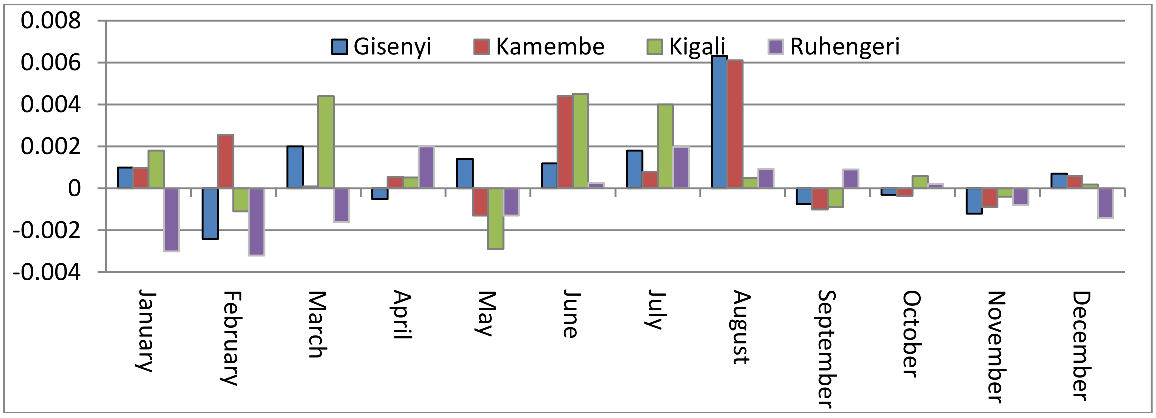


Figure 4.7 Projected monthly minimum temperature trends (°C per year) for the period 2017-2050

The figure above shows a decreasing trend (highest) of between 0.004 °C and 0.006 °C per year at Kigali weather station in March, June, and July; at Gisenyi in August and at Kamembe in June and August. The highest increasing trend of 0.0063 °C per year is expected at Gisenyi in August. The highest increasing trend in minimum temperatures is expected during long dry season (June-August) across the country. Northern regions represented by Ruhengeri weather stations will present more months (6 months: January, February, March, May, November and December) with declining minimum temperatures) compared to the other regions which expect to have less than five months with negative trends. November is the only month showing a decreasing trend of between 0.00039 °C and 0.0012 °C per year in minimum temperatures at all selected weather stations. Arising from these estimates, it is safe to conclude that Rwanda is likely to experience more cool spells in the coming years especially in the northern highlands, which naturally have the lowest temperatures. However, these changes will not have much impact on both natural and human activities as long as they are not significant.

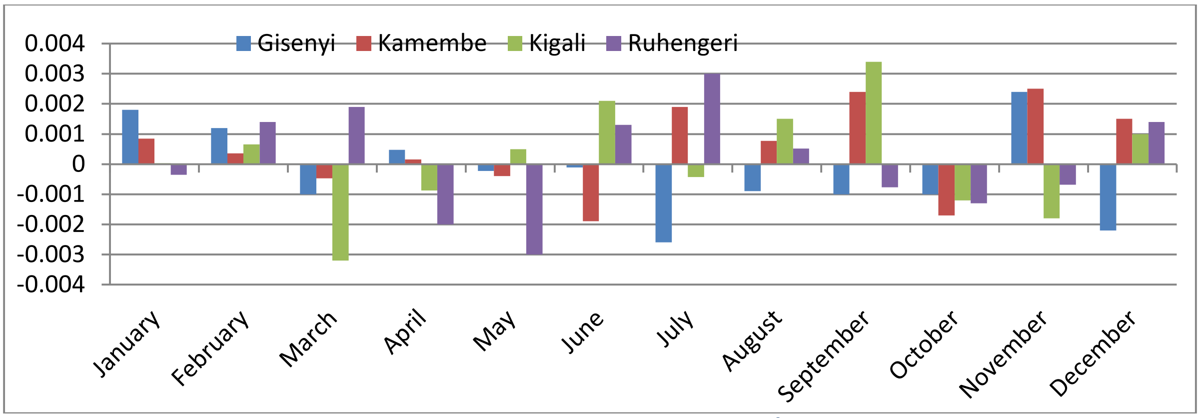


Figure 4.8 Projected monthly maximum temperature trends (⁰C per year) for the period 2017-2050

The monthly maximum temperature present less variability compared to minimum temperatures for the period of 2017-2050 (**Figure 4.8**). October is the only month with a decreasing trend of between 0.001 °C and 0.0043 °C per year at all selected weather stations. A high decrease of 0.0032 °C per decade in maximum temperature is forecast in February in eastern region represented by Kigali weather station, while the highest increase of 0.0034 °C will be observed in November in the same climatic region. Kamembe is expected to register an increasing pattern in 8 months, Kigali and Ruhengeri in six months, and Gisenyi in 4 months within a year. This is a clear indication that warmer spells are likely to be reduced in Rwanda in the coming years.

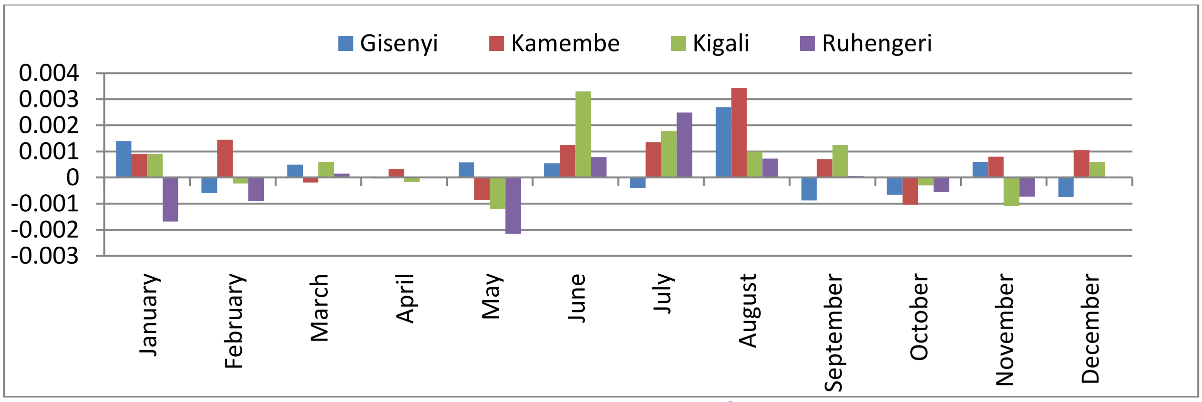


Figure 4.9 Projected monthly mean temperatures trends (⁰C per year) for the period 2017-2050

The highest increase in annual mean temperature of 0.0034 °C and 0.0033 °C per year are expected at Kamembe weather station in August and at Kigali in June respectively (**Figure 4.9).** Low temperatures are expected in northern highlands region represented by Ruhengeri weather station, which is located in the northern highlands. The table below shows the magnitude and direction of temperature trends (minimum, maximum and average) at seasonal and annual time scales for the period 2017-2050.

Table 4.6 The seasonal temperatures trends (^{0}C per year) for the period 2017-2050

Stations	Short dry season			Long rainy season			Long dry season			Short rainy season			Annual		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Gisenyi	-0.0007	0.0008	0.0001	0.0028	-0.0007	0.0011	0.0093	-0.004	0.0028	-0.002	0.0004	-0.001	0.00924	-0.003	0.003
Kamembe	0.004	0.0027	0.0034	-0.0007	-0.0007	-0.0007	0.0113	0.0007	0.006	-0.0022	0.0032	0.0005	0.0125	0.006	0.009
Kigali	0.0009	0.0017	0.0013	0.002	-0.0036	-0.0008	0.009	0.0032	0.0061	-0.0007	0.0004	-0.00015	0.01122	0.0016	0.006
Ruhengeri	-0.007	0.0024	-0.0026	-0.001	-0.003	-0.002	0.003	0.0048	0.004	0.0003	-0.0028	-0.0012	-0.005	0.00141	-0.002

It is clear from the Table 4.6 that increasing trends of between 0.0002 °C and 0.0093 °C per decade in minimum and maximum temperatures are predicted during both the short and long dry seasons. All weather stations present a decreasing pattern in maximum temperature during the long dry season. At annual resolution, a negative trend in maximum and minimum temperature is predicted at Gisenyi and Ruhengeri respectively. The expected increase in annual mean temperatures varying between 0.003°C and 0.009°C per year is lower than increasing trend of between 0.0068 °C and 0.041 °Cobserved in the period of 1991-2016. This means that the period of 1991-2016 was warmer compared to the period of 2017-2050. This will likely reduce the rate of evapo-transpiration leading to general decrease in rainfall over the country especially over central plateau and south-eastern lowlands which receive naturally a low amount of rainfall. It is important mentioning that the summative rise in annual mean temperature for the period of 1971-2016 and 2017-2050 falls in the range of a rise of 2.5 °C expected over East Africa by 2050s since the end of the 1960s (Parry *et al.*, 2007; Druyan *et al.*, 2008).

Table 4.7 Expected seasonal and annual changes in temperatures (0C) in 2050

Key: Min.= Minimum; Max.= Maximum; Av.= Average

Stations	Short dry season			Long rainy season			Long dry season			Short rainy season			Annual		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Gisenyi	-0.023	0.026	0.0016	0.095	-0.025	0.035	0.31	-0.12	0.094	-0.074	0.013	-0.03	0.3	-0.10	0.10
Kamembe	0.14	0.089	0.11	-0.022	-0.024	-0.023	0.37	0.025	0.199	-0.075	0.11	0.015	0.41	0.19	0.30
Kigali	0.029	0.055	0.042	0.066	-0.12	-0.025	0.29	0.104	0.20	-0.023	0.013	-0.05	0.37	0.055	0.21
Ruhengeri	-0.25	0.081	-0.087	-0.03	-0.1	-0.07	0.11	0.16	0.13	0.01	-0.09	-0.04	-0.16	0.046	-0.06

It is clear from the above table that a seasonal increase of between 0.029 °C and 0.095 °C is expected to be added on the minimum recorded temperature by 2050 while between 0.013 °C and 0.089 °C will be added on maximum temperatures though the these temperatures will be increase during long rainy season across the country.

At annual resolution, a decline in minimum (0.16 °C) and maximum (0.10 °C) temperatures is predicted at Gisenyi and Ruhengeri weather stations respectively while the remaining weather stations are expected to have the increased temperatures. Hence, between 0.10 °C and 0.30 °C will be added on mean annual temperature across the country apart from in the northern region where a decrease of 0.06 °C is expected. This means that the period of 1971-2016 was warmer compare to the period 2017-2050 which will likely reduce the rate of evapo-transpiration leading to general decrease in rainfall over the country.

Figure 4.10 shows the projected annual mean rainfall variability for the selected four weather stations representing each of the climatic regions of Rwanda. Kamembe and Gisenyi, Kigali, and Ruhengeri weather stations represent western, eastern lowlands and highlands respectively.

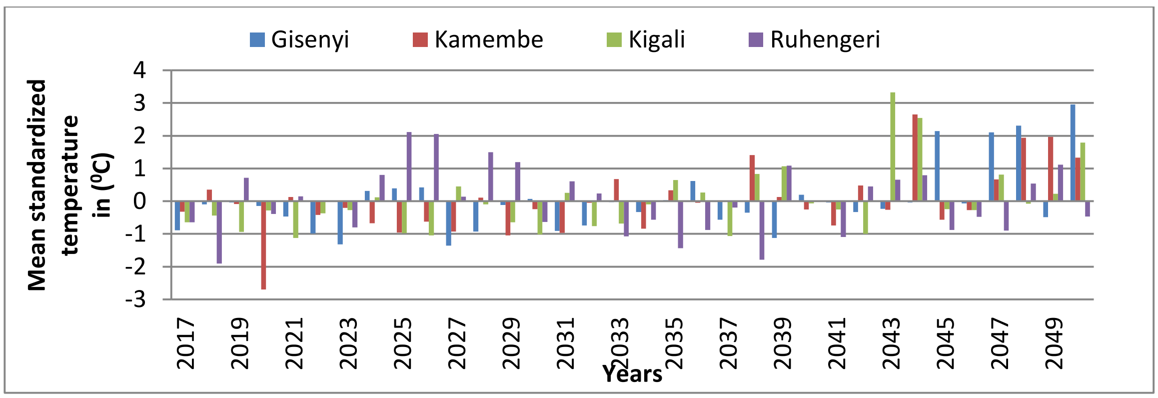


Figure 4.10 Projected annual minimum standardized temperatures (2017-2050)

The figure above depicts very low temperature variations for the period of 2017-2042 with higher positive anomalies for 2043-2050. The lowest variations in minimum temperature are expected from 2029 t0 2037 while the higher are predicted for 2023-2029 and 2043 to 2050 where most of parts of the country will have positive anomalies.

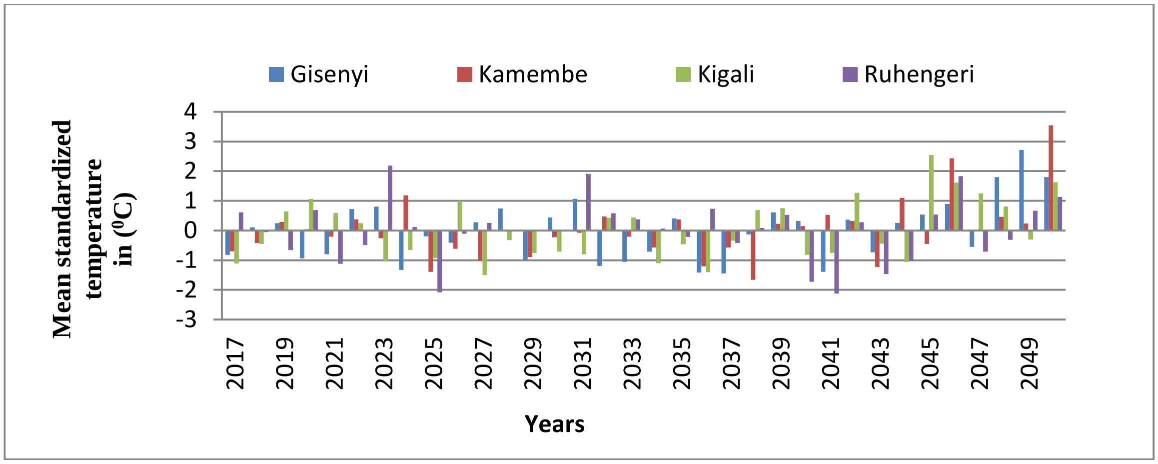


Figure 4.11 Projected annual maximum standardized temperatures (1995-2050)

It is predicted that the periods 2035-2044 are to have decreasing maximum temperatures while the period 2045-2050 will register increasing maximum temperatures at most of the weather stations under investigation. A low high variability in annual maximum temperatures tending to increase is projected in the coming years up to 2050 in most of these weather stations.

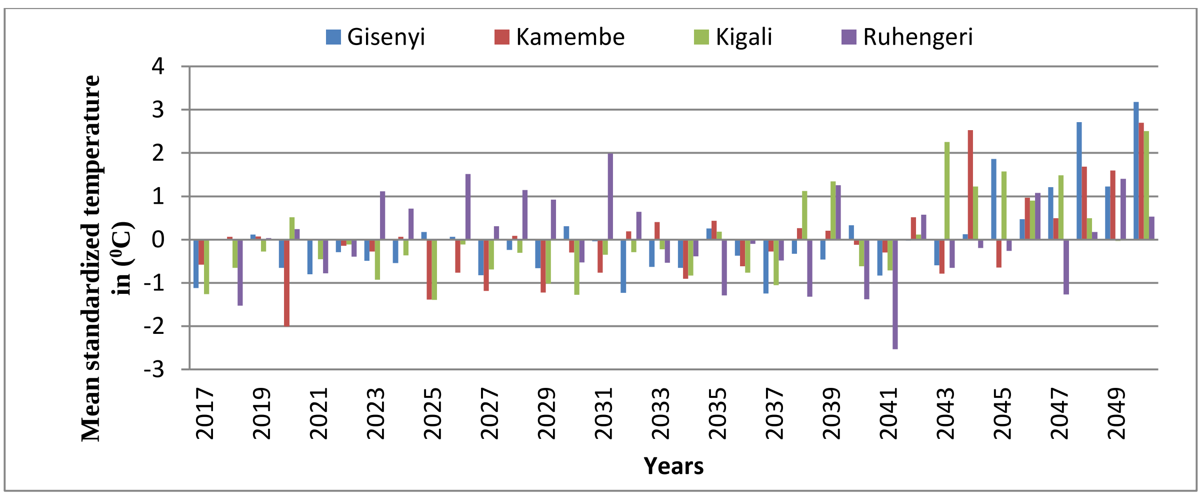


Figure 4.12 Projected annual mean standardized temperatures (2017-2050)

It is evident from the figure above that the period 2017-2037 appear to have decreasing trend at most of the stations except in the northern highlands represented by Ruhengeri weather stations. The periods 2043-2050 are projected to experience an increase in annual mean temperature. The increase in temperatures predicted during the dry seasons particularly the long dry seasons might not add much on the mean rainfall from the fact that the country will be under the influence of dry Saint Helena and Azores anticyclones (Ilunga *et al.*, 2008; Kizza et al., 2009; Muhire *et al.*, 2015). However, the anticipated decrease in temperatures during the rainy seasons might lead to reduced evapo-transpiration, resulting in reduction of intensity, frequency of mean rainfall during the said seasons.

4.3. Vulnerability assessment and adaptation of the key sectors

4.3.1. Climate change vulnerabilities and adaptation of the Rwanda Energy Sector

4.3.1.1 Policies and strategies to climate change

Rwanda's energy sector is heavily dependent on environmental resources with around half of its electricity coming from hydropower and more than 80% of the population depending on wood fuel for their energy needs(MININFRA, 2015a). Considering this situation combined with the country's high climate change and natural disaster vulnerability, an effort was made to develop climate change adaptation and mitigation measures to preserve the environment. Various policies and strategies related to energy sector were formulated as thoroughly documented in various references including NAPA report (MINITERE, 2006), EDPRS 2 (Rwanda, 2012), National energy policy and strategy(MININFRA, 2015d), INDC(Republic of Rwanda, 2015), energy sector strategic plan(MININFRA, 2015a), Initial National Communication (INC), and the Rwanda second National Communication (SNC)among others.

Various energy policies and strategies were formulated and put in action during the period between 2005 and 2015, including the following:

- Invest more in energy generation infrastructures sector by building other hydropower stations. Potentials exist on Nyabarongo river, Rusizi, Akagera and on smaller streams where there are potentials for micro-hydropower stations;
- Promote new and renewable energies;
- Control erosion on hillsides around Lakes Burera and Ruhondo to prevent sedimentation that in the end, would lead to their drying up whereas they stand for compensating reservoirs for Ntaruka and Mukungwa hydropower stations.
- IWRM (integrated water resource management);
- Introduction of early warning systems/ rapid intervention;
- Introduction of wood varieties resistant to environmental conditions;
- Development of energy sources alternative to firewood.

4.3.1.2 Vulnerabilities and adaptation of the Biomass Energy

The biomass energy has an estimated deficit of 3 million cubic meters annually. This results from stresses on forestry resources in various parts of the country, including Bugesera district, which is considered as a hotspot for potential climate change impacts.

The expected decreasing trends in mean rainfall and number of rainy days during the rainy seasons in regions like the southeastern lowlands and central plateau, which already have a limited water supply, are likely to cause a decline in water storage. This may result in shortening the crop-growing period and the biomass supply. This will affect negatively both the agricultural and the biomass energy sectors. Rainfall quantity (amount and timing) can also affect the moisture content of the soil (affecting yields) or feedstock quality (resulting in low energy feedstock inputs at the generating plant). The Table 4.8below gives a summary of the predicted climate change-related impacts on biomass energy. Though we did not analyze the trend in the wind velocity due to the lack of data, it is worth mentioning its possible effects on biomass resources. In fact, wind velocities can affect the dispersion characteristics of pollutant emissions. As CO_2 concentrations increase, some quick-growing varieties (which are often less dense) can out-compete more dense vegetation species, which over time can reduce energy content per unit area of land. It is therefore recommended to be considered in future reports.

Table 4.8 Predicted Climate change-related impacts on Biomass Energy

Expected climate change	Climate change impacts on Biomass Energy
Drought expected in the central plateau and southern regions	Increased incidences of drought will imply a reduced biomass productivity and a decline in fuel wood supply;
Number of extreme events such as floods, landslide, etc. expected in northern highland and southwest regions	•Land degradation/erosion with possibly lower fuel supply and less useful energy output; • Possible damage to fuel supplies

Adaptation measures for biomass energy resources are generally similar to those of high-intensity agriculture (ADB, 2012). Various adaptive measures for improving climate change resilience in agriculture were proposed by the Food Agriculture Organization (FAO) as referred to in (ADB, 2012). They include expansion of rainwater harvesting, water storage and conservation techniques, water reuse, desalination, water use and irrigation efficiency, adjustment of planting dates and crop variety, crop relocation, and improved land management (erosion control and soil protection through tree planting)The latter measures are equally applicable to biomass energy resources and mixed energy/food systems. Biomass availability for energy during climate change can be increased if the crops selected are robust, with high biological heat tolerance and water stress tolerance. Expansion of irrigation systems or improvement of the efficiency of irrigation can counteract drought impacts if sufficient water is available from sources outside drought-hit areas. Flood protection can be improved by building dikes and improving drainage.

In addition, the intensification of fast-growing species such as eucalyptus and the multipurpose tree/shrub species appropriate for small land holdings could be a valuable option to cope with prolonged droughts. Other possible adaptive measures include the strengthening of the use improved cooking stoves and other energy efficiency measures, the use of biomass alternatives such as biogas, LPG, etc. Enforcement of behavioral adaptation measures include early warning systems for seasonal rainfall and temperature anomalies, support for emergency harvesting for an imminent extreme event, and provision of crop insurance systems.

4.3.1.3. Vulnerabilities and adaptation of electricity sector

Rwandan hydropower generation is vulnerable to climate change. It was demonstrated that the changing annual or seasonal patterns are affecting river flows and water levels behind dams, either by reducing or increasing power output. Also, siltation (which is a result of soil erosion from watersheds) reduces reservoir storage capacity.

Below are some case studies:

Ntaruka and Mukungwa hydropower plants

During the period between 2004 and late 2008 the country experienced a prolonged drought that resulted into considerable water level decrease in lake Burera and hence reducing the generation capacity of Ntaruka Hydropower plant (which is located at the outflow of Lake Burera to Lake Ruhondo). As it can be seen below the lake level started in 1996 with overflow at the dam spilling water as the power station had been out of operation since the 1994 genocide against Tutsi. The average lake level in the period was 1862.16 m. There has been no spill of water and the "overuse" of water compared to the inflow is equivalent to 1.8 m in this period. The highest level of 1863.60m was recorded in 2007 after stopping almost all energy production for two years to raise the water level. Despite good rainfall in the period after 2007, the lake has been operated at lower levels than the one raised to in 2007.

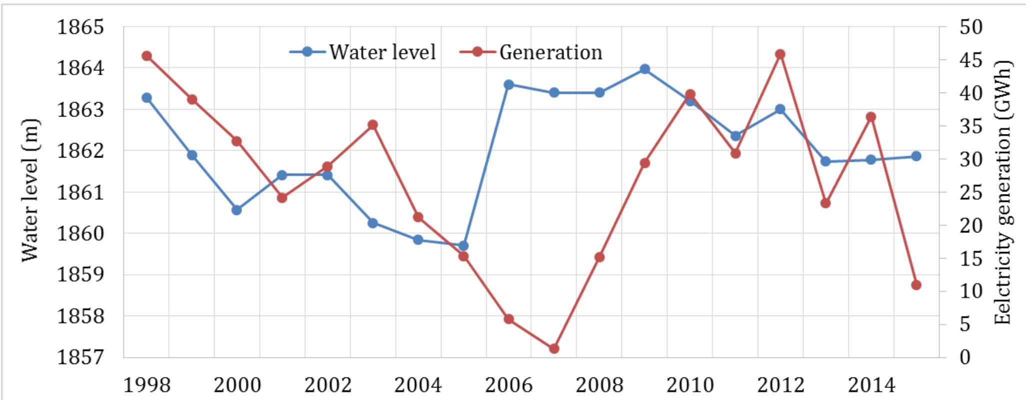


Figure 4.13 Relationship between the water levels and energy productions for Ntaruka power plant

Mukungwa I hydropower plant is located downstream of Ntaruka Hydropower Plant on lake Rondo. It has been commissioned in 1982 with a total installed capacity of 12MW. In the design of this power plant, the maximum and minimum water levels were 1,759.20 m and 1,7656.00 m, respectively. The tail water lever was 1,664.60 m, which makes the maximum water fall of 114 m. The maximum water discharge is $14m^3$/sec.

The lake Ruhondo inflow comes from rainfalls, outlet (tail water) of Ntaruka Hydro Power Plant, and streams (Guhugu & Rugendabari) in the catchment area. Mukungwa I power plant has been designed to generate annually 48 GWh. As illustrated in the Figure 4.13 above most of the time the plant generates more energy than the initial design. Even though the generating units can endure this stress, water level in Ruhondo lake does not.

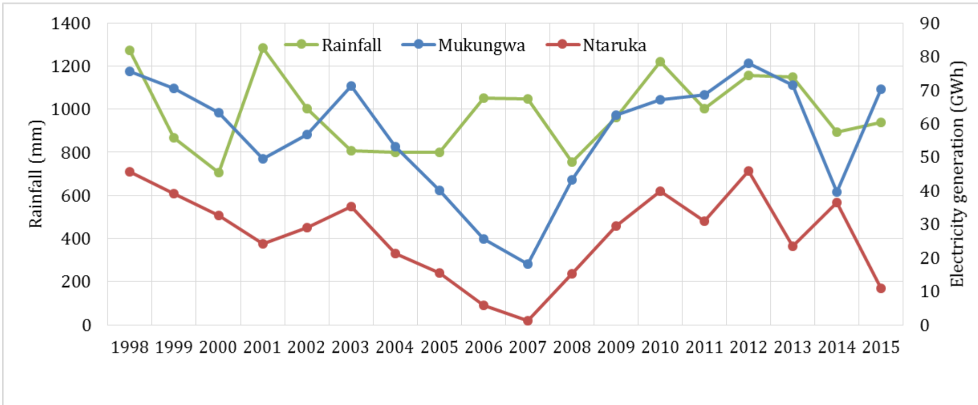


Figure 4.14 Relationship between rainfall and Energy productions for Ntaruka and Mukungwa I power plants between 1998 and 2015

Relationship between rainfall and Energy productions for Ntaruka and Mukungwa I power plants is depicted. As it could be seen from that figure, the production of the two power plants followed similar trends and they were correlated with the rainfall, except for the period between 2006 and 2008. As explained earlier during this period, all energy production activities were almost stopped for two years to raise the water level in the lake Burera.

To confirm the correlation between energy production and rainfall, a 4-year moving average analysis was conducted between 2001 and 2015. A moderate correlation was observed for the two power plants confirming the impact of the rainfall on electric power generation during the studied period. It is worth mentioning that due to lack of data at the nearest stations, the effects of temperature were not considered in this study and we recommend that the latter should be considered in future analyses.

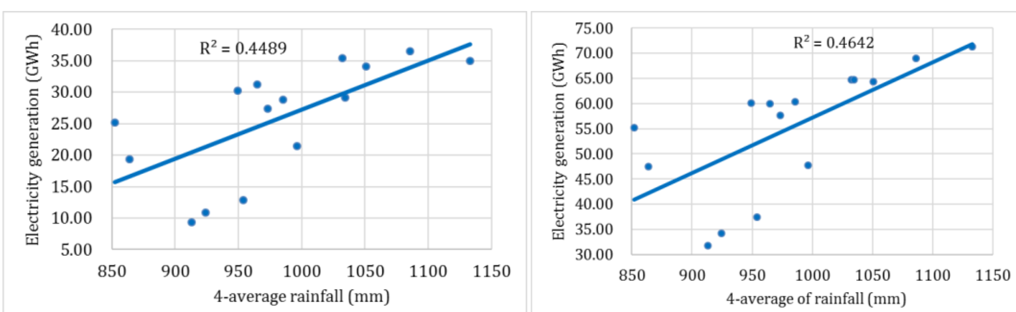


Figure 4.15 Correlation between annual rainfall and power generation at (a) Ntaruka 1 and (b) Mukungwa between 2002 and 2015

Gisenyi and Gihira power plants

Gisenyi and Gihira power plants are part of the group of five power stations in the western province on the bank of Lake Kivu, viz., Gisenyi (1.2 MW) stations, Gihira (1.8 MW), Keya (2.2 MW), Cyimbiri (0.3 MW) and Nkora (0.68 MW), which are all in the same water system are managed as single block.

Figure 4.16 shows the relationship between the rainfall and electric energy generation between 2002 and 2015. As it is clear from the figure, during the period between 2002 and 2008 the electric energy generation was strongly correlated with the rainfall for the two power plants. However, the remaining period was characterized by fluctuating rainfall and a weak correlation between the rainfall and the electric energy generation.

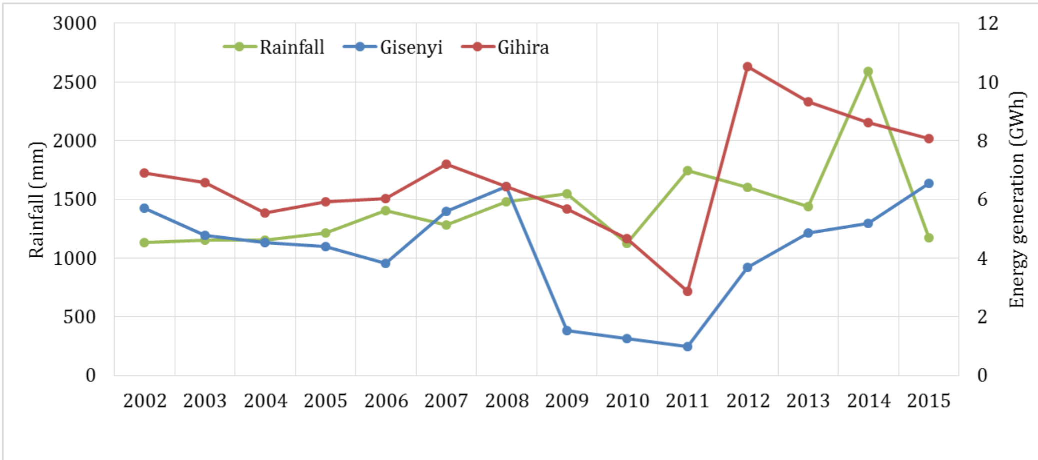


Figure 4.16 Relationship between rainfall and Energy productions for Gisenyi and Gihira power plants between 2002 and 2015

The correlation between the rainfall and the electric energy generation was further analyzed using a 4-year moving average methodology (**Figure 4.17**). Clearly, the electric power generation from Gihira power plant strongly correlated with the rainfall while for the Gisenyi power plant a weak correlation was observed.

From the above statistical analysis, it could be concluded that the electric generation in the studied period was strongly related to the changes in the rainfall since a positive correlation was observed for the 4 power plants. Thus, confirming a current vulnerability to the change in rainfall pattern.

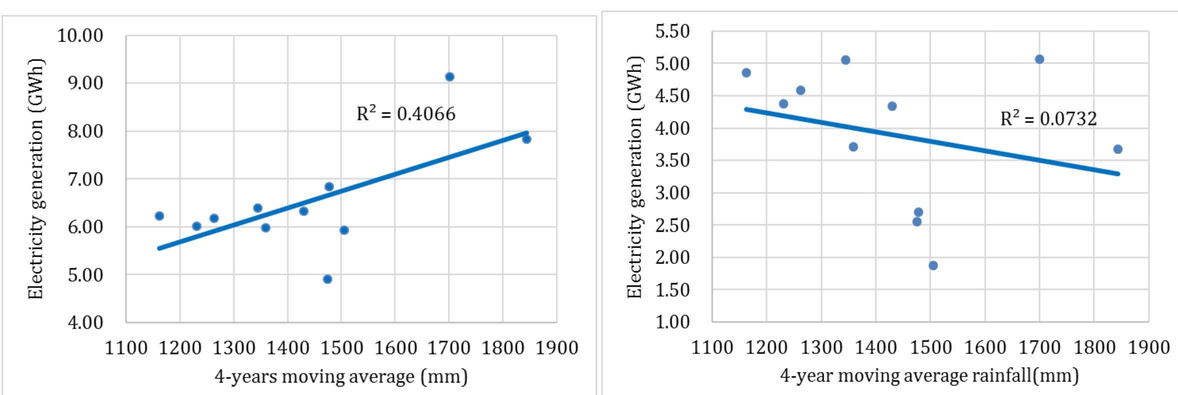


Figure 4.17 Correlation between rainfall and Energy productions for (a) Gihira and Gisenyi power plants between 2002 and 2015

The future vulnerability of the hydropower was analyzed based on plants location and climatic scenarios. The north-west highlands and southwestern regions will be characterized by a reduction in temperature and an increase in mean rainfall and number of rainy days. Obviously, the increased mean rainfall will be a constant supply of water, which is beneficial to hydroelectricity generation in these regions. However, it is important to state that the increase in the rainfall in these regions can lead to more occurrences of extreme weather events such as flooding episodes, soil erosion, and landslides affecting negatively the hydropower generation. For the hydropower plants located in the central and southern regions of the country such as Nyabarongo, will face a decline in mean rainfall and number of rainy days. This decline will cause a reduction of river recharge as the runoff will also reduce. In addition, the analysis of extreme temperature events is expected to increase in these regions as discussed in previous sections.

Possible adaptation measures to address the above mentioned issues include the following:

- Increase water storage in the dam;
- Improve hydropower plant to be more resistant to heavy rains;
- Improve efficiency of turbines;
- Develop an improved hydrological forecasting techniques and adaptive management operating rules;
- Develop basin-wide management strategies that take into account the full range of downstream environmental and human water uses;
- Restore and better manage upstream land including afforestation to reduce floods, erosion, silting, and mudslides.

4.3.1.4. Vulnerability and adaptation of Solar Photovoltaic Systems

Rwanda Solar energy generation (using Solar PVs) include on-grid and off-grid systems. Currently the total on-grid installed capacity is 12.08 MW and many households are using standalone solar PV systems. However, no studies were found that have been conducted to assess the vulnerability of these systems. We therefore recommend that studies on these systems should be conducted.

Considering the forecasted climatic scenarios in Rwanda and the lifetime of PV systems infrastructure which is estimated to 20 years, solar photovoltaic (PV) infrastructure and output could be vulnerable to wind, and extreme temperatures, change in cloud, humidity, dust, etc.(DOE, 2013; Patt, Pfenninger, & Lilliestam, 2013). The details of the potential vulnerabilities and corresponding adaptation measures are summarized in table 4.9:

Table 4.9 Potential Climate change-related impacts/vulnerabilities and adaptation measures for solar photovoltaic electricity generation

Climate change	Climate impacts & vulnerability	Adaptation measures
Increase in temperature	• Lowers cell efficiency and energy output of solar PV array • •Increases soil temperature Control system, inverters, cables	• Enhance the meteorology-based weather/climate forecasting. • Improve airflow beneath mounting structure to reduce heat gain and increase outputs. • Adopt hybrid photovoltaic-thermal systems using enhanced cooling systems Specify heat-resistant PV cells and module components designed to withstand short peaks of very high temperature.
Precipitation increases	Precipitation Can wash away dust in short time. However, higher precipitation reduces panel efficiency due to reduced solar radiation	• Select appropriate tilt panel angle to clean dust. • Select module surface conducive to self-cleaning. • Choose locations with lower probability of dust, grit, etc.
Cloud cover	• Lowers efficiency/output • Rapid fluctuations in cloud cover can destabilize grid	• Consider distributed systems (rather than feeding power into single part of the grid) to improve cloud impact. • Site PV systems where expected changes in cloud cover are relatively low. • Consider micro-inverters for each
Extreme events (flood, and strong wind	• Can damage systems (e.g., lightning strikes)	• Specify stronger mounting structure • Specify cabling and components that can deal with high moisture content and flooding.

4.3.1.5. Vulnerability and adaptation for thermoelectric power generation

Generally, climate change can affect the output, efficiency, and financial viability of thermoelectric power generation. An increase in ambient temperature results in a decrease in the difference between ambient and combustion temperature, reducing the efficiency of gensets, boilers, and turbines. This is also true for air-cooled systems.

For gas turbines, the reduction in power output is proportional to temperature increase: it is estimated that an increase of 5.5°C in ambient air temperature may reduce output by approximately 3% to 4%.

The thermoelectric power generation in Rwanda is composed of oil, peat, and methane gas thermal power plants. During the previous years there has been no observable climate impact on the thermoelectric power generation in Rwanda since some power generation such as peat and methane gas fueled plants, and there is no studies found that have been conducted on oil-fueled power plants. In this report, some potential vulnerability on resources and power generation infrastructures and corresponding adaptation measures are provided in the following table 4.10.

Table 4.10 Climate change related impacts/vulnerability and adaptation for thermal power plants (Peat, methane gas, oil)

Precipitation increase or decrease	• Heavy rains could cause reduced peat quality and combustion efficiency due to higher moisture content • Decrease in precipitation could affect availability of freshwater for cooling (for both peat and methane gas power plants) Reduction in thermal power plant output	• Protect fuel storage • Withdraw less water from source and consume less water internally (once through or re-circulating system) • Increase volume of water treatment works and/or develop new water sources • Redesign cooling facilities (water recovery from condenser and heat exchangers, reduction of evaporative losses, secondary or wastewater usage, construction of dry cooling towers) • Restore/afforest/reforest land
Air temperature	Higher air temperature will reduce the efficiency of thermal power systems	• Concentrate investment in locations where temperatures are likely to be cooler • Decentralize generation • increasing the volume of water treatment works or developing alternative sources of water
Wind speed	• High wind speed could result in damage of thermal power plants infrastructure • High wind speed could also lead to higher dispersion of pollutant	• Develop and implement higher structural standards for new or renovated generation infrastructure
Inland water level	• Increased inland water levels and storm surges could damage methane gas infrastructures • Increased inland water levels could also affect peat quality and combustion efficiency due to higher moisture content	• Develop flood control (embankments, dams, dikes, reservoirs, polders, ponds, relocated flood defense barriers, and higher channel capacity) • Construct or relocate to less exposed places • Raise level of structures • Improve drainage and reroute water pipes • Protect fuel storage

4.3.1.6. Vulnerability and adaptation of the electric power transmission and distribution systems

The observed vulnerabilities of the electric power transmission and the distribution systems are mainly associated with extreme weather event such as floods, landslides, rain with storm, extreme wind speed, hailstorm, etc.

The following table highlights some of the damages that were recorded in the previous years.

Table 4.11 Damages of electrical power transmission and distribution between 2013 and 2016

	Electrical	Transformer	Cash power	Electricity grid
2013	19	1	18	0
2014	30	4	12	1
2015	12	1	1	0
2016	5	1	4	1

Source: MIDIMAR, 2017

Considering the forecasted increase in the extreme weather event in Rwanda, the observed vulnerabilities could be exacerbated. It is therefore necessary to enforce the adaptation measure. The main vulnerabilities related adaptation measures related to the electric power transmission and distribution are summarized in the table below:

Table 4.12 Climate change-related impacts / vulnerabilities and adaptation for electricity transmission and distribution Networks

Climate change	Impacts & vulnerability	Adaptation measures
Temperature increase	• Can reduce electricity carrying capacity of lines including transmission lines and distribution cables • Can increase losses within substations, switching gears transformers, etc. •De-rating of transformers of around –1% load per 1°C rise	• Specify more effective cooling for substations and transformers. • Specify certified ICT components that are resilient to higher temperatures and humidity.
Precipitation and flooding	• Heavy rains and flooding could undermine transmission tower structures through erosion • Drought can increase dust and lightning damage. • Flooding can damage underground cables and infrastructure in general.	• Build a resilient high-capacity transmission system. • Design improved flood protection measures for equipment mounted at ground level in substations. • Forbid the construction of power lines near dikes and ban "permanent" trees next to existing dikes. • • Protect masts, antennae, switch boxes, aerials, overhead wires, and cables from precipitation (water ingress,); wind; unstable ground conditions (flooding, subsidence); and changes in humidity.
Wind speeds	• Strong winds can damage transmission and distribution lines, towers (pylons) and poles	• Reinforce existing transmission and distribution structures and build underground distribution systems. • Require higher design standards for distribution poles.
Extreme events (flood, typhoons, drought)	• High temperatures, storms, erosion, or flooding can damage control systems through loss of ICT service or reduced quality of service.	• Increase the system's ability to return to normal operations rapidly if outages do occur. • Change routes of overhead lines along roads away from trees, rigorously prune trees, use covered and/or insulated conductors, and use more underground cables, especially in wooded areas. • Increase decentralized energy generation (with less transmission and distribution grid requirements). • Allow increased rerouting during times of disruption. • Include lightning protection (earth wires, spark gaps) in the distribution network. • Design redundancy into ICT systems. • Develop and use "smart transformers" and "smart grids."

4.3.1.7. Vulnerability and adaptation for electricity end use

Due to the lack of data the current vulnerability of this system was not analyzed. However, considering the importance of the electricity end use in the household and institution a research should be conducted to analyses the vulnerability and specific energy measures that can be taken. Potential adaptation measures to cope with increased energy demand with temperature rises as per future climate scenarios are of three types:

(i) increasing generation (MWh) and capacity (MW) to meet increased demand (business as usual approach);
(ii) improving the efficiency of energy supply (generation, transmission, distribution system improvements); and
(iii) Improving end-use efficiency.

4.3.1.8. Cross-sectoral considerations

The linkage between the energy sector and other sectors were analyzed via a system thinking methodology and the so-called energy water and land nexus was analyzed as shown in the table below.

Table 4.13 Nexus of energy water and land system

Resource system interaction	Illustrative components involved
Water needed for energy	Energy resources extraction (peat) Peat processing Biomass resources Thermal power plant cooling
Water needed for land	Agriculture Industrial, institutional, commercial and residential uses
Energy needed for water	Water extraction Water transport Water treatment
Energy needed for land	Resource extraction and conversion Agriculture Transportation Industrial, institutional, commercial, and residential uses
Land needed for energy	Energy resource extraction (peat) Biomass resources Energy infrastructure, including dams/reservoirs, power plants, solar farms, power lines, etc.
Land needed for water	Water capture and watershed Ground cover vegetation

Based on this linkage some adaptation measures were proposed. These include to:

- Establish or enhance cross-ministerial committees for managing adaptation to climate change, including ministries and departments dealing with overall energy policy, petroleum and gas, renewable energy, and energy-efficient transport.
- Strengthen the departments of environment, disaster risk management, and meteorology to improve and disseminate information on which to make decisions.
- Introduce early warning and response systems for energy ministries and power utilities to improve maintenance schedules and to respond quickly to post-disaster recovery needs.
- Promote no-risk and low-risk adaptation strategies that will have development benefits regardless of the nature and extent of climate changes.

- Integrate adaptation plans for energy and water into a joint strategy as the two are closely linked.
- Introduce climate change vulnerability and adaptation considerations to criteria used for selecting and prioritizing projects for implementation and financing.
- Develop sector-specific and country-specific screening tools to identify proposed projects at risk.
- Incorporate contingency budgets for specific adaptation interventions as the need arises, including at least order-of-magnitude estimates of the likely costs, risks, and benefits of the adaptation action and inaction.
- Adjust zoning regulations for energy infrastructure (for example, to avoid flood).
- Design flexible energy infrastructure that can accommodate incremental changes over time.
- Incorporate climate change indicators into energy planning budgeting frameworks.

4.3.1.9. Ranking of climate change adaptation measures and cost benefit analysis

The prioritization of the measure identified in energy sector was carried out using the so-called Multi-criteria analysis (MCA) or multi-objective decision-making. The proposed climate change adaptation measures were ranked from 0 to 1 and the percentage of the obtained total scores is calculated. Higher score was given to climate change adaptation measures that respond better to selected criteria. Based on this analysis, key adaptation measures are ranked in descending order.

Table 4.14 Ranking of climate change adaptation measures in electricity generation and transmission

Adaptation measures	**Criteria and Score (0-1)**					**Total (%)**	**Ranking**
	National development goal	Contribution to socio-economic development	Cost (high= 0 and low=1)	Feasibility /adaptation culturally	Ensure adaptation to climate change impact identified		
Optimize reservoir management and improve energy output by adapting to changes in rainfall or river flow patterns (important to planned projects)	1	0.8	0.5	1	0.7	80	5
Adopt hybrid photovoltaic-thermal systems using enhanced cooling systems	1	0.9	0.6	0.8	0.9	84	4
Develop and use smart transformers and smart grids.	1	0.9	0.6	1	1	88	3
Behavioral adaptation measures including early warning systems for	0.7	1	1	0.8	1	90	2

rainfall and temperature anomalies, support for emergency harvesting for an imminent extreme event, and provision of crop insurance systems							
Expansion of irrigation systems or improvement of the efficiency of irrigation	1	0.7	0.9	0.9	0.8	86	6
Establish or enhance cross-ministerial committees for managing adaptation to climate change, including ministries and departments dealing with overall energy policy, petroleum and gas, renewable energy, and energy-efficient transport.	1	1	1	0.9	1	98	1

4.3.2. Vulnerabilities and adaptation of agriculture, livestock and forestry sectors

4.3.2.1. Vulnerability of agriculture and livestock in Rwanda

Rwandan agriculture is heavily dependent on climate conditions as most of agriculture productive system depend on rainfall. Extreme weather events such as floods, heavy rainfall, wind and storms highly affect the agriculture and livestock. An analysis of agricultural production since 1999 revealed that yield fluctuations are remarkably related to annual precipitation although from 2006 the crop intensification program has greatly influenced the yield trend. (Fig.4.18).The analysis of the existing yields between 1999 and 2014 (Fig.4.18) showed significant positive Pearson correlations of total annual rainfall with yields of maize ($r=0.279$, $p<0.05$), rice ($r=0.257$, $p<0.05$) and wheat ($r=0.635$, $p<0.05$). However, no significant relationship with crop yield was found for the number of rainy days, min and max temperature at country level. A more localized study could be appropriate to compare agro- ecological zones, microclimates and regions where specific crops are grown to understand better the relationships with climatic parameters and develop more specific adaptation recommendations.

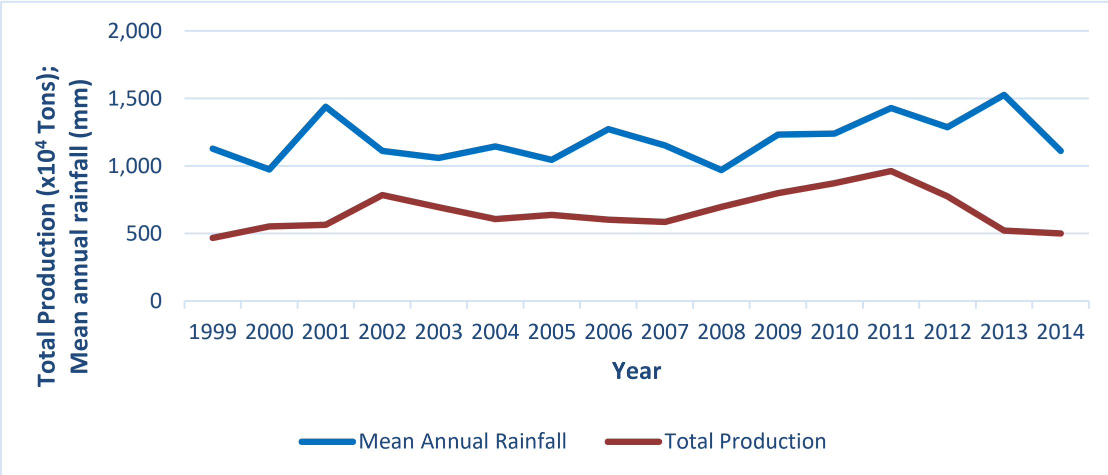


Figure 4.18 Total annual rainfall (mm) and total crop production in Rwanda (x104 Tonnes) from 1999 to 2014

Beside the precipitation, drought, landslides, violent storms as well as crop and livestock pests, diseases and epidemics are other major hazards that affect the agriculture sector. Drought is considered as the most critical factor which affects different parts of Rwanda mostly Eastern regions as a result of a prolonged dry season or a delay in the onset of the rainy season. Some of the recorded drought events in Rwanda are summarised in Table 4.15.

Table 4.15 List of drought events in Rwanda (MIDIMAR, 2015)

Event date	Affected zone	Secondary hazards	Chained events	Death	Affected Pop
1910	Kibungo/Zaza (EP)			0	1,700,000
1976-1977	National	Famine/ Crop failure	Famine/ Crop failure	0	420,000
October 1984	National	Famine/ Food shortage	Famine/ Food shortage	0	60, 000
December 1989	Gikongoro, Gitarama and Butare (SP)	Famine/ Crop failure	Famine/ Crop failure	237	82,000
1996	Gikongoro	Famine/ Food shortage	Famine/ Food shortage	0	894,545
November 1999 - Early 2000	Umutara, Kibungo (EP), Kigali (Central), Gitarama, Butare and Gikongoro (SP)	Famine/ Food shortage	Famine/ Food shortage	0	267,000
March 2003	Kigali Rural (Gashora and Bugesera), Kibungo, Umutara (EP), Butare, Gikongoro and Gitarama (SP)			0	1,000,000
February 2005	National	Famine/ Crop failure	Famine/ Crop failure		
March - September 2006	Kibungo, Umutara, Bugesera (EP), Butare, Gikongoro and Gitarama (SP)	Famine/ Food shortage	Famine/ Food shortage	0	1,011,200
June 2014	Bugesera and Kayonza Districts (EP)				

The results from crop assessment of 2014 on vulnerability of crop yield to drought are shown in figures 4.19 and 4.20:

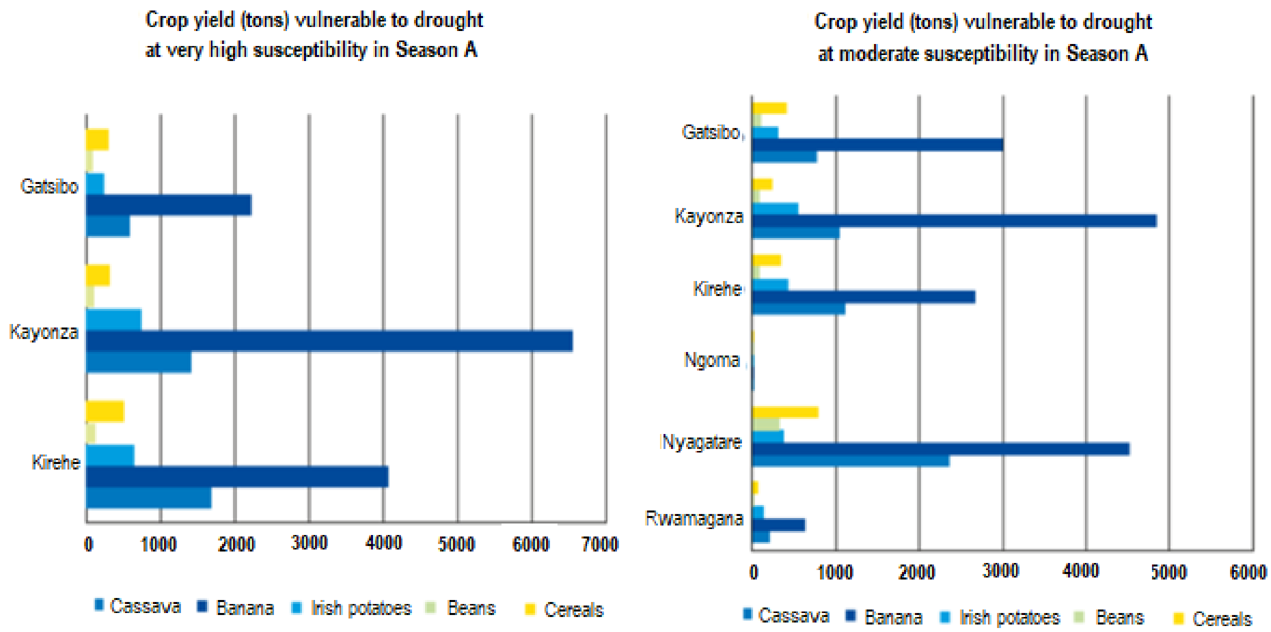


Figure 4.19 20 Crop yield (tonnes) vulnerable to drought in Season A

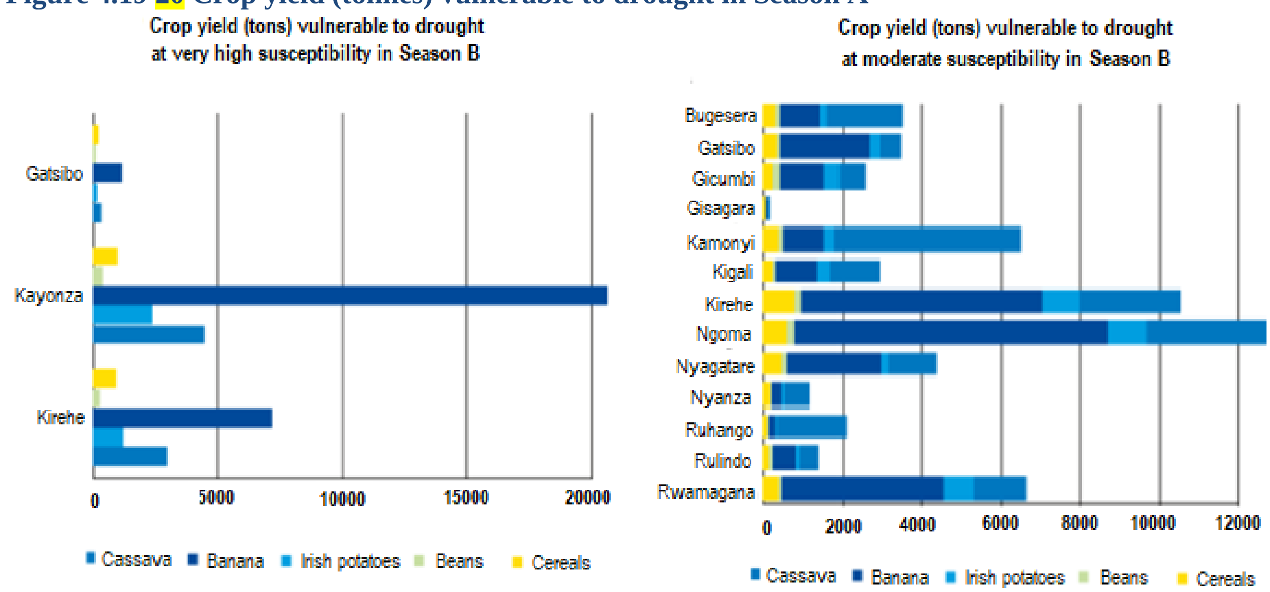


Figure 4.20 Crop yield (tonnes) vulnerable to drought in Season B

A scenario analysis of potential climate change impacts on agriculture and livestock sector is provided in the following table:

Table 4.16 Scenario analysis of potential climate change impacts on agriculture and livestock sector

Climate change scenarios (TNC report on CCS&P)	Potential impacts on agriculture and livestock
Increasing trend in mean temperatures (projected annual mean temperature increase between 0.10°C and 0.30°C)	• Decrease in tea and coffee production; • Leads to significant reduction of crop yields of cereals; • Shift in pest ecologies, and thus resulting in pest and disease outbreaks in new areas; • Heat stress affects physiological processes health and mortality of livestock.; • Higher disease pressure on livestock, through change of the thermal optimum for pathogens, hosts, vectors and epidemiology, together with a number of indirect effects;
Decreasing trend in mean rainfall and number of rainy days coupled with more days with extreme rainfall intensities particularly in the Eastern and parts of Southern regions	• Late harvests, delay of sowing in the next season, seasonal crop failures and low yield; • Famines and food insecurity; • Limited grazing and feed resources during long dry spells significantly reduce milk productivity and thus affect food security of cattle farmers;; • Increased use of swamps for agricultural purposes will soon or later also have implications for overall water balance in the country and its availability for agriculture.
Increase in rainfall intensities in North-west highlands and South-western regions	• Increase soil loss and nutrient leaching from soil, thus challenging agricultural productivity growth. • Increased runoff during heavy storms destroy existing soil conservation facilities, increase sedimentation of lakes and ponds thus altering fish habitats..
More frequent violent storms (strong winds, hailstones, thunders, torrential rains)	• Crop damage or total crop destruction and thus yield reduction; • Increased flooding and landslides destroying crops cultivated on vulnerable/fragile areas such as valleys and steep slopes;

Policy and strategic documents show the Government’s will to address the challenges posed by climate change impacts, to improve productivity in the agricultural sector so as to meet national targets in food security and to transition towards sustainable agriculture. However there are several other measures that need to be adopted in order to overcome the above mentioned potential impacts of climate change to Agriculture. These adaptation strategies are listed in Table 4.17and in Table 4.18.

Table 4.17 Climate change impacts and proposed adaptation strategies for the agriculture sector

Sub-sector	Climate change challenges	Possible adaptation strategies
Crop	• Increased vulnerability of agriculture to droughts and other extreme weather events • Food insecurity due to reduced crop yields	• Broadcast weather forecasts and sowing date recommendations. • Land husbandry, conservation agriculture, inter- or multi-cropping and precise fertilizer use under CIP and beyond • Breed new climate smart and nutrient efficient varieties using molecular markers • Breed and disseminate varieties more resistant to pests and diseases

	because of droughts and other extreme weather events • Increased crop pests and diseases • Increased soil degradation due to high rainfall, • Limited water availability for irrigation due to decline of rainfall	• Promote conservation agriculture (e.g. Zero tillage and mulch use); • Prevent and respond appropriately to pests and diseases infestations • Develop new strategies for disease vector control and prevention • Plan for crop change with increasing changing temperature and rainfall decline • Apply IPM and ISFM strategies • Promote judicious use of water • Develop adapted crop varieties; creation of windbreaks using agro-forestry • Promote Crop-Tree-Livestock integration • Develop precise fertilizer recommendations • Mapping damages of extreme events • Use IT for extension requests and feedback from farmers; • Promote environmental friendly fertilizers (e.g. Manure and compost) • Attract private sector for seed multiplication, dissemination of fertilizers and training services • Incentivize mechanization • Promote closed production systems (greenhouses, aeroponics, hydroponics) • Expand on appropriate irrigation and rain water harvesting technologies. • Incentivize rainwater harvesting and expand investment in water harvesting at settlement and community levels • Plan regular maintenance of agricultural infrastructure (e.g. rural roads and irrigation channels) • Promote technologies to offset the risks of agricultural production and other challenges; • Create rural non-agricultural employment and small businesses (e.g. in food processing); • Prepare quality control and new market niches for increased horticultural production • Develop value chain for increased horticultural production • Develop food processing industries • Expand loans in agriculture sector as well as weather related crop insurance
Livestock	• Reduced animal feed due to bad weather and low income of farmers • Insufficient manure production due to drought and rainfall decline • Increased pests and disease epidemics	• Increase and support small stock husbandry • Develop and promote poultry,rabbits and aquaculture • Reduce number of large stock (local cattle breeds) and promote improved breeds (cross breeds) • Promote cooperative cattle farms • Improve manure management • Develop manure quality control • Strengthen disease diagnostic, prevention and surveillance • Develop new feed formulations and alternative feeds(Crop residues, hay and silages). • Promote leguminous multipurpose trees with higher nutritive fodder

Table 4.18 Recommended adaptation strategies and justification in Agriculture sector

Adaptation strategies	Explanation and justification (socio-economic and ecological considerations)	Prioritization*
Crop sub-sector		
Development of specific fertilizer recommendations based on soil data and using IT and mobile phone applications	Most of current fertilizer use is based on general crop requirements without considering specific soil properties. Thus expensive mineral fertilizers are applied sometimes in excess of what is necessary. If specific fertilizers are applied, their use may be more efficient than it is today and thus less fertilizer (unused by crops) would be lost in soil. Moreover, their use should be adjusted to the current rainfall pattern to use multiple small doses instead of single larger doses. This would reduce their runoff from soil and have great economic benefits as much of fertilizer applied would be kept in soil for crops. Saving mineral fertilizer through more judicious use would help to apply them on larger area (at least 20%) and/or provide additional yield increase of at least 10%. More efficient fertilizer use will result in slower increase in GHG emissions due to the planned expansion of the mineral fertilizer use.	1
Use of extended rotation and multiple cropping under Crop Intensification Program	Intensive mono-cropping under limited rotation causes build-up of pests and diseases and results in pests and diseases epidemics and crop yield failure thus making the current production systems less sustainable. Narrow range of crops and prohibition to intercrop makes systems to be mostly mono-cropping and with rotation limited often to just 2 crops. Multi-cropping systems and at least 4 crops in rotation may increase system productivity by at least 50%, however, these considerations were not part of any current agricultural policies. The cost of this adaptation measure would be limited to the delivery of the clear recommendations on rotation sequence and crops for each AEZone (it is expected not to exceed 5% of crop production value). However, the increase of system productivity would by far cover the cost of application of this measure.	2
Encourage use of IT for timely orders and delivery of agricultural inputs (seeds, fertilizers)	Input deliveries delay making fertilizer applications sub-optimal and causing losses of nutrients. Early orders through use of IT would improve timely preparation and delivery of agri-inputs and thus it would positively affect productivity. RAB has recently introduced Smart Nkunganire system for declaring crop production and mineral fertilizer orders. It is expected that if the system is used by the majority of farmers the production will increase by at least 10%.	3
Encourage private sector to produce and deliver seeds, fertilizers and professional trainings	The current agri-input sector is very unstable by limited demand, mismatch of demand and supply and lack of professional skills – all this makes crop yield to be lower than the potential for the existing environment. This adaptation measure requires large investment and a system like Smart Nkunganire to match demand and supply, and to plan the deliveries. It may be useful to develop policy support to motivate private sector and help with planned seed production orders at start-up	4

	or develop a seed production insurance system. Increase of use of improved seed would result in at least 20% increase in crop production. This would offset the large investments in seed industry at the initial stage.	
Weather forecasts for timely programming of sowing dates	Unequal rain onset for wet seasons and fear of drought at sowing time make farmers to delay planting. Thus farmers need to be assisted with timely season preparations and early sowing to catch up with scarcer rains. This will reduce crop failures and increase resilience of the existing cropping systems. Thus weather forecasts would be matched with announcement of sowing dates and closer follow up of the sowing. This measure doesn't require separate funding but only the linkages to the existing activities of season preparation.	5
Promotion of early yielding/drought tolerant/shorter cycle crops and varieties	Due to rain variability, season onset is highly variable, thus farmers delay with planting waiting for the season onset. This causes crop failures if rain frequency is reduced. Early yielding crops may be more successful with adapting to climate change. Large investments are required to maintain modern crop breeding at RAB. This includes professional skills development, laboratory maintenance and acquisition/upgrading of modern breeding tools/equipment. The cost of this adaptation measure would have return in a longer run but it is an essential step to keep the pace of the increasing need to produce more in shorter time for more people.	6
Promotion of drip irrigation and closed greenhouse production systems for more efficient water use	Water resources are not scarce in Rwanda today but will inevitably be scarce tomorrow. Use of drip irrigation may help to reduce overuse of water and help to make agricultural systems more productive. Waste water and run off from settlements which is currently unused should be effectively used for irrigation This adaptation measure will require important investment at the initial stage but should be expanded. However, it is expected to be more largely applied with population growth and increase of investment capacity as the resources will become scarce. With increase in rainfall variability, the pay-back from the investment in drip irrigation will increase because water supply irregularity for soil remains among the most limiting crop yield factors.	7
Integration of climate tolerant fruit trees, multipurpose or fodder trees into terraces, road sides and public spaces	Land scarcity has led to cultivation of all available land. Additional production may be achieved by filling the niches on terraces, road sides and public spaces. Judicious use of tree species should be made to maintain indigenous diversity, additional fruit and fodder production. The cost of this adaptation measure will result in additional fruit/fodder/wood production, and its cost may be included in the planned re-forestation activities. The pay-back of this measure will be on longer term similar to forestry programs.	8
Investment in cutting-edge research to develop new varieties using molecular breeding techniques, varieties responsive to bio-	Development of crop varieties with more efficient nutrient uptake will help to reduce mineral fertilizer use without the loss of productivity. This may help to maintain system productivity under changing climate and help to reduce GHG emissions from Agriculture.	9

fertilizers and more efficient in nutrient use/absorption	The cost of this adaptation measure would have return in a longer run but it is an essential step to keep the pace of the increasing need to produce more nutrient efficient varieties and more in shorter time for more people.	
Further development of irrigation infrastructure and rain water harvesting facilities	Most of the rain water is lost as the existing infrastructure is too little to stock any important quantity of water. As an example, even for households having a water tank from a house roof, the quantity of water stored is often limited to that from a single rain. More investment in water harvesting technology and its use for irrigation will lead to improved crop production under changing climate conditions. Local development programs would include development and maintenance of community rain water harvesting and irrigation infrastructure.	10
Investment in highly intensive urban agriculture (greenhouse production, mushroom units)	Increase in urban food production and technologies with moderate use of water (e.g. mushrooms) will help to improve agriculture productivity under changing climate conditions. The cost of this adaptation measure would be fully absorbed by the private sector. Returns from initial investment for start-up would be rapidly paid back. This adaptation measure will result in intensified food production for city and with moderate water consumption.	11
Promotion of closed and/or recycled systems for greenhouse production	Food production in closed systems presumes very limited use of water and other resources. Promotion of these systems will improve food production under changing climate conditions. As water scarcity will become more important, such technologies will save water and thus will help to tackle climate change by more judicious water use. This adaptation measure will require important investments, especially for hydroponics and aeroponics, development of sufficient technical skills, and involvement of private sector. However, in a longer term it will pay back with significant increase in food production which will become more important for job creation and meeting food demand in city.	12
Livestock sub-sector		
Reducing cattle number through expansion of more productive exotic crossbreeds	Reducing of cattle number will reduce GHG emissions and reduce resource use from the limited land. In fact, GHG emissions from enteric fermentation can be reduced by shifting to more productive modern cows and reducing the number of local cows. This may positively affect resource allocation and reduce space for fodder production or grazing area. This adaptation measure will require significant resources supporting the cost and size of planned replacement of local cows by crossbreds or the exotic races.	1
Organization of the existing individual cattle units in cooperative holdings with improved manure management and generate biogas from these units	Promotion of collective cattle farming and building of improved manure storage facility will improve the quality of local manure and thus positively affect crop yield while reducing GHG emissions from poor manure management. This adaptation measure will result in producing better quality manure and thus higher crop production; job creation in collective farm units, and increased milk production and marketing from collective farms. It will require significant initial investments with pay back in a medium term.	2

Expansion on less resource-consuming sources of protein production – aquaculture and poultry	Aquaculture and poultry cause less GHG emissions and are more resource efficient. They should be promoted to tackle the problem of insufficient protein production and consumption. This adaptation measure will require development of technical skills, supporting fed industries and it is expected to offset the expansion of big cattle and fit into existing niches of the available scarce resources. It will pay back rapidly and offset the initial investment cost.	3
Development of animal and fish feed industries	Livestock development is limited by high prices and scarcity of animal feed. Supporting feed industries will positively affect the switch from large to small stock at required high growth rate. This adaptation measure will slow down the GHG emission increase from cattle population and support the development of small stock production.	4
Promotion of biogas use in community and public settlements (e.g. schools, health centers, etc.)	Biogas technology will tackle the problem of poor manure management and N_2O emissions and thus should be promoted. High initial cost will result in more economic use of resources and promote large stock keeping in community places. This will result in additional milk production.	5
Shifting resource allocation from large to small stock development	Small stock development has higher potential and is more convenient for rapid expansion and it is also less producing GHG emissions. This adaptation measure will contribute to more ecologically friendly production of proteins and additional job creation in small stock units.	6
Strengthening disease diagnostic and prevention units as well as surveillance system	Livestock epidemics should be prevented by the development of good surveillance system and prevention of livestock diseases to optimize productivity of livestock under higher disease pressure due to changing climatic conditions. Supporting this adaptation measure will result in better livestock production through timely reduction of animal disease epidemics and revenues from additional livestock products due to successful disease prevention and control, job creation and more stable livestock production in a longer run.	7

4.3.2.2. Vulnerability and adaptation in the forestry sector

It is difficult to distinguish the impacts of climate change on forest resources from other non-climate change factors such as agriculture, infrastructure development, urbanization, etc. However, it is recognized that the socio-economic and political drivers will likely be exacerbated by future climate change with projected increase in temperature, decreased rainfall in many parts of the country and occurrence of extreme events such as drought, flooding and landslides. The potential climate change impacts are summarized in table 4.19.

Table 4.19 Scenario analysis of potential climate change impacts on Forestry

Climate change scenarios	Potential impacts on Forestry
Increasing trend in mean temperatures (projected annual mean temperature increase between 0.10°C and 0.30°C)	• Increasing temperature will create a favourable environment for more forest pests and diseases. This will reduce productivity of forests and may increase risks of deforestation and forest degradation.
Decreasing trend in mean rainfall and number of rainy days	• Decrease in rainfall will likely increase water stress of trees particularly in semi-arid areas in Eastern and Southern regions, reducing their productivity and leading to dieback; • More frequent droughts will upsurge anthropogenic stress and increase deforestation and forest degradation, frequent and severe forest fires and reduce capacity of water catchment;
Increase in rainfall intensities coupled with strong winds, hailstones, thunders, torrential rains in North-west highlands and South-western regions	• Increased forest productivity due to increased rainfall availability; however, subsequently increased extreme weather events such as strong winds, violent storms, violent floods and landslides will affect negatively forest resources particularly in fragile areas such as on steep slopes and valleys.

To address these pressures and increase resilience to climate change impacts, different adaptation strategies in the forestry sub-sector are described in Table 4.20.

Table 4.20 Recommended adaptation strategies for the forestry sub-sector

Adaptation measures	Explanation and justification	Prioritization *
Development of agro-forestry for sustainable agriculture and landscape restoration	Agro-forestry is one of agro-ecology practices that should be promoted on all farmlands. In addition to increasing agricultural productivity of farms, agro-forestry will reduce the pressure of deforestation and forest degradation which may result from frequent droughts, increased incidences of forest pests and diseases and anthropogenic stress as impacts of projected climate change.	1
Afforestation/ reforestation of remaining free and designated areas through improved germplasm and technical practices in planting and effective post-planting/tending operations	The forest sector is and is likely to remain under pressure in the future to meet the ever increasing demand for wood products particularly biomass energy. There is need to increase forest area by planting all remaining free and designated areas using quality germplasm, planting trees at the right time (rain season) and improving post-planting care (tending operations). Furthermore mixed-species approaches should be promoted, which may contribute to increasing ecosystem resilience and biodiversity.	2
Improved Forest Management of degraded forest resources	The productivity of degraded forest plantations should be improved through proper forest management practices. This presents an opportunity to enhance carbon sequestration and increase wood biomass supply without converting additional land.	3
Efficient use of wood and biomass energy	There is considerable waste that occurs due to conversion of wood into products (Timber, charcoal, biomass energy etc.) and the wood value chain is poorly organised which makes wood products greatly undervalued. Poor efficiency implies that more trees are cut to meet	4

	wood demand and leads to over exploitation. A rapidly growing population that is based on extractive livelihoods and is highly dependent on biomass energy will continue over exploiting the wood resources unless action is taken. Therefore, there is need to reduce wastages from wood conversions by increasing efficiency of the conversion process and improving the value of wood products. This will also make wood products more profitable than today. GHG emissions will also be reduced.	
Promotion of Public-Private partnerships in forest management	One of the problems facing the forest sector is poor management of public plantation forests. There is need to promote public-private partnerships in order to ensure sustainable management of all public plantation forests through multi-year contracts with forests operators (in cooperatives) who will plant and maintain young plantations until they reach their commercial size. This will likely improve the protection of forest resources in the country and contribute to enhancing livelihoods of people living in the neighbourhood of productive forests through increased employment and social responsibilities of logging companies.	5

4.3.2. Vulnerabilities and adaptation of water resources sector

Water resources sector is affected by the changes in rainfall and temperature. The following figures illustrate the results of analysis done on the flow of Nyabarongo River from 1961-2015(taken as a case study) in relation with changes in rainfall and temperatures.

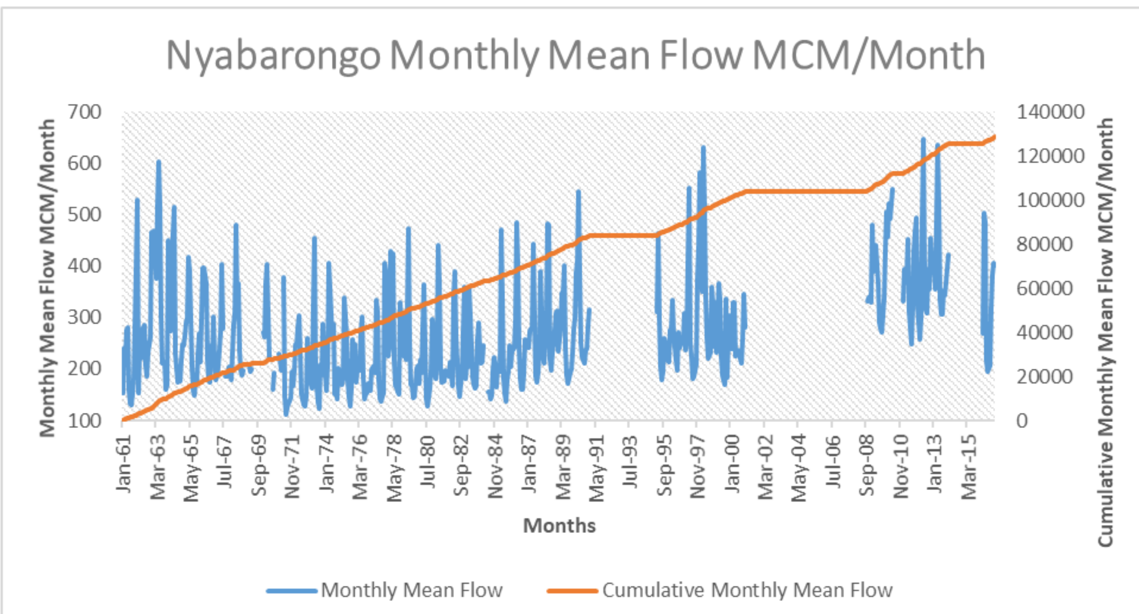


Figure 4.21 Nyabarongo River Monthly flow MCM/Month.

A correlation analysis, using a double mass curve (Buishand, 1982), was done between the Nyabarongo River Flow and Rainfall (obtained from the Rwanda Meteorological Agency) as illustrated on Figure4.21 The analysis indicated a strong correlation between the Nyabarongo River Flow and Rainfall for most of the analysed period. The parabolic tendency observed in the mass curve shape, may likely be related to a progressive influence of heavy sedimentation in the River at the location of the gauge station. The strength of the correlation indicates that the entire hydrograph of the Nyabarongo River, including the base flow, is directly related to the rainfall more than anthropogenic water abstractions. Such conditions indicate that the Nyabarongo catchment's hydrology is vulnerable to any change in climate.

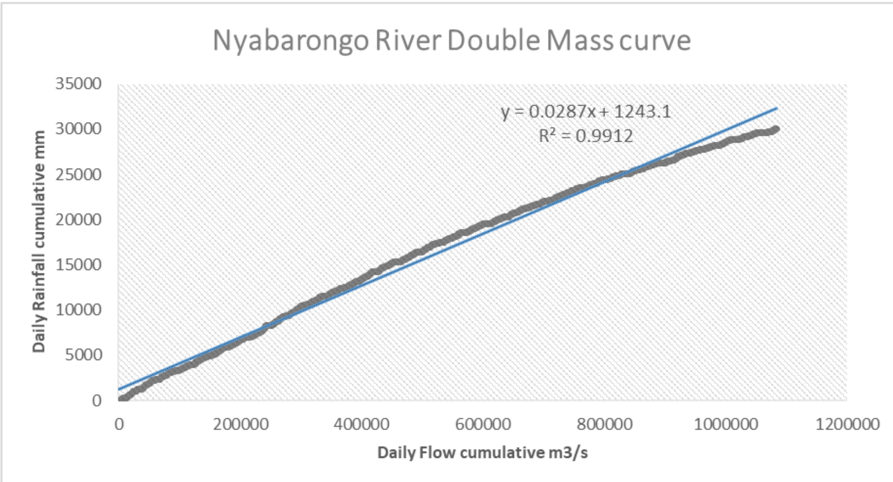


Figure 4.22 Nyabarongo Double Mass curve

The existing hydrological behaviour of the Nyabarongo River is directly related to the Rainfall seasons in Rwanda. This is illustrated in Figures 4.23 and4.24 respectively. Peak flows are observed during the periods of March to May directly followed by a period of low flows from June to August and a medium flow period from November to January.

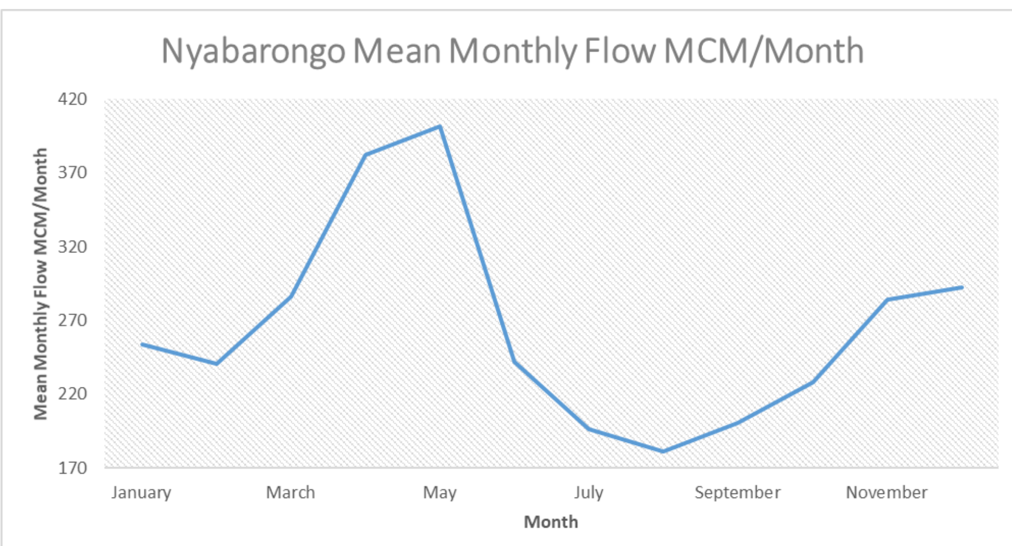


Figure 4.23 Nyabarongo Mean Monthly Flow MCM/Month

Figure 4.24 shows the existing time series which indicate that the highest, medium and lowest year monthly flows, based on their average; are 2013, 1989 and 1976, respectively. A clear distinction of these 3 periods can be observed emphasizing the high sensitivity of the Nyabarongo River hydrology to rainfall variations and therefore to climate change.

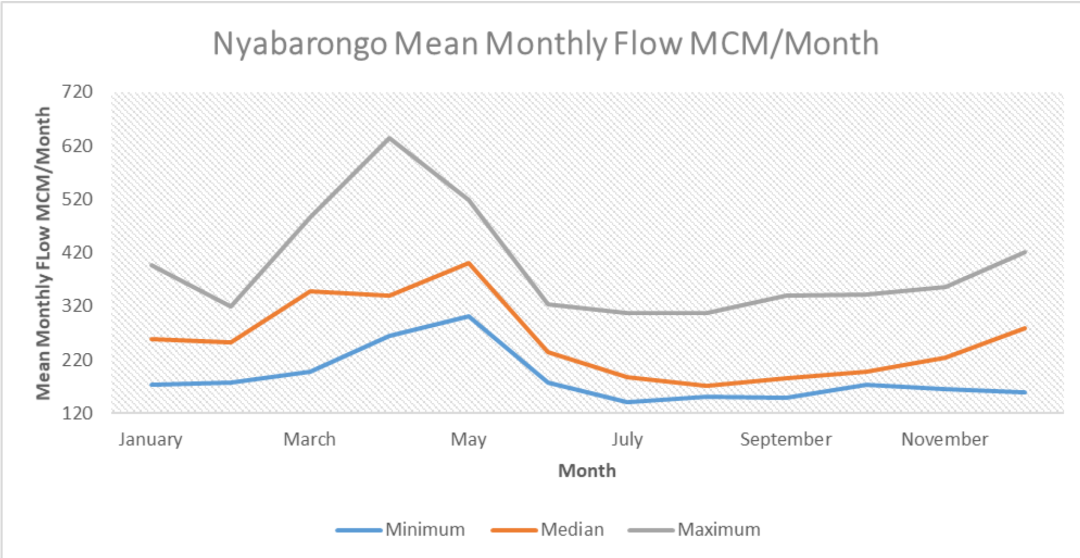


Figure 4.24 Nyabarongo Min, Median and Max Mean Monthly Flow MCM/Month.

The prediction of Nyabarongo River flow (2000-2050), at the Ruliba station in Kigali, was done through application of rainfall runoff modeling. In this analysis, a lumped continuous modeling approach was applied. The modeling tool used was the HBV model (Lindström et al., 1997). This is a mathematical model designed for runoff simulation, hydrological forecasting and water balance studies. The model incorporate different catchment characteristics such topography, land use land cover, soil characteristics and meteorological data to simulate the dominant hydrological processes in the catchment. The model general water balance is summarized in Equation

$$P - E - Q = \frac{d}{dt}[SP + SM + UZ + LZ + Lakes] \qquad \text{Eqn. 1,}$$

Where P is precipitation, E is evapo-transpiration, Q is runoff, SP is snow pack, SM is soil moisture, UZ is upper ground zone, LZ is lower ground zone and Lakes is lake water storage.
The HBV model structure, as provided by Lindström et al. (1997), is summarized in Figure 4.25. The major forcing factors of the HBV model are precipitation, temperature and snow melt (which was ignored for this particular case).

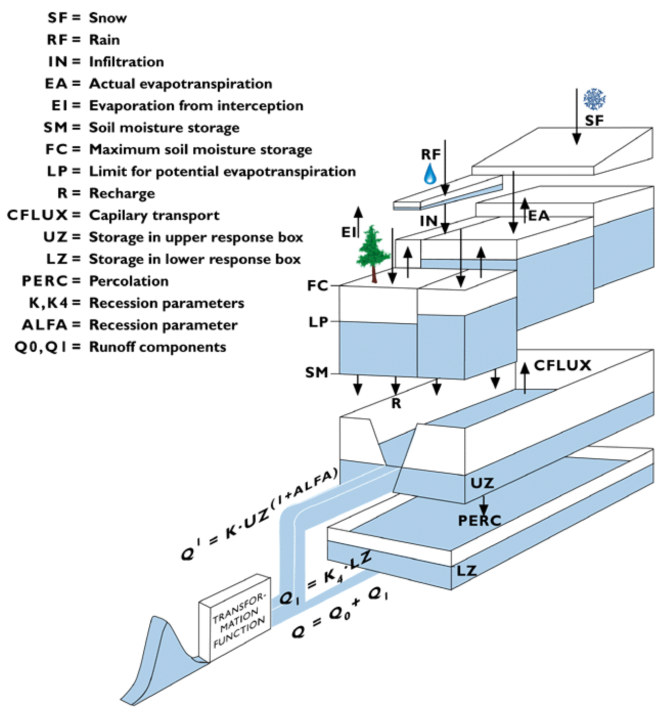


Figure 4.25 HBV model structure schematic

In the soil moisture sub routine, the runoff formation occurs with Actual evapotranspiration. The total runoff is subdivided into fast runoff (governed by the exceedance of water in the soil moisture reservoir of the catchment to the maximum soil moisture storage indicated by the FC parameter) and a slow runoff. When the soil moisture saturation is not reached, the precipitation infiltrates (IN) in the soil moisture reservoir first to refill it and then seeps through the soil layer as represented by R in Figure 4.25. The hydrograph is shaped through a transformation routine where the discharge of the basin is routed by a triangular distribution function. In the HBV model, the water balance is solved for every simulation in each reservoir at each time step and for the entire simulation period.

The model was set up and forced with the existing time series of precipitation, temperature and evapotranspiration. The Nyabarongo River Flow was used to calibrate the model. The performance criterion used in this model was the model efficiency which is described in Equation 2.

$$R_{eff} = 1 - \frac{\sum\left(Q_{sim}(t) - Q_{obs}(t)\right)^2}{\sum\left(Q_{obs}(t) - \overline{Q_{obs}}\right)^2} \qquad \text{Eqn. 2,}$$

Where $Q_{sim}(t)$ is simulated flow and $Q_{obs}(t)$ is observed flow. A value of 1 is the perfect fit.
In study, a value of 0.6 was obtained as a combination of different errors in the data used, the model structure and the missing values. However, 0.6 is an acceptable value for model calibration therefore the model was applied in this case.

In order to predict the Nyabarongo River flow up to 2050, the Inter-Governmental Panel on Climate Change (IPCC), which defined among its several scenarios used for global climate prediction models, SRES B1 was used.

For Rwanda, this socio-economic development scenario was based on the policies and strategies published by the various Ministries. These policies were generally built forth on national planning by the government, which are the Economic Development and Poverty Reduction Strategy one and two (EDPRS 1 & 2). In combination with statistical data from Ministries and the National Government, it was possible to use forward projections for the definition of realistic scenarios.
This scenario was applied in the BCM 2.0 climate model and produced time series of rainfall and temperature that were used as forcing factors in the calibrated HBV model of the Nyabarongo River.

Based on the simulated rainfall time series, the annual precipitation is expected to slightly increase (the slope of the trend line up to 2050 is 0.0027) as illustrated on the following figure

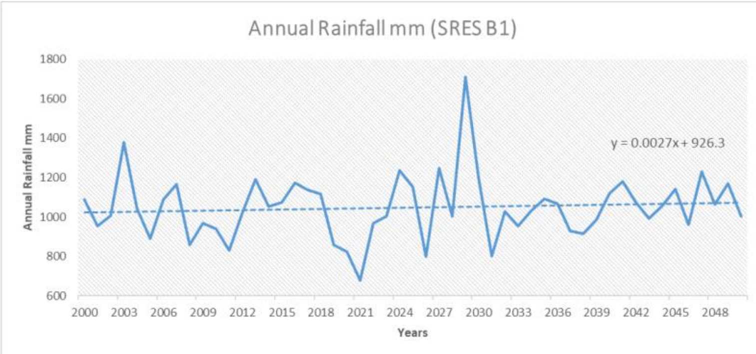


Figure 4.26 Simulated Rainfall from the SRES B1.

The trends in temperature variation up to 2050 based on the SRES B1 scenario projections indicate negligible changes. This is illustrated on Figure.

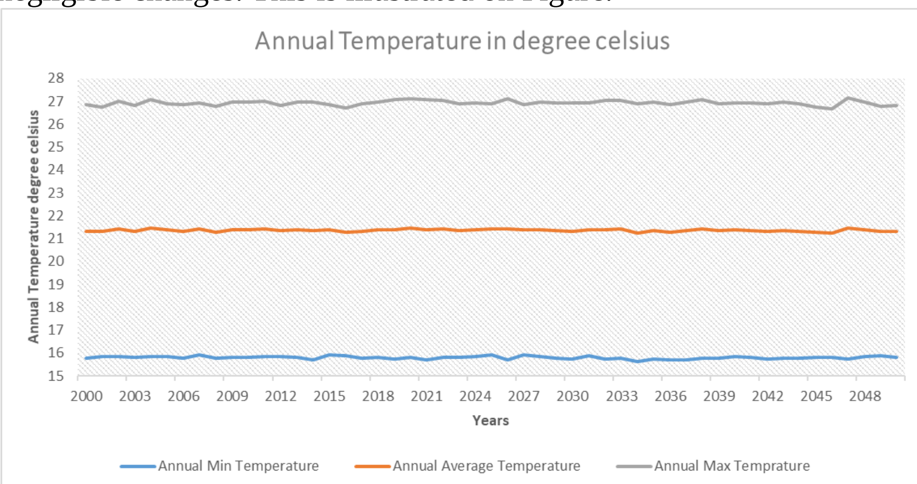


Figure 4.27 Simulated Temperature from the SRES B1.

Figure 4.28 illustrates the simulated Nyabarongo River flow at the Ruliba gauging station in Kigali. A qualitative analysis of the simulated flow was done using cumulative monthly flows and average monthly flows.

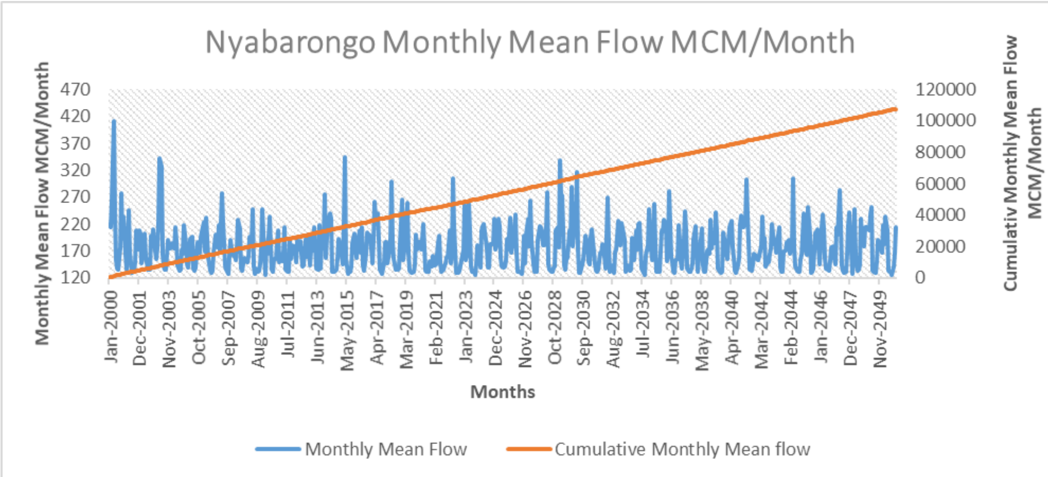


Figure 4.28 Nyabarongo Monthly Mean Flow MCM/Month

The model simulated high actual evapotranspiration while maintaining a more or less linear base flow. Based on the result of the model, unproductive evapotranspiration is parameters that need to be minimized in the basin. The following may contribute to climate change resilience. In addition, the B1 scenario incorporate increase of water abstractions for human use which is seen in this case as contributing to reducing the flow of the Nyabarongo River.

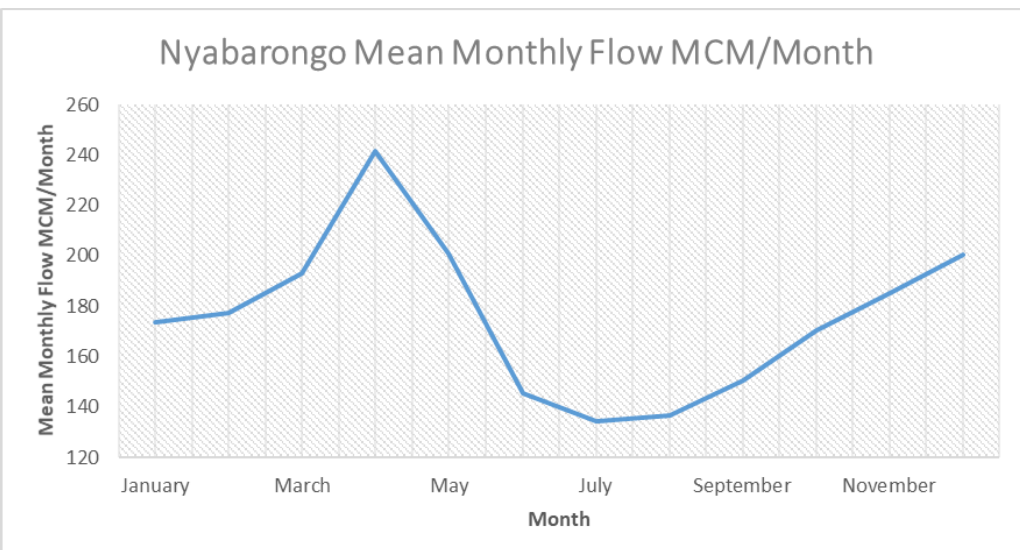


Figure 4.29 Nyabarongo Mean Monthly Flow MCM/Month

Figure 4.29 illustrates that the dependence of the Nyabarongo River to Rainfall will still be high and direct. Therefore, any anthropogenic interactions with the natural hydrology of the Nyabarongo River would have to be implemented with caution.

Figure 4.30 projects a pronounced dry period as the minimum may be reached even during period of high flow. Also, the model predicts high flows in the beginning of the simulation toward reduced flow period in the far future. During the dry season, water abstractions will be affecting the flow of the Nyabarongo River heavily.

Climate adaptation measures to address impacts on water resources are described in **the Table 4.21** below:

Table 4.21 Prioritized adaptation measures in water sector

Performance indicators	Expected change by 2050	Climate indicators	Climate impacts (vulnerability)	Actions
Water availability	High	Floods and Landslides	Loss of lives; Destruction of infrastructures like roads, houses; Inundation of crop lands; etc	Develop and implement floods control plans in floods prone catchments
				Improve rainfall monitoring and forecasts
				Develop and implement floods early warning systems in flood prone catchments
				Relocate people living in flood prone areas
				Develop and implement catchments management plans with special focus on the most degraded catchments
	Low	Drought	Water scarcity	Develop and implement water allocation plans at all the 20 level two catchments
				Develop hydrological models and establish water balances
				Develop water allocation models at catchment level and country level
				Develop water storage infrastructures with emphasis on multi-purpose dams
				Promote rainwater harvesting at household level
				Establish and support catchments committees at all the 20 level two catchments
				Promote water use efficiency
				Promote drought resistant crops especially in water scarce areas
				Develop and implement a drought management plan
				Support water users associations
				Strengthen the coordination mechanism among the water dependent sectors (agriculture, energy, environment, etc.)
Water quality	Poor	Floods, high erosion	Siltation of rivers	Control erosion from all agriculture lands and mining areas
			Eutrophication of water bodies especially lakes	Put in place mechanisms for controlling water invasive species like water hyacinth
			Water related diseases	Provide potable water for domestic activities
				Raise awareness on hygiene and sanitation
				Establish centralized wastewater treatment systems in urban areas

4.3.3.1 Strategies related to climate vulnerability and adaptation in the water resource sector

The major strategies related to climate vulnerability and adaptations in the water resource sector are the Green Growth Strategy (2011-2050) and the Strategic Plan for Water Resources Management (2013-2018). However, within the water resources management strategic plan, the key aspects related to adaptation to climate vulnerability are all captured under the Rwanda green growth strategy.

Within the green growth strategy, Integrated Water Resources Management (IWRM) is one of its programmes of action and the strategic actions under the IWRM Program are:

a. **To establish a National Integrated Water Resources Management (IWRM) framework**: In terms of IWRM; Rwanda has put in place a policy, legal and institutional framework which promotes IWRM and this can be illustrated by the adoption of the first National policy for water resources management and the establishment of an Integrated Water Resources Management Department in 2011, the 2008 Water Law which is under review and its related Ministerial Orders, the development of the National Water Resources Master Plan in 2015, the initiation of the process for elaborating specific catchments plans, etc.

b. **District and Community based catchment management;** In terms of District and Community based catchment management; water resources management committees have been established in all the 30 Districts of the country, as provided for by the 2008 Water Law and these are closely working with water users association in agriculture as well as domestic water supply. However, the level of operationalization of these committees is still low mainly due to financial limitations.
   Initiation of catchment-based water resources management approach was adopted in the 2011 National policy for water resources management but unfortunately not captured in the 2008 Water Law. The catchment management Task Forces are being piloted in some catchments. The good development is that a draft of the revised water resources management law provides for water resources management committees at catchment level.

c. **Understanding the water balance: Monitoring, modeling and analysis, information management:**
   In terms of understanding water balance and water resources information system; preliminary water balance for all the nine level one catchments have been conducted in 2015, while developing the National water resources management and detailed water balances are now being elaborated for three level 1catchments (Upper Nyabarongo, Lower Nyabarongo and Muvumba) and two level 2catchments (Sebeya and Upper Akagera_1) using WEAP model. As far as the water information system is concerned, the water resources data based has been upgraded in 2016. (The previous database (Aqualium) was an access based data base and the new one being used is a web based called Aquarius). In the same connection, a web based water permit system has been elaborated and it is now operational.

d. **Water security through efficiency and conservation:** In terms of water security, there have been a lot of efforts in developing water storage systems over the recent past years like dams, valley dams, ponds and roof top rainwater harvesting. Assessment of water storage per capita conducted in 2015 has revealed that the artificial water storage per capita in Rwanda is around 6.8 m^3. In the same connection, a National rainwater harvesting strategy is being elaborated.

4.3.4. Vulnerabilities and adaptation of infrastructure sector

4.3.4.1. Vulnerabilities and adaption of Transport infrastructures

According to the recent assessments, about 45% and 39% of paved and unpaved national roads in 2015 are exposed to landslides, respectively. These figures correspond respectively to 553 km of paved national roads and 691 km of unpaved national roads. In addition to this, 74% of district roads are also exposed to landslides (MIDIMAR, 2015). In addition, the majority of road network in Rwanda were considered unprepared for current weather events which could be worse for the future variations due to climate change(GoR, 2011a).The estimated total economic loss due to road landslide exposure is equivalent to 54.54 billion Frw (MIDIMAR, 2015). The Figure 4.30 below illustrates the potential economic losses due to the landslide exposure.

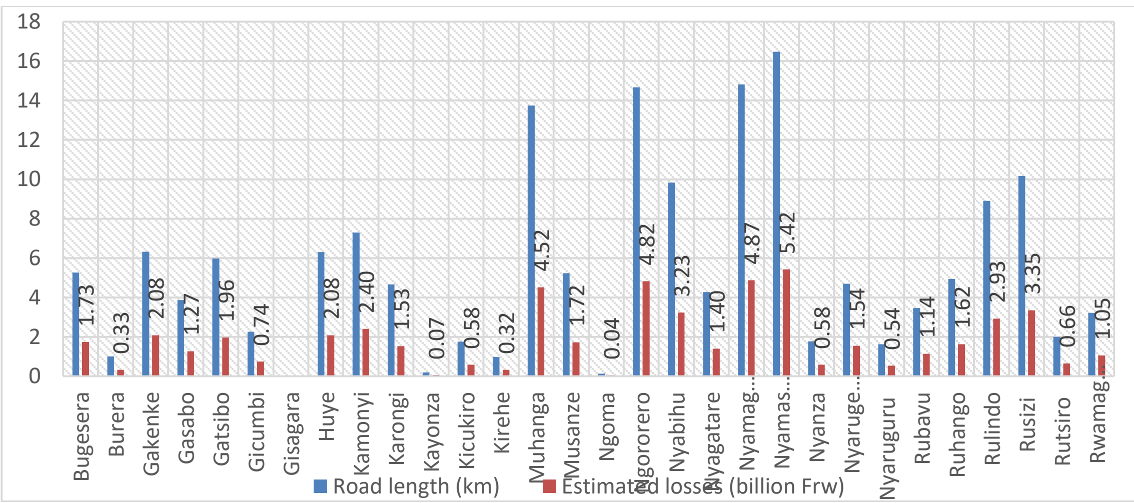


Figure 4.30 Potential economic losses associated to road landslide exposure in Rwanda (MIDIMAR, 2015)

Floods also become potential threat to the transport infrastructure.Historically, in 1988, 1997, 2006, 2007, 2008 and 2009 floods occurred with various impacts including human deaths and damages to infrastructures. The Table 4.22 below gives a highlight of some historical flood-related damages that happened in some parts of Rwanda

Table 4.22 Historical floods and infrastructure damages

Date	Infrastructure	Region
6-9 May 1988	19 bridges destroyed 7 roads cut off	Ruhengeri, Kibuye, Gisenyi, Gitarama and Gikongoro
21 November 2000	Roads damaged	Gisenyi
6 October 2008	Bridges and roads destroyed	Western and Northern province

Source: (MIDIMAR, 2015)

In the future, most existing transport infrastructures will undergo climatic conditions that are expected to differ to those for which they have been constructed. Thus, in transport sector, the following adaptation actions are recommended and are classified as high priority interventionsin their descending order:

1. Integration of climate information in transport infrastructure planning and design
2. Catchment management / IWRM
3. Institutional capacity development on adaptation mechanisms
4. Application of climate adapted material and technologies
5. Regular maintenance and upgrading of road and drainage infrastructures (Improved transport infrastructure)
6. Real time awareness and intervention during transport failure.

4.3.4.2. Vulnerability and adaption in housing infrastructures

The built environment sector is frequently affected by a number of climate change-related hazards. These include landslides, heavy rainfall, winds and storms, floods, etc which destroy houses and properties across the country. Figure 4.31shows how the building sector is highly affected by the landslides. However, it should be noted that the loss of life, health injuries and damage of households equipment's were not counted in this estimate, thus this is the lowest economic estimate of the landslide impact. Therefore, climate change impacts could worsen the mentioned losses.

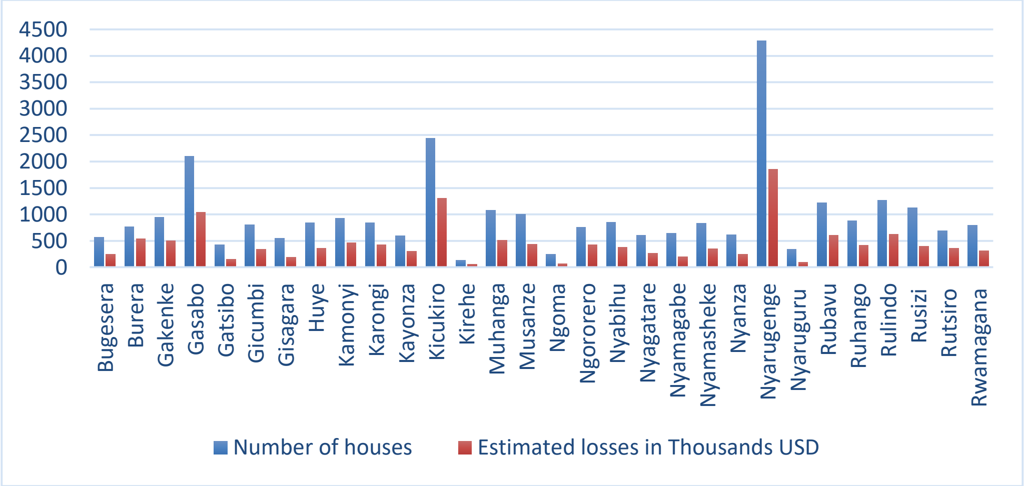


Figure 4.31 Number of vulnerable houses to landslides and their potential monetary losses Source: adapted from (MIDIMAR, 2015)

Plate 1: Floods on 8th May 2016 in Gakenke district, Rwanda. (Photo courtesy MIDIMAR)

The built environment in Rwanda comprises with infrastructures which are generally threatened by a number of vulnerabilities that slightly differ in urban and rural area. Due to the high concentration of informal settlements in the urban centres like Kigali City, the urban infrastructures are generally threatened to the runoff and landslides that obstruct rain water channels with gravels, soils and other materials that destroy roads and houses built with easily broken materials. Considering the rural area, a situation analysis that was conducted by RHA through the country focusing on areas that have been affected or prone to heavy rains, winds and storms has identified the following main causes for the destruction of houses in rural areas (RHA, 2012):

- Inadequate enforcement of building control regulations at local levels;
- Inadequate technical know-how in terms of house construction;
- The magnitude of heavy rains with wind and storms;
- Lack of awareness of people;
- Settlements in high risk zones;
- Weak construction materials;
- Lack of drainage system to evacuate rain/roof water.

ADAPTATION MEASURES

Climate change is expected to put increasing burdens on the community and its supporting infrastructure in the future decades. In recent years, the government of Rwanda has made different intervention to promote safe, suitable and well-kept building infrastructures as well as services which has positively contributed to the national socio-economic development. In this regards, a number of building documents have been developed such as design manuals for construction, guidelines, codes and standards including the “Building control regulations” and “policies concerning human settlement, Urban housing and construction in Rwanda”(RHA, 2012).

In the housing sector, the following climate change adaptation measures were given high priority, in descending order, for Rwanda:

a. Mapping of vulnerability areas before construction
b. Preventing construction on unsuitable sites, such as flood plains and steep slopes
c. Developing green model cities
d. Establish climate resilient infrastructure
e. Establishment of early warning system for disaster response plans
f. Relocate households from high risk zones
g. Buildings erected for housing.

In order to reduce the vulnerability of transport infrastructure and housing sectors, different measures were selected and ranked. And they are summarized in the Table 4.24 and Table 4.25 below.

Table 4.24 Summary of vulnerability assessment and adaptation to climate change for transport infrastructures

Climate indicators	Expected change by 2050		Performance Indicator	Climate impacts (vulnerability)	Actions to reduce impacts	
	Worst case	Best case			Adaptation measures	Conflicting actions & Solutions
Increasing rainfall	High	Low	Road quality	• More occurrence of flooding episodes, • Soil erosion and landslides in particular for north-west highlands and south-western regions of Rwanda might lead to more destruction of transport infrastructure, • Landslides could occur repeatedly as saturated soils are exposed to increased rainfall, • Flooding that could interrupt traffic wash out the soil and channels that support roads and bridges.	• Catchment management / IWRM • Integration of climate information in transport infrastructure planning and design • Application of climate adapted material and technologies • Regular maintenance and upgrading of road and drainage infrastructures • Real time awareness and intervention during transport failure	• Conflict on land use may occur as water catchmentare located in lands exploited by the community who also want to use the land for different purposes • The main solution will be to increase the understanding of the community and their employment during the implementation of adaptation measures
Storms (strong wind, thunder or heavy precipitation)	High	Low	Road quality	- Increased flood and landslides that cause damages to bridges, culvert and roads: (i) 45% and 39% of total classified national paved and unpaved roads in the country by 2015 could be damaged by landslides (ii) 74% of the total length of classified district roads by 2015 in Rwanda could be damaged by landslides - Temporary closure of roads which negatively affect the economy	• Integration of climate information in transport infrastructure planning and design • Catchment management/ IWRM • Institutional capacity development on adaptation mechanisms • Application of climate adapted material and technologies • Regular maintenance and upgrading of road and drainage infrastructures	• Many water catchments are located in lands exploited by the community who also want to use the land for different purposes. • The community involvement and capacity building during the implementation of adaptation measures could address the conflict

Climate indicators	Expected change by 2050		Performance Indicator	Climate impacts (vulnerability)	Actions to reduce impacts	
	Worst case	Best case			Adaptation measures	Conflicting actions & Solutions
					(Improved transport infrastructure) • Real time awareness and intervention during transport failure	
Decreasing rainfall combined with days with extreme rainfall	High	Low	Road quality	• The days with extreme rainfall intensities may result in flooding, soil erosion and landslides leading to the destruction of buildings and road infrastructure • Increased damage to rural transport facilities, including feeder roads	• Regular maintenance and upgrading of road and drainage infrastructures (Improved transport infrastructure) • Real time awareness and intervention during Catchment management/ IWRM (introduction of buffer zones) • Institutional capacity development on adaptation mechanisms • Integration of climate information in transport infrastructure planning and design • Application of climate adapted material and technologies	• Buffer zones may reduce arable lands • Compensation policy for the land owner could solve the community conflict • transport failure •
Temperature	High	Low	Road quality	-Higher temperatures may cause asphalt pavement on roads to soften and expand -Thermal cracks formation in concrete -Increase in dust emissions from non-asphalt roads -Increased number of days with extreme temperature could lead to enhanced asphalt deterioration	• Application of climate adapted material and technologies • Integration of climate information in transport infrastructure planning and design	• Increased operational cost through road building and maintenance may increase the cost of transport services and essential goods which negatively affect

Climate indicators	Expected change by 2050		Performance Indicator	Climate impacts (vulnerability)	Actions to reduce impacts	
	Worst case	Best case			Adaptation measures	Conflicting actions & Solutions
				-Increasing costs for road maintenance and building	• Institutional capacity development on adaptation mechanisms • Regular maintenance of road infrastructures	lower income households • Job creation to lower income households and home grown development programme (ubudehe) during road maintenance activities will be the key solution

Table 4.25 Summary of vulnerability assessment and adaptation to climate change for housing infrastructures

Climate indicators	Expected change by 2050		Performance indicator	Climate impacts (vulnerability)	Actions to reduce impacts	
	Worst case	Best case			Adaptation measures	Conflicting actions & Solutions
Increasing rainfall **Storms (strong wind, thunder or heavy precipitation)**	High	Low	Quality of building infrastructure	• More occurrence of flooding episodes that inundate buildings triggering damage to infrastructure • Soil erosion that polish foundations and landslides in particular for north-west highlands and south-western regions of Rwanda might lead to more destruction of housing infrastructure • Landslides could occur repeatedly as saturated soils are exposed to increased rainfall • Unplanned clustered rural housing and unplanned urban housing could be the mainly affected by storms	• Mapping of vulnerability areas before construction • Preventing construction on unsuitable sites, such as flood plains and steep slopes • Developing green model cities • Establish climate resilient infrastructure • Establishment of early warning system for disaster response plans • Relocate households from high risk zones	• The population possess the land recorded as unsuitable sites for construction and they may resist the expropriation to a better place due to family tight. • Appropriate land compensation measures should be used • Increase the good understanding of the adaptation measures to the community • off farm jobs creation
Decreasing rainfall combined with days with extreme rainfall	High	Low	Quality of building infrastructure	• The decline in mean rainfall may reduce the water supply for domestic use • Extreme rainfall causes soil erosion that polish foundations and lead to building destruction	• Developing green model cities (with rain water harvesting at household level) • Mapping of vulnerability areas before construction • Preventing construction on unsuitable sites, such as flood plains and steep slopes	• The population possesses the land recorded as unsuitable sites for construction and they may resist the expropriation to a better place due to family tight.

Climate indicators	Expected change by 2050		Performance indicator	Climate impacts (vulnerability)	Actions to reduce impacts	
	Worst case	Best case			Adaptation measures	Conflicting actions & Solutions
				• Floods may inundate buildings triggering damage to infrastructure • Building destroyed by heavy rain, flood and landslides during the extreme rainfall events	• Establish climate resilient infrastructure • Establishment of early warning system for disaster response plans • Relocate households from high risk zones	• Appropriate land compensation measures should be used • Increase the good understanding of the adaptation measures to the community • off farm jobs creation
Temperature	High	Low	Quality of building infrastructure	• Higher temperatures may cause thermal cracks formation in concrete • Reduction in domestic water supply • Increased use of air conditioning in public building • Building covered with dusts and increased corrosion of roof made in steel alloys • Increasing costs for building maintenance	• Developing green model cities (with rain water harvesting at household level • Establish climate resilient infrastructure and promote designs that allow natural aeration and optimization of air conditioning (green buildings) • Mapping of vulnerability areas before construction	• Complex issues of water supply could also affect green model cities • In order to cope with this, rainwater harvesting and wastewater reuse need to be considered to maximize the resulting economic and social wellbeing

4.3.5. Vulnerabilities and adaptation of Biodiversity and Tourism sector

4.3.5.1. Vulnerabilities of Biodiversity

Climate change is affecting both physical habitats and species from various Rwandan ecosystems. Eastern ecosystems are the most exposed to the prolonged droughts which affect plant species and reduce the availability of food and water for herbivores which dominate the animal population of the Akagera National. The Nyungwe National Park ecosystems, and a number of ecosystems located in Congo-Nile region are vulnerable to landslides. Indirectly, climate change affects the remaining ecosystems due to increased human activities resulting in deforestation for firewood and agricultural activities.

A study to establish a national list of threatened terrestrial ecosystems and species in need of protection in Rwanda (REMA, 2015c) identified ecosystems and species that are vulnerable using the IUCN Red List Categories. The results indicated that majority of natural forests, animal and plant species are critically endangered. The tables 4.26, 4.27, 4.28, 4.29, and 4.30 document on lists of natural forest ecosystems, plant, birds, mammal and reptiles species that are threatened.

Table 4.26 Rwanda natural forest ecosystems classification into IUCN Red List categories (REMA, 2015c)

#	Ecosystem name	District	IUCN Threat category
1	Akagera National Park	Nyagatare, Gatsibo, Kayonza	Endangered
2	Busaga National Forest	Muhanga	Critically Endangered
3	Dutake Natural Forest	Karongi	Critically Endangered
4	Gishwati Natural Forest	Rutsiro, Ngororero, Nyabihu	Critically Endangered
5	Ibanda-Makera Forest	Kirehe	Critically Endangered
6	Karama Natural Forest	Bugesera	Critically Endangered
7	Karehe-Gatuntu Natural Forest Complex	Karongi	Critically Endangered
8	Kibilizi-Muyira Natural Forest	Nyanza	Endangered
9	Mashoza Natural Forest	Mgoma	Critically Endangered
10	Mashyuza Natural Forest	Rusizi	Collapsed
11	Mukura Natural Forest	Rutsiro & Ngororero	Critically Endangered
12	Muvumba natural Forest	Nyagatare	Endangered
13	Ndoha Natural Forest	Karongi	Collapsed
14	Nyagasenyi Natural Forest	Kirehe	Critically Endangered
15	Nyungwe National Park	Karongi, Nyamasheke, Rusizi, Nyamagabe, Nyaruguru	Endangered
16	Sanza Natural Forest	Ngororero	Collapsed
17	Volcanoes National Park	Nyabihu, Musanze, Burera	Critically Endangered

Table 4.27 List of threatened plant species and their location in Rwanda (REMA, 2015c), and climate change vulnerability information (Carr et al., 2013)

#	Species name	Threat category	Location	Climate change vulnerable?
1.	*Blighia unijugata*	Critically Endangered	Karama, Mashoza, Ibanda-Makera	Not assessed
2.	*Lobelia mildbreadii*	Critically Endangered	VNP, NNP swamps	Not assessed
3.	*Nymphaea thermarum*	Critically Endangered	Springs of Mashyuza	Not assessed
4.	*Osyris lanceolata*	Critically Endangered	ANP, Karama,Kibirizi-Muyira	Not assessed
5.	*Pterygota mildbraedii*	Critically Endangered	Mashoza	Not assessed
6.	*Vernonia auriculifera*	Critically Endangered	Gishwati	Not assessed
7.	*Xyris vallida*	Critically Endangered	NNP, VNP, Rugezi	Not assessed
8.	*Acacia kirkii*	Endangered	ANP, Umutara	Not assessed
9.	*Afrocanthium lactescens*	Endangered	Karama, Umutara	Not assessed
10.	*Albizia amara sercocephala*	Endangered	ANP, Karama, Nyagatare, Kayonza	Not assessed
11.	*Bersama abyssinica*	Endangered	NNP, VNP, Gishwati, Busaga	Not assessed
12.	*Caesaeria runsorica*	Endangered	NNP, Gishwati	Not assessed
13.	*Chassalia subochreata*	Endangered	NNP, Busaga, Gishwati	Not assessed
14.	*Commiphora africana*	Endangered	ANP, Karama, Kibirizi	Not assessed
15.	*Dombeya torrida*	Endangered	NNP, VNP, Busaga, Gishwati, Cyamudongo	Not assessed
16.	*Entandrophragma excelsum*	Endangered	NNP, Cyamudongo, Ruhande	YES
17.	*Erica johnstonii*	Endangered	NNP, VNP, Dutake	Not assessed
18.	*Harungana montana*	Endangered	NNP	Not assessed
19.	*Ixora burundiensis*	Endangered	NNP	Not assessed
20.	*Kigelia africana*	Endangered	ANP, Karama	NOT VULNERABLE
21.	*Lindackeria kiwuensis*	Endangered	NNP	Not assessed
22.	*Mimulopsis excellens*	Endangered	NNP	Not assessed
23.	*Miscanthus violaceus*	Endangered	NNP & Rugezi swamps	Not assessed
24.	*Newtonia buchananii*	Endangered	NNP, Cyamudongo	Not assessed
25.	*Ocotea usambarensis*	Endangered	NNP	NOT VULNERABLE
26.	*Pentadesma reyndersii*	Endangered	NNP	Not assessed
27.	*Prunus africana*	Endangered	NNP, Cyamudongo, Mukura	NOT VULNERABLE
28.	*Sterculia tragacantha*	Endangered	Mashyuza, Gahini	Not assessed
29.	*Strombozia scheffleri*	Endangered	NNP, Mukura	Not assessed
30.	*Symphonia globulifera*	Endangered	NNP, Gishwati	YES
31.	*Tabernaemontana odoratissima*	Endangered	NNP	Not assessed
32.	*Zanthoxylum chalybeum*	Endangered	ANP	YES
33.	*Aframomum wuerthii*	Vulnerable	Kamiramzovu swamp	Not assessed
34.	*Dorstenia nyungwensis*	Vulnerable	NNP (Kamiranzovu peat bog & Karamba)	Not assessed
35.	*Lobelia petiolata*	Vulnerable	NNP (Uwasenkoko, Bigugu)	Not assessed
36.	*Myrianthus holstii*	Vulnerable	NNP, Busaga, Gishwati	YES
37.	*Oxyanthus troupinii*	Vulnerable	NNP, Gishwati	Not assessed
38.	*Vaccinium stanleyi*	Vulnerable	NNP (Kamiranzovu, Bigugu, Uwasenkoko), VNP	Not assessed

Table 4.28 List of threatened bird species in Rwanda and where they were observed recently (REMA, 2015c), and those that are climate change vulnerable (Carr et al., 2013)

#	Species name	Threat category	Location	Climate Change Vulnerable?
1.	*Balaeniceps rex*	Critically Endangered	ANP	YES
2.	*Balearica regulorum*	Critically Endangered	Karago, Burera, Kivu, Ruhondo, Kamiranzovu, ANP, Rugezi	YES
3.	*Bucorvus leadbeateri*	Critically Endangered	ANP (Mutumba and Akagera valley)	Not assessed
4.	*Microparra capensis*	Critically Endangered	Kamatana, Murago, Rugezi	NOT VULNERABLE
5.	*Netta erythrophthalma*	Critically Endangered	Karago lake	NOT VULNERABLE
6.	*Palemaetus bellicosus*	Critically Endangered	ANP	Not assessed
7.	*Psittacus erithacus*	Critically Endangered	NNP	NOT VULNERABLE
8.	*Terathopius ecaudatus*	Critically Endangered	ANP	NOT VULNERABLE
9.	*Thalassornis leuconotus*	Critically Endangered	Kamatana valley	NOT VULNERABLE
10.	*Torgos tracheliotus*	Critically Endangered	ANP	YES
11.	*Trigonoceps occipitalis*	Critically Endangered	ANP, NNP	YES
12.	*Ardeola idea*	Endangered	Huye, Nyabarongo, ANP, Kivu	NOT VULNERABLE
13.	*Bradypterus graueri*	Endangered	NNP, Rugezi, VNP, Mukura	NOT VULNERABLE
14.	*Calamonastides gracilirostris*	Endangered	Akanyaru, Nyabarongo, Rugezi	Not assessed
15.	*Laniarius mufumbiri*	Endangered	Akagera, Nyabarongo, Akanyaru	NOT VULNERABLE
16.	*Lybius rubrifacies*	Endangered	ANP, Bugesera	YES
17.	*Necrosyrtes monachus*	Endangered	ANP, Kibuye, Kivumu – Musambira	NOT VULNERABLE
18.	*Neotis denhami*	Endangered	ANP	YES
19.	*Scleroptil levaillantii*	Endangered	ANP, NNP	NOT VULNERABLE
20.	*Serinus koliensis*	Endangered	Akanyaru, Nyabarongo, Kibaya	YES
21.	*Cryptospiza shelleyi*	Vulnerable	Mukura, VNP, Busaga, Gishwati	YES
22.	*Francolinus afer*	Vulnerable	Most areas in Rwanda, ANP	YES
23.	*Francolinus nobilis*	Vulnerable	NNP, Mukura, Gishwati	YES
24.	*Kupeonis rufocinctus*	Vulnerable	NNP	YES
25.	*Numida meleagris*	Vulnerable	ANP, karama, Gako, Ibanda-Makera, Mashoza	NOT VULNERABLE
26.	*Pitta angolensis*	Vulnerable	Akagera, Buhanga	YES

Table 4.29 List of threatened mammals and their location in Rwanda (REMA, 2015c), and those that are vulnerable to climate change impacts in Rwanda (Carr et al., 2013)

#	Species name	Threat category	Location	Climate Change Vulnerable?
1.	*Giraffa camelopardalis*	Critically Endangered	ANP	YES
2.	*Gorilla beringei beringei*	Critically Endangered	Virunga massif	YES
3.	*Loxodonta Africana africana*	Critically Endangered	ANP	NOT VULNERABLE
4.	*Loxodonta Africana cyclotis*	Critically Endangered	VNP	NOT VULNERABLE
5.	*Redunca arundinum*	Critically Endangered	ANP	Not assessed
6.	*Rhinolophus hilli*	Critically Endangered	NNP	NOT VULNERABLE
7.	*Aepyceros melampus*	Endangered	ANP	Not assessed
8.	*Cephalophus nigrifons*	Endangered	ANP, VNP, NNP	Not assessed
9.	*Cercopithecus ascanius*	Endangered	NNP	NOT VULNERABLE
10.	*Cercopithecus hamlyni*	Endangered	NNP	YES
11.	*Cercopithecus l'hoesti*	Endangered	NNP, Gishwati	YES
12.	*Cercopithecus mitis kandthi*	Endangered	Virunga massif, Gishwati	YES
13.	*Cercipithecus mona*	Endangered	NNP	Not assessed
14.	*Colobus angolensis angolensis*	Endangered	NNP	NOT VULNERABLE
15.	*Crocidura lanosa*	Endangered	NNP	YES
16.	*Damaliscus korrigum*	Endangered	ANP	Not assessed
17.	*Delanymys brooksi*	Endangered	NNP	YES
18.	*Equus quagga*	Endangered	ANP	YES
19.	*Hippopotamus amphibious*	Endangered	ANP	YES
20.	*Hippotragus equinus*	Endangered	ANP	YES
21.	*Kobus ellipsiprymnus*	Endangered	ANP	YES
22.	*Lophocebus albigena*	Endangered	NNP	NOT VULNERABLE
23.	*Lophuromys rahmi*	Endangered	NNP	YES
24.	*Oreotragus oreotragus*	Endangered	ANP	NOT VULNERABLE
25.	*Pan troglodytes*	Endangered	NNP, Gishwati	NOT VULNERABLE
26.	*Panthera pardus*	Endangered	ANP, Ibanda-Makera	NOT VULNERABLE
27.	*Phacochoerus africanus*	Endangered	ANP	YES
28.	*Ruwenzorisorex suncoides*	Endangered	NNP	YES
29.	*Sylvicapra grimmia*	Endangered	ANP	NOT VULNERABLE
30.	*Sylvisorex lunaris*	Endangered	NNP	YES
31.	*Sylvisorex vulcanorum*	Endangered	VNP	YES
32.	*Syncerus caffer caffer*	Endangered	ANP, Makera	NOT VULNERABLE
33.	*Syncerus caffer nanus*	Endangered	VNP	NOT VULNERABLE
34.	*Taurotragus oryx*	Endangered	ANP	Not assessed
35.	*Thamnomys venustus*	Endangered	NNP	NOT VULNERABLE

36.	*Tragelaphus scriptus*	Endangered	VNP, NNP	NOT VULNERABLE
37.	*Tragelaphus spekii*	Endangered	ANP, Akanyaru	NOT VULNERABLE
38.	*Cercopithecus mitis doggetti*	Vulnerable	NNP, ANP, Gishwati, Busaga	YES
39.	*Felis aurata*	Vulnerable	NNP, VNP	Not assessed
40.	*Laptailurus serval*	Vulnerable	ANP, NNP, Ibanda, Mukura, Gishwati, VNP, Buhanga	Not assessed
41.	*Potamochoerus larvatus larvatus*	Vulnerable	ANP, NNP, Ibanda	NOT VULNERABLE
42.	*Rousettus aegyptiacus*	Vulnerable	ANP, VNP, NNP	NOT VULNERABLE

Table 4.30 Threatened Amphibians and Reptiles and their location in Rwanda (REMA, 2015c) and their climate change vulnerability (Carr et al., 2013)

#	Species name	Threat category	Location	Climate Change Vulnerable?
1.	*Hyperolius castaneus*	Critically Endangered	VNP, NNP swamps	NOT VULNERABLE
2.	*Leptopelis kalissimbensis*	Critically Endangered	VNP, NNP	Not assessed
3.	*Python sebae*	Endangered	ANP, Bugesera	NOT VULNERABLE
4.	*Xenopus wittei*	Endangered	VNP, NNP (rivers, lakes)	YES

On the contrary of the afore mentioned climate change impacts on terrestrial ecosystems, the aquatic ecosystem biodiversity in Rwanda will face the vulnerability due to heavy rains that are expected to increase temperatures. It is expected that heavy rains will increase the turbidity of aquatic systems, and water contamination will be increased by solid and liquid materials that will be taken by erosion.

To address the above described vulnerabilities, four adaptation strategies are proposed as follows:

Effective conservation of existing biodiversity

Effectively conserving existing biodiversity under uncertain future climatic conditions requires an integrated institutional mechanism that builds on existing capacities and mechanisms. This requires enforcing conservation in protected areas that Rwanda has (Nyungwe National Park, Akagera National Park, Volcanoes National Park and Gishwati-Mukura National Park), and restore the biodiversity and associated degraded patches.

Reduce sources of harm not linked to climate change

Harm not linked to climate change includes human impacts such as habitat degradation including pollution, destruction of natural habitats, overexploitation of species, deforestation, diseases transmission, etc. By removing or reducing these stressors, actions to combat climate change will be more effective by allowing wildlife to enhance its resilience and resistance to above mentioned threats.

Conservation of forest ecosystems and enhance forest cover

Continuing the effort to increase forest cover and sustainable management of forest ecosystems will result into increased habitat for biodiversity.

Mainstreaming climate change into biodiversity policies

Existing biodiversity policies have identified climate change as one of the threats to biodiversity in Rwanda but did not address the activities that can be done to help biodiversity to resist or adapt to climate change. The Conference of the Parties to the Convention on Biological Diversity, at its eighth meeting, highlighted that it is important to integrate biodiversity considerations into all relevant national policies, programs and plans, in response to climate change and develop mechanisms for the implementation of activities that contribute to climate change adaptation. Rwanda as signatory of CBD, must update the biodiversity policies with clear strategies to tackle impacts of climate change on biodiversity. This is also supported by REMA (2014), which recommended the integration of climate change adaptation measures in protected area planning, management strategies, and in the design of protected area systems. The report by USAID (2017a) also indicated that all sectors need to develop climate-smart policies and sector based climate change strategies and more research on impacts of climate change on biodiversity and ecosystems.

Table 4.31 Indicators, vulnerability assessment and adaptation strategies in biodiversity sector

Climate indicators	Expected change by 2050		Performance indicators	Climate impact (vulnerability)	Adaptation options
	Worst case	**Best case**			
Increased temperature + Drought	High	Low	Ecosystem health status	Increased ecosystems degradation, increased deforestation, suppressed vegetation growth, increased wild fire	Increased conservation of protected areas
			Species health	Increased number of threatened species, increased extinction of species, increased migration of species as result of food shortage	Reduce harm not linked to climate change: poaching, deforestation, etc; protect the most threatened species
Heavy rain	High	Low	Species health	Increased death	Introduce veterinary services for wildlife, ex Gorillas doctors.
			Aquatic ecosystem quality	Increased pollution of aquatic ecosystems,	Protect the landscapes against erosion, tree planting

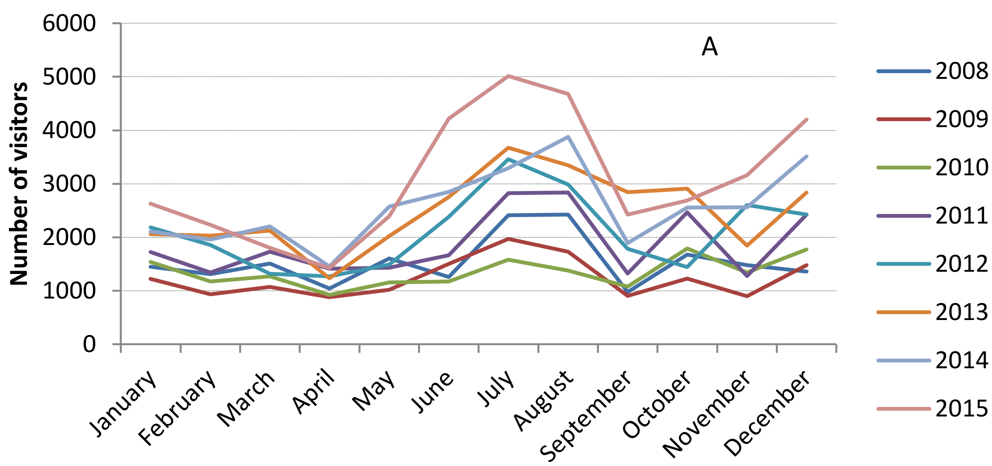
4.3.5.2. Vulnerability and adaptation of tourism sector

Climate change will change the geographical distribution of species (USAID, 2017a), and thus affect the availability of biodiversity that is visited and consequently reduce the satisfaction of tourists. For instance, visits to Gorillas in the VNP pick during June to October (Fig.4.35), and it is known that during dry period of July and August when temperature is highest, Gorillas migrate in the altitudes (McGahey et al., 2013; Musana and Mutuyeyezu, 2011; RoR, 2014), and consequently increasing the distance traveled by tourists. As a consequence,this may discourage tourists with physical fitness challenges (such as the elderly and those with disabilities) to visit gorillas, and therefore tourism revenues will decrease.

It is also indicated that climate change will affect the population of Mountain gorillas by affecting their diet, ranging patterns, water, and their health (McGahey et al., 2013). The climate change impacts on Mountain gorillas will seriously affect the income from tourism because visits to gorillas in VNP contribute to 90% of total national parks revenues.

In the Akagera National Park, increase of temperatures in dry seasons will probably reduce the visibility of game animals and water availability to tourists because wild animals could retreat to places where there is shade (under trees) which could not be close to trails used by visitors. As a consequence, tourists would be less satisfied and probably tourism revenue decreases in a long-term.

Climate change will affect the energy and water supply to tourism hostels, and maintaining quality of such services will be associated with higher costs. Climate change is also expected to impact the infrastructure that is used by tourists: road and buildings. These impacts were also reported by USAID (2017).



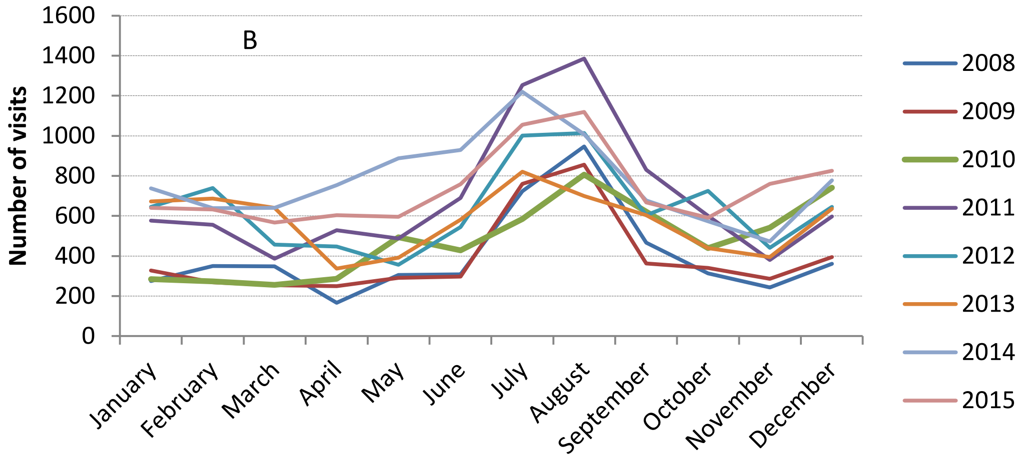


Figure 4.32 Seasonal/Monthly variability of tourism visits to Volcanoes National Park (A) and Akagera National Park (B) from 2008 to 2015

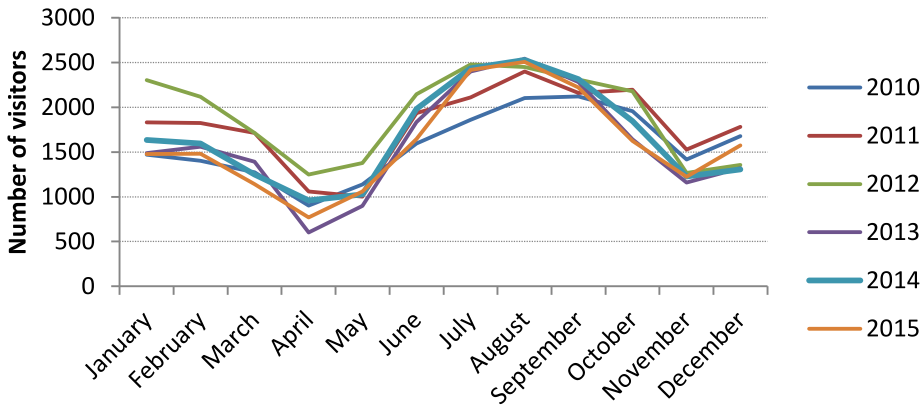


Figure 4.33 Seasonal/Monthly variability of visits to Gorillas in Volcanoes National Park from 2010 to 2015

Statistics of visits to National Parks in Rwanda indicate that the majority of visitors are foreigners: 65.2% foreign visitors, and 9.6% foreign residents. Globally, it is known that climate change will affect negatively the economy of people and reduce saving capacity for tourism activity. The economic crisis due to climate change will most likely affect the statistics of visitors to Rwanda.

Considering the numbers of international arrivals from 2007 to 2014, 38.7% come for business and conferences and 30.8% come for visiting friends and relatives, while 7.8% come for holidays or vacation. Monthly variability of these arrivals for the years 2012-2014 does not show that they are coming in specific seasons (**Figure 4.34**). Therefore, it is uncertain to predict how much climate change or variability in Rwanda will affect the international arrivals for tourism reason.

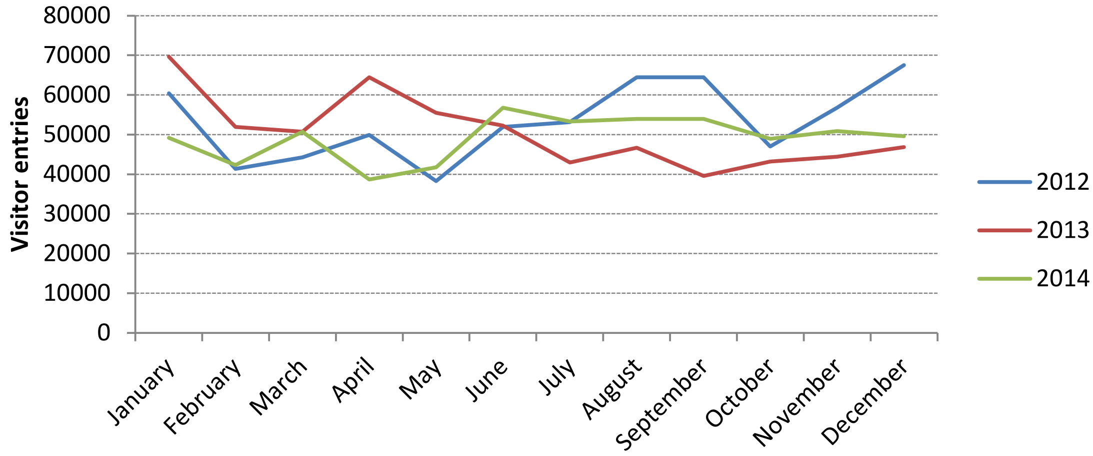


Figure 4.34 Monthly variability of international visitors to Rwanda from 2012 to 2014. Only arrivals that have declared that are coming for visit were considered.

As it is described in the above sections, the tourism sector is likely to be affected by the changes in the species diversity, damage of tourism and transport infrastructure. Therefore, there is a need to propose the adaptation measures to increase the adaptive capacity in the tourism sector. The following are the proposed measures.

Table 4.32 Summary of vulnerability assessment and adaptation strategies in tourism sector

Climate indicators	Expected change by 2050		Performance indicators	Climate impact (vulnerability)	Adaptation options
	Worst case	Best case			
Increased temperature	High	Low	Number of tourists	Reduced number of tourism activities	Redirect tourists away from impacted destination; diversify tourism activities
				Migration of Gorillas to higher altitudes	Change season for visiting; redirect tourist to other tourism destinations
Increased drought				Reduced visibility of savannah animals	Change the season for the visitors

Heavy rainfall	High	Low	Number of tourism operations	Reduced number of tourism operations due to adverse climate which reduce traffic services	Building modern roads, modern or high quality transportation buses
Extreme events	High	Low	Number of infrastructures affected	Storm events affecting hostels and restaurants	Protect buildings with storms; High quality buildings

4.3.6. Vulnerabilities and adaptation of human health sector

Climate change affects the human health. Recent reports have shown the impacts of climate change on human health in Rwanda including the increase in vector borne diseases such as malaria, diarrhea, and respiratory infections, among others. Also, increase in deaths, injuries and malnutrition cases were reported (REMA, 2015a) as the result of climate-related disasters which destroyed houses, and damaged crops and livestock. The following sections describe the vulnerabilities of the health sector:

4.3.6.1. Respiratory infections

The outpatient visits with acute respiratory infections occupied the first rank among all outpatient visits to health facilities during the period between 2008 and 2015, with their proportion varying between 25 and 39%. In addition, the mortality rate due to respiratory infections was also high, varying between 4.9 and 12%during the same period (Table 4.33) and children under 5 years were the most affected.

Table 4.33 Total morbidity cases and deaths due to respiratory infections registered in health centers and district hospitals from 2008 to 2015 (MoH)

Year	Morbidity Cases	%	Death (%)
2008	2,197,294	33	12
2010	3,254,778	39	10.6
2011	2,619,761	36	9
2012	1,805,026	21.6	3.4
2013	2,552,814	29	7
2014	2,051,749	25	7.82
2015	3,331,300	26.4	4.9

Analysis of statistics on respiratory infections from 2012 to 2015 indicates that highest outpatient cases were from Gatsibo, Nyagatare, Gasabo, Kirehe, Rusizi and Gisagara districts (Fig.4.35). These districts are known to be in the hottest regions of Rwanda, suggesting that high temperature influence respiratory infections because drought periods correspond to periods with air pollution with aerosols, which infect respiratory tracks. Deaths that occurred in health facilities and due to acute respiratory infections and pneumonia remained almost constant, varying between 677 and 738 deaths. Districts with highest numbers were Musanze, Gicumbi, Ngororero, Gatsibo, and Rusizi.

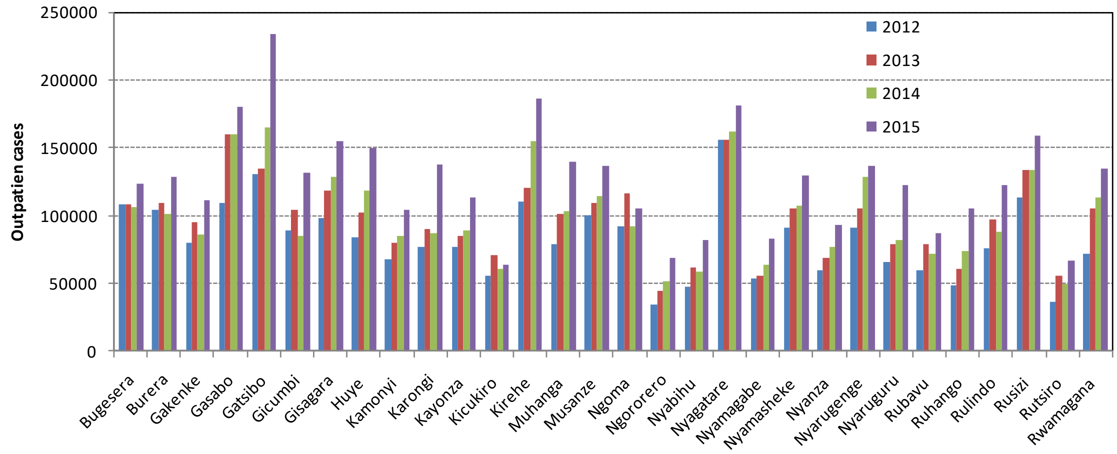


Figure 4.35 Statistics of outpatient visits with respiratory infections (all types combined) from 2012 to 2015 in all districts.

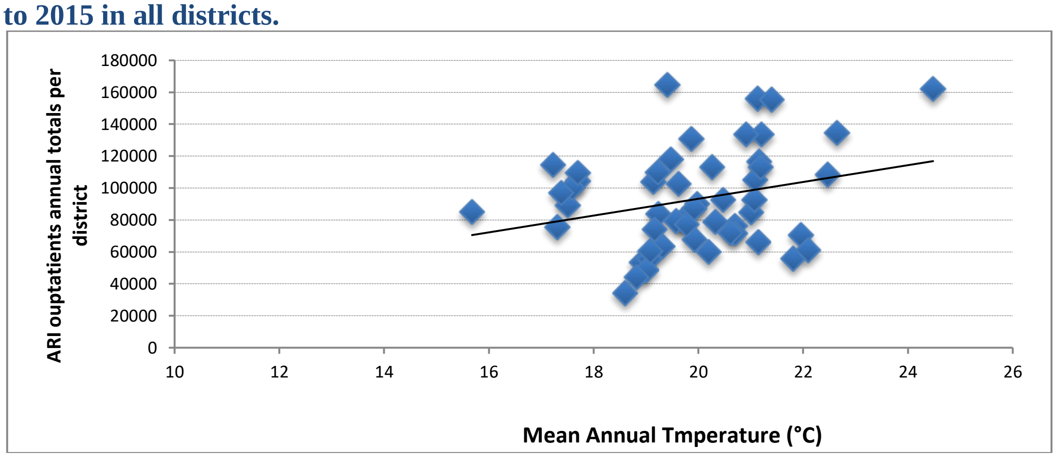


Figure 4.36 Relationship between mean annual temperature and total outpatient visits due to respiratory infections in districts

4.3.6.2. Malaria

Malaria is the second cause of outpatient visits to health facilities, its morbidity was 37.5% in 2005 and decreased to 7.6% in 2012 as a result of health interventions against malaria, but it increased again to 11% in 2013 and 20.1 in 2015 (**Figure 4.38).**

Studies and Statistics (Bizimana; MoH) have shown areas prone to high temperature to be the hotspots of malaria. Eastern and some districts in the Southern Province have the highest malaria morbidities (>12%) with some areas having higher than 50% malaria morbidities**.** In 2015, eleven districts were considered high malaria burden representing 73% of total malaria morbidity in Rwanda. These include Gatsibo, Huye, Ngoma, Nyanza, Kirehe, Kayonza, Ruhango, Kamonyi, Rwamagana, Nyagatare, Muhanga and Bugesera (Fig.4.37). Outpatient visits to health centers due to malaria increased from 2012 to 2015 and increases were highest in Gatsibo, Rusizi, Huye, Kirehe, Ngoma, Nyanza and Kayonza districts where annual total outpatients due to malaria were above 150,000 cases in 2015 (Fig.4.38).

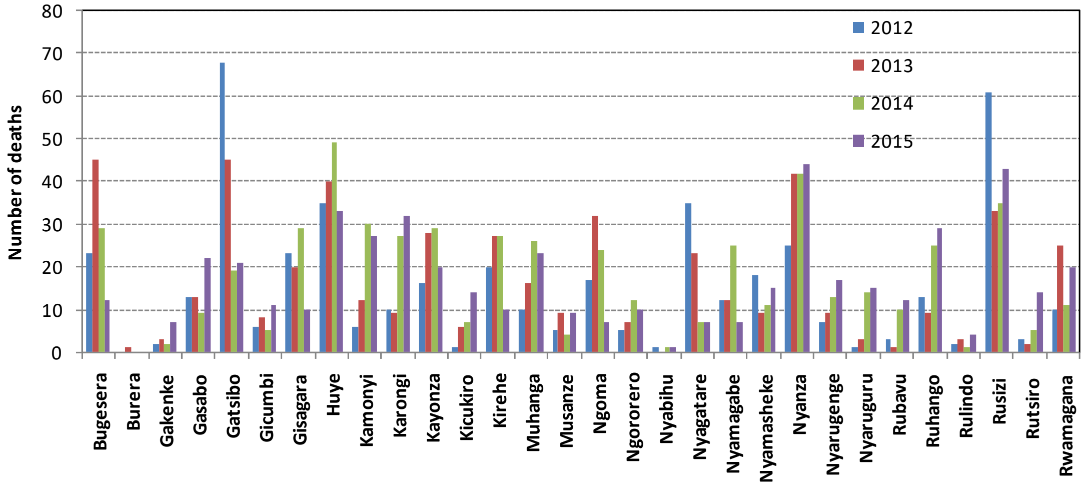


Figure 4.37 Statistics of deaths due to malaria in Rwanda health facilities from 2012 to 2015, presented as annual total per district.

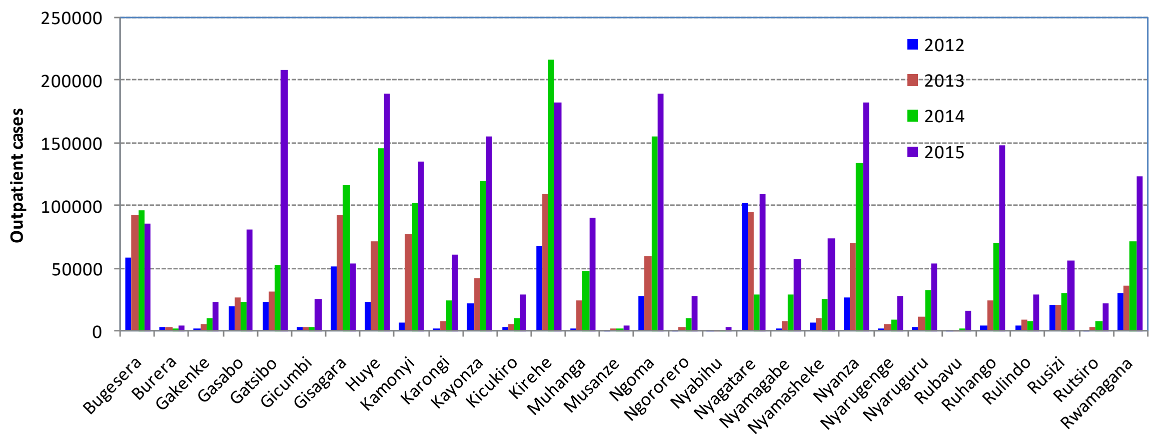


Figure 4.38 Statistics of outpatient visits to Rwanda health facilities due to malaria from 2012 to 2015.

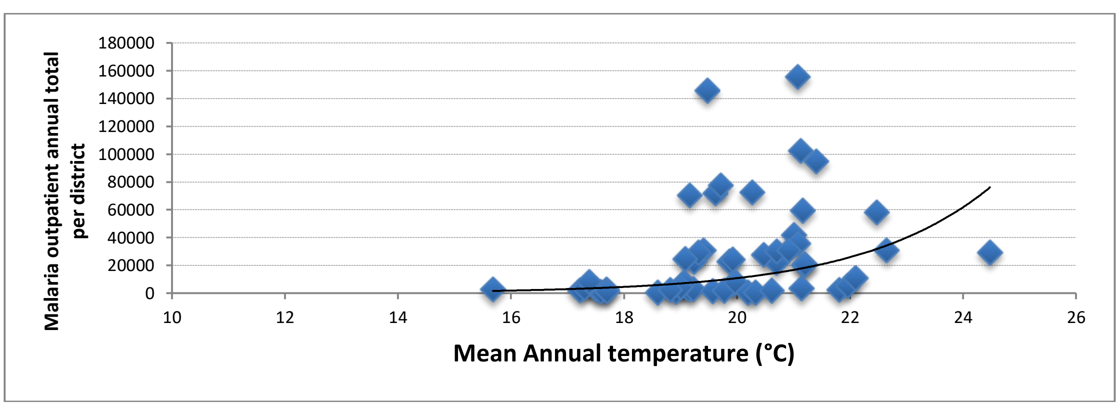


Figure 4.39 Relationship between mean annual temperature and total outpatient visits to health facilities due to malaria for districts in Rwanda.

4.3.6.3. Child mortality

Children are the most vulnerable to climate change-related health issues because their immune system is not well developed when they are under 5 years. In Rwanda, neonatal illnesses constitute the first cause of death, and varied between 13.7% and 41% of all deaths in health facilities between 2012 and 2015 (MoH, 2015a).

In 2010, the main causes of under five deaths in health centers and hospitals were prematurity (23.4%), respiratory infections (15.5%), malaria (10.5), malnutrition (6.9%) and diarrhea (4.8%) (MoH, 2010). In 2014, total number of deaths for children under 5 years in health facilities was 3,722, and the most frequent cause of death was neonatal illnesses with 70% proportional child mortality (MoH, 2014). In 2015, in total, 4,315 children less than 5 years died in health facilities, and the main cause of deaths were neonatal illness (39.7%), prematurity (32.7%), congenital anomalies (6%), pneumopathies and respiratory infections (9.7%), and malaria (3.1%) (MoH, 2015a).

4.3.6.4. Food and water-borne diseases

Between 2010 and 2015, outpatient visits to health centers that suffered from intestinal parasites were between 5.7% and 9%, while the proportion of outpatient visits with gastro-intestinal parasites were between 3.1% and 5% of all cases. Proportion of total deaths due to diarrhea diseases is less than 4%. Analysis of cases with diarrhea shows that Gasabo, Kirehe, Nyarugenge, and Nyagatare districts have highest values (Fig.4.40).

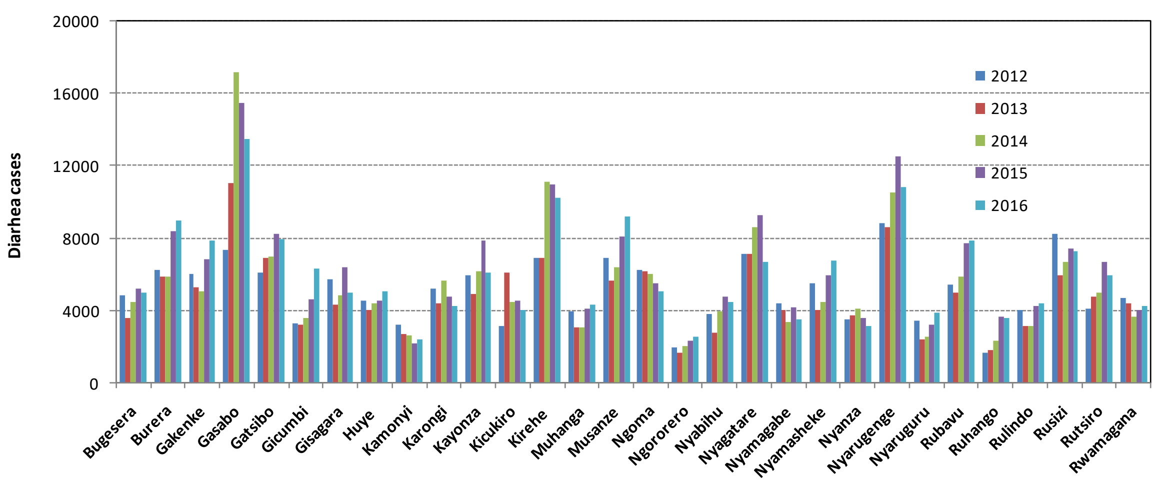


Figure 4.40 Abundance of diarrhea diseases in 30 districts from 2012 to 2016 in Rwanda

With regard to Neglected Tropical Diseases (NTD) such as *Entamoeba histolytica* and *Ascaris lumbricoides*, the most numerous cases of NTD are located in Eastern Province (29%), followed by Southern Province (26.1%), Northern Province (18.8%) and least in Kigali City (10.4%). Figure 4.41 shows the distribution of total outpatients with NTD within 30 districts in Rwanda.

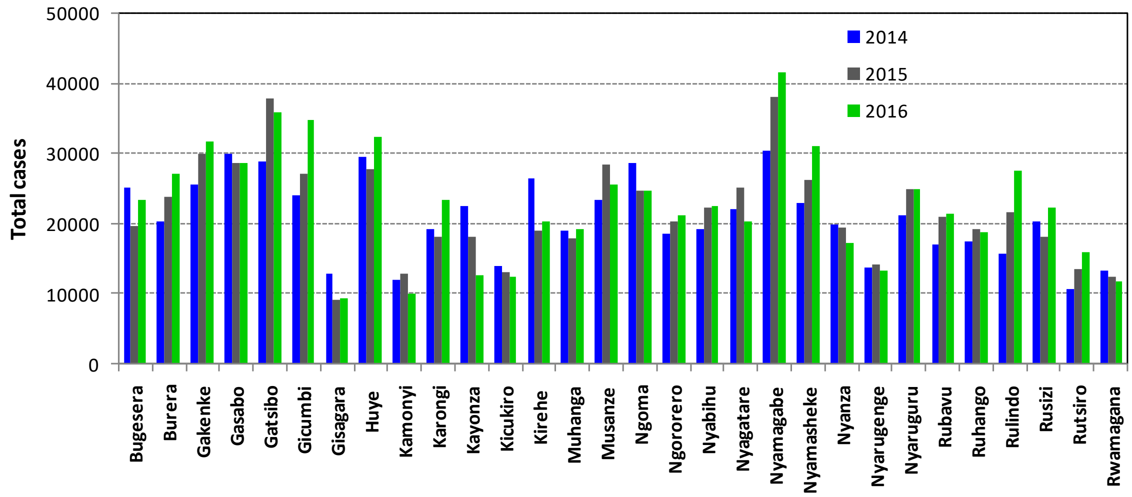


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Figure 4.41 Prevalence of top seven neglected tropical diseases in 30 districts of Rwanda from 2014 to 2016

4.3.6.5. Malnutrition

Malnutrition is associated to climate change as it decreases the agriculture productivity. Table 4.34 shows the statistics of undernourishment rate and deaths between 2009 and 2014 which remained below 3.5% of all deaths in health centers and district hospitals.

Table 4.34 Malnutrition statistics from 2009 to 2014 (MoH, 2010; NISR, 2014) in district hospitals and health centers

	2009	2010	2011	2012	2013	2014
Outpatient malnutrition treatments	75,278	64,583	60,239	24,854		
Hospitalization for childhood malnutrition	1,920	2,136	2,029	26,636	21,697	32,866
Malnutrition deaths	243	166 (192)	133	232	142	323
%	3.4	3.5	1.6	2.3	1.3	2.9

4.3.6.6. Injuries and deaths caused by climate extremes (landslide, flood, drought, storms, etc)

During the recent years, the frequency and severity of natural disasters have increased. Table 4.35 presents numbers of people that have been affected by disasters in Rwanda as reported by REMA (2015b).

Table 4.35 Statistics of population affected by disasters and location in Rwanda (REMA, 2015b)

Disaster type	Year	Population affected	Location
Flood	2007	4000	
		20 people died	Rubavu, Nyabihu
Flood	2008	11,346	
Mass movement	2010	5,937	
Flood	2010	3 people died	Kigali
Flood	2011	3,608	
Flood	2012	11,160	
Storm	2011	9 people died	Karongi, Nyaruguru, Gicumbi
		6 people injured	Gatsibo
	2012	20 people died	Kirehe, Nyamagabe, Rubavu, Huye, Rusizi, Kicukiro, Bugesera, Gicumbi
		1 person injured	Gasabo
		1,804 houses destroyed	
	2013	28 people died	Rubavu, Burera, Gasabo, Musanze, Nyabihu, Nyagatare, Nyarugenge, Rusizi
		47 people injured	Bugesera, Burera, Nyabihu, Nyagatare, Ruhango, Rulindo, Rwamagana,
		3,190 houses destroyed	
Landslide	2006	24 people died	Kigali
	2011	25 people died	Ngororero, Nyabihu, Gasabo, Nyamasheke, Burera
	2013	35 people died; 18 people injured	Gasabo, Nyarugenge, Rutsiro, Rulindo, Gakenke, Gicumbi, Burera, Rubavu, Karongi
Drought	Mar-Sep 2006	1,011,200 people affected	

To address the vulnerabilities of health sector to climate change, different strategies are summarized in Table 4.36.

Table 4.36 Indicators, vulnerability assessment and adaptation strategies in health sector

Climate indicators	Expected change by 2050		Performance indicators	Climate impact (vulnerability)	Adaptation options
	Worst case	Best case			
Increased temperature + rainfall	High	Low	Number of people affected by diseases	Increases in number of people affected by vector-borne diseases, water borne diseases, food-borne diseases,	Increased vector control, increased sanitation, improving health care services, improving accessibility to health care services, monitoring of food-borne and waterborne diseases

			Number of deaths	Increased number of deaths, or children died due climate sensitive diseases	Increased childcare services, increased healthcare services
Decreased rainfall + Increased temperature	Low	High	Number of people affected	Increased malnutrition cases	Improved nutrition services
Increased heavy rainfall and climate extremes	High	Low	Number of people affected	People died or injured by landslides, storms, floods, etc	Increased disaster risk management
Increased temperature, increased drought			Increased air pollution	Increased airborne diseases	Increased healthcare services

4.4 CONCLUSION & RECOMMENDATIONS

- Climate change is real and it is causing the diverse impacts in different parts of the Rwandan territory. A study on climate change trends and scenario reveals a rise in mean annual temperatures and a decrease in number of mean rainfall days in some regions while an increase in heavy rainfall and other extreme weather events were registered in different parts of the country. Different sectors were assessed to be highly vulnerable to these continuous changes. These include energy, agriculture, water resources, infrastructure, biodiversity and tourism as well as health sector. In addition to the current situation, the vulnerability of Rwanda's sectors is projected to increase with the projected impacts of climate change.

- To reduce the observed vulnerabilities from sectoral perspective, and to prepare the country for future climate change impacts, specific adaptation measures were proposed and prioritized. The adaptation measures include policies, strategies and project activities to increase the adaptative capacity of the Rwandan population while reducing sectoral exposure and sensitivity. It was highly recommended that further studies should be conducted to fill the gaps in data from all sectors. This will give more accuracy in assessing vulnerability of those sectors hence more ambitious adaptation measures.

  The recommended further studies in different sectors should focus on the following:

  - Assessment of impacts of climate change on water bodies (lakes, rivers,..) in Rwanda;
  - Conduct a detailed economic losses associated to infrastructure (road and housing) exposures to landslide, flood, soil erosion and windstorm;
  - Conduct study to analyse the linkages between diseased and climate change, socioeconomic and environmental factors;
  - Assessment of impact of climate change on energy generation including hydropower, solar and thermal power plants;
  - Assessment of impact of climate change on energy consumption in buildings (energy end use);
  - Data on agriculture, livestock and forest vulnerability to climate change were not readily available. There should be regular (monthly and annual) documentation of extent and damages of crops, livestock and forests and related social and economic losses (valuation) due to various hazards such as droughts; floods; erosion and landslides; pests and diseases;

  - Inadequate data on national forest coverage which limits the reliability of baseline estimations and projections. The Forestry department should undertake high resolution mapping of forest resources and establish a reliable forest cadastre that would enable easy annual updates;
  - There is also need to conduct a study on the extent of infestation of bronze bug pests and other pests on Eucalyptus plantations in recent years and their impact on yield and economic returns.

CHAPTER 5

OTHER INFORMATION CONSIDERED RELEVANT TOTHE ACHIEVEMENT OF THE OBJECTIVES OF THE CONVENTION

CHAPTER V: OTHER INFORMATION CONSIDERED RELEVANT TO THE ACHIEVEMENT OF THE OBJECTIVES OF THE CONVENTION

5.1. Integration of Climate changes issues into relevant social economic policies and strategies

Integration of Climate change issues implies its mainstreaming into relevant policies, plans, programs, and projects at the national, sub-national, and local scales. It is the mainstreaming of policies and measures to address climate change into ongoing sector planning and management, so as to ensure the long-term viability and sustainability of Sectoral and development investments."

Due to the lack of institutional economic and financial capacity to cope with multiple impacts of climate change, developing countries are likely to be the most affected by climate change despite having contributed least to greenhouse gas emissions. Poorer countries are at risk since they are more reliant on agriculture, more vulnerable to water resource changes, and have less financial, technical and institutional capacity to adapt.

In Rwanda, the Government regards climate change as a serious threat to its development. The existing high rates of land degradation and high dependence on subsistence agriculture, and rapid population growth aggravate the climate change impacts. Thus, integration of climate change issues into relevant social economic policies and strategies is very critical.
However, until recently, little attention had been paid to the risks and uncertainties associated with climate.

Today, there are growing efforts to reduce negative impacts and seize opportunities by mainstreaming climate change into development planning, programmes and budgeting. In this regard, a number of initiatives have been undertaken. Major sectors are integrating climate change in their policies, strategies and plans; awareness raising and Policy direction has triggered climate change integration in developing projects and activities.

5.1.1 Integration of environment and climate change into national planning and budgeting

The vision 2020 describes the issues of global climate change consequences including; flooding, resulting in disasters such as landslides that cost lives and resources, and droughts that adversely affect agricultural output. The climate change effects have had several impact to the development of the country and leads to destruction of social and economic infrastructure as well as environmental degradation. Also, it mentioned the threats to the environment which take the form of depletion of bio-diversity, degradation of ecosystems such as swamps and wetlands and pollution of waterways.

Through vision 2020, Rwanda committed to put in place strategies to mitigate the impact of climate change by focusing on developing eco-friendly policies and strategies in all sectors of the economy and by promoting green growth. Policies and Strategies were developed to facilitate the implementation of these commitments like Environmental Policy, Environmental organic law and Green Growth and Climate Change Resilience.

5.1.2 Integration of Climate change in Agriculture sector

Reliance on agriculture for livelihoods under increasingly unpredictable seasons and extreme weather events such as irregular dry spells and floods lead to crop failure threatening food security, nutrition and livelihoods. The shift in rainfall patterns on the other hand leads to reduction in amounts of rain water harvested therefore affecting both hillside and valley irrigation projects, through either decreased water levels in ponds/dams or high amounts of water destroying dam/pond embankments and causing erosion and silting.

In Rwanda, the country is currently highly vulnerable to climatic variances due to the national reliance on rain-fed agriculture and hydro-power. The challenges and risks to agriculture from climate change are multi-dimensional and complex. The obvious and frequently discussed is ‘increased rainfall variability which can directly affect agricultural production by the shortening of seasonal rains thus reducing crop productivity, particularly if such conditions occur towards the end of a crop cycle when water demand is higher. Climate change causes rising temperatures and is likely to affect rainfall patterns that may result in increased flood and drought episodes. A comprehensive programme to introduce flow control, irrigation and storage is needed.

The impacts of climate change present a new set of challenges in our efforts to reduce poverty and promote social justice. Changing temperatures, erratic rainfall, floods, landslides and droughts all have significant consequences for the livelihoods, health, food security; educational opportunities and the survival of people living in poverty, and of recent first-hand the effects of a changing climate are evident

The resilience of the agricultural systems to climate risks depends on the extent to which they incorporate flexible adaptive and mitigation measures. It is in this regard that the National agricultural policy, strategies and programmes, were designed on the basis of stable climatic conditions. These measures need to be adapted to the risks associated with extreme weather conditions, disruption in seasonal trends and climate variability. The ability to respond adequately to potential climate-related hazards is of critical importance to the success of agricultural programmes and their contribution to national development (REMA, Guidelines for Mainstreaming Climate Change Adaptation and Mitigation in the Agricultural Sector, 2011)

Some actions were suggested to effectively integrate climate change issues into agricultural sector:

- Comprehensive assessments of the risks posed by climate change on agriculture systems and the economy;
- Integrated agricultural environment surveillance;
- Delivery of interventions for the effective management of climate-sensitive agricultural sector concerns;
- Preparedness for, and response to, the consequences of extreme weather events;
- Agricultural and climatology Research;

- Strengthening of human and institutional capacities and inter-sectoral coordination.
- Strong joint monitoring and evaluation on the field for mainstreamed climate change activities in agricultural plans and strategies.

5.1.3 Integration of Climate change in Water sector

The government's core policy objectives for the water supply and sanitation sector are to improve the provision of water, extend the water supply network, and increase access to sanitation services, using means that promote technically and financially viable projects based on strong community participation, as well as to strengthen capacity at both the central government and the district levels.

There is considerable change in behavior and practice with regard to efficient use of water and energy resources. Rehabilitating critical watersheds and protecting water bodies is yielding tangible results in water quality and aquatic ecosystems. Nearly all lakeshores and riverbanks are protected through various programmes.

Climate change was integrated into the National Policy for Water Resources Management. The Policy plans to establish systems and technology to monitor and observe water resources, to understand the water balance and perform water accounting, improve meteorological services, and observe and respond to climate variance and long-term impacts of climate change. To reach this, it provides for strategic actions including:

- Establishment meteorological services to water users, agriculture, industry, and communities to include Early Warning Systems and dynamic information networks;
- Establishment a climate centre of excellence to contribute to water observation and monitoring, and water resource management, planning and decision-making;
- Preparation of water and climate impact risk assessment and hazard mapping as part of District planning and watershed management;
- Establishment of a water information management and custodial framework linking meteorological and climate services, agro-meteorology, water balance monitoring groundwater, supply and abstraction demand.

Climate change adaptation should permeate through from the policy level down to household levels, where the consequences of inaction are most felt. There is need to popularize water harvesting and put in place a national mechanism for water security. Rainwater harvesting strategy has been developed.

5.1.4 Integration of Climate change in Energy sector

Exploitation of energy resources can lead to severe impacts on the environment and may result in greenhouse gas (GHG) emissions known to contribute to climate change. Likewise, climate change can have a severe impact on energy projects. The dominant modern energy source in Rwanda, the hydropower, is likely to be the most directly affected by climate change, because it is sensitive to the amount, timing, and geographical patterns of precipitation and temperature. On the other hand, the National Energy Policy and National Energy Strategy, recognize that the use of biomass energy has potentially serious environmental implications and may be non-renewable unless managed properly.

The policy therefore, proposes more efficient production and use of biomass energy by households and that this should be complemented by promoting other sources of energy, including biogas, peat and promote new and renewable energy technologies through enabling frameworks including feed-in-tariffs. In energy sector, cleaner, cheaper and efficient energy technology diffusion initiatives are helping to arrest deforestation, improve biomass cover, and restore degraded ecosystem.

The climate change measures were integrated in National Energy sector policy. The policy provides to effectively achieve the objectives of environmentally sustainability within energy sector. These objectives focus on elaborating clear planning criteria that influence the prioritization of new energy investments toward environmentally friendly and climate resilient energy infrastructure, promoting technological innovation and transfer, developing stronger national technology standards for energy products and services, and outlining clear environmental guidelines to be used for major energy investments and programs. Guidance toward harmonizing approaches to climate technology transfer and adoption shall be further taken from the EAC Climate Change Policy.

Among the priority actions to achieve this objective include:

- Introducing controls and systems in energy infrastructure planning and design processes to robustly address climate change and disaster risk management;
- Progressively reducing the carbon intensity of the electricity grid through increased investment in and use of renewable energy resources such as micro-hydro, solar, and possibly geothermal power;
- Promoting cleaner fuels and technologies for heating and cooking such as LPG, biogas, and modern biomass technology solutions in both households and institutions as well as more sustainable biomass energy consumption through promoting more efficient charcoal production practices, market transformation activities, fiscal reforms, and smart subsidies;
- Aligning energy strategies to the green growth strategies and integrated infrastructure solutions, especially in secondary cities;
- Pursuing bilateral research and technology development cooperation with other governments and research centers. More proactive efforts to increase the flow of climate finance into low-carbon energy projects ranging from renewable power generation projects to dissemination of improved cook stoves.

According to Rwanda Green Growth Strategy, it is expected that by 2050, development will be achieved with low carbon domestic energy resources and practices, reducing Rwanda's contribution to climate change while allowing it to be independent of imported oil for power generation.

5.1.5 Integration of climate change in Forestry sector

According to FAO, forests have four major roles in climate change: they currently contribute about one-sixth of global carbon emissions when cleared, overused or degraded; they react sensitively to a changing climate; when managed sustainably, they produce wood fuels as a benign alternative to fossil fuels; and finally, they have the potential to absorb about one- tenth of global carbon emissions projected for the first half of this century into their biomass, soils and products and store them in perpetuity.

Over the last half a century, Rwanda lost more than half of its natural forest estate to deforestation, as population growth increased and the area under agriculture expanded. With this, the resilience and ability of ecosystems to provide productive and climate- regulation services declined considerably. For this reason, the Government of Rwanda has embarked on a number of programmes to restore the forest estate through national interventions and private sector initiatives in carbon marketing. In this regard, climate change mitigation strategies in the forestry sector include extending carbon retention in harvested wood products, product substitution, and producing biomass for bio-energy.

The forestry policy was established with specific objectives including:

- To encourage the participation of private sector to invest in the forest sector for poverty reduction, employment creation and improvement of livelihood through sustainable use, conservation and management of forests and trees;
- To contribute to sustainable land use through soil, water and biodiversity conservation, and tree planting through the sustainable management of forests and trees;
- To strengthen the participation of communities and other stakeholders in forest management to conserve water catchment areas, forest biodiversity and ensure sustainability of the forest sector;

This forestry policy is expected to facilitate achievement of targets set respectively in EDPRS and the Vision 2020 in terms of increased forest cover. In this context, national forest cover will be brought to 30%of total area equivalent to 790,140ha of forests in year 2020.

5.1.6 Integration of climate change in Land Use

Integrated land use planning and water resource management are fundamental for adapting to climate change and preserving biodiversity and ecosystem services. This includes allocating land to agricultural activities that will be resilient to future changes in climate.

Irrigation infrastructure is vital for adapting to changing rainfall patterns, particularly changes in the seasons, and is designed to optimize water usage. In Rwanda, the loss of wetlands has been under stress and destruction from agriculture and other productive activities. Increasingly low and unreliable rainfall has caused many farmers to resort to marshlands which have a steady water supply. This has the effect of reduced climate moderation ability and decline ecosystem maintenance, among others.

According to the Agriculture policy, marshlands management and rational use of waters will remain Government priorities. Speculations practiced in the managed marshlands must make good use of investment done. This will imply a reasonable choice of crops economically viable and which respond well to edapho-climatic conditions of the area. Special care shall be taken to conserve ecologically fragile areas in order to conserve the biodiversity there in and to protect areas prone to soil erosion and landslides. The policy takes into consideration the soils and water management needs mainly on erosion control, irrigation under its entire form, collection and utilization of rainwater from farming ends.

5.1.7 Integration of Climate change in Transport sector

The long-term development Vision 2020 assigns fundamental importance to the development of the economic infrastructure of the country, and in particular transportation infrastructure. Transport in Rwanda is taking steps in the right direction, a number of projects are being undertaken in order to reduce the cost of transportation, which has an additional effect to reduce fuel use and emissions.

Mitigation of climate change effects involves transformation of the transport sector, with new efficient technologies, and emergence of climate-sensitive lifestyles to curb GHG emissions. The Government of Rwanda has taken measures to address climate change in the transport sector including:

- Regulating the growth of personal vehicles especially of high emission, old automobiles;
- Set standards for low emissions;
- Strengthen fuel economy technologies (including group transportation systems) and
- Promotion of high efficiency vehicle market penetration.

The climate change was integrated into National Transport Sector policy. Among the priority actions to be implemented, the Transport policy has focused on:

- Promotion of the use of intermediate means of transport and the most efficient vehicles in terms of environmental standards.
- Establishment of regulations and tariffs against pollution emissions from vehicles.
- Establishment of measures focused on the reduction of environmental impact of transport development projects.
- Keeping the population informed and ensure their participation in environmental management in the transportation sector.

5.1.8 Integration of Climate change in Health sector

The impacts of climate change on health arise from the following:

- Climate change effects on ecosystems increase the numbers of people at risk of malnutrition, the geographic range and incidence of vector borne zoonotic, food-and waterborne diseases, and prevalence of diseases related to air pollutants and aeroallergens.
- Climate change-related alterations in the frequency, intensity, and duration of extreme weather events (e.g. heat waves, floods, droughts, and windstorms) affects people, damage public health infrastructure and cause huge economic losses.
- Climate change induces economic dislocation of people and environmental decline, as well as through development setbacks incurred by damage to public health infrastructure and livelihoods.

- Climate change makes it more difficult to control a wide range of climate-sensitive health outcomes. In this regard, health policies have to explicitly consider these risks in order to maintain and improve public health.

The resilience of the health systems to climate risks depends on the extent to which they incorporate flexibility and adaptive management. The Rwanda National health policy and programmes are designed on the basis of stable climatic conditions. According to the Policy, the institutional structures, systems and tools used in the health sector need to be adapted to the risks associated with extreme weather conditions, disrupted seasonal trends and accelerating climate variability. The ability to respond adequately, quickly and effectively to potential climate-related hazards is of critical importance to programme success, as failure to adapt will result in huge costs.

5.2. Environmental technology transfer

5.2.1. Technology needs and need assessment

Technology transfer has been under focus since the Rio Summit in 1992, where issues related to technology transfer were included in Agenda 21 as well as in the United Nations Framework Convention on Climate Change. Environmental technology is defined as a technology that reduces significantly the amount of pollution released into the environment from various human activities.

In the, context of climate change, the environmental technologies refer to all technologies that are used to address impacts of climate change and to reduce greenhouse gas emissions. In Rwanda, different technologies are applied in different sectors but there is need to prioritize the technologies with high impacts. It is in this context that in 2012, Rwanda has conducted the Technology Needs Assessment (TNA) in Energy and Agriculture as sectors with highest vulnerability characteristics to the effects of climate change to identify and analyze technology needs on mitigation and adaptation. In 2018, the TNA will also conducted in Industry and Urbanization as other sectors of great focus of National Strategy for Transformation (NST1).

The 2012 TNA highlighted most appropriate technologies which would support Agriculture and Energy sectors and the country in general, to mitigate or adapt to the effects of climate change. Such technologies became a milestone of environmental sound technology projects and programmes in assessed sectors.

The following table (Table 5.1) summarizes the technologies identified appropriate in Energy and Agriculture.

Table 5.1 Identified technologies in Energy and Agriculture

Mitigation/Adaptation	
Sector : Energy	**Sector : Agriculture**
Small Hydropower	Seed and grain storage
Kivu methane-based CCGT 16	Agro forestry
Geothermal 17	Radical terraces

Biomass-Steam	Drip irrigation
Large Solar PV	Rainwater harvesting
Peat-based IGCC	Integrated fertilizers and pesticide management
Solar CSP	Biotechnology for CC adaptation of crops
Biodiesel (engine internal combustion)	Sprinkler irrigation
ECBM (Enhanced Coal /Peat-bed methane)	
Biogas for thermal applications	

Source: TNA, 2012

In 2015, an assessment of sectoral opportunities for the development of Nationally Appropriate Mitigation Actions (NAMAs) in Rwanda has revealed fifteen (15) potential NAMA opportunities for Rwanda and from the these NAMAs the following technologies can be retained.

Table 5.2 Summarized technologies linked to potential NAMAs in Rwanda

Sector	Mitigation technology	Description
Transport	Efficient Integrated Freight Transport System (EIFTS)	Activities for supporting optimal transport and logistics planning, vehicle emission standards, fleet renewal, and other regulatory action
	Bus Rapid Transit (BRT) System in Kigali City	Activities for supporting optimal route and passenger terminals, creation of a BRT corridor and rush hour lanes, vehicle emission standards, fleet renewal, and other regulatory actions.
Waste	Solid waste Landfill Gas (LFG) utilization;	The extraction and utilization of Landfill Gas (LFG) for power generation in connection to the development and implementation of semi- or fully- controlled landfills for urban areas
	Solid Waste-to-Energy	The development and implementation of one Waste-to-Energy (WtE) plant servicing the Kigali urban area, including improved solid waste collection
Land Use Land Use Change and Forestry (LULUCF)	Improved Management of Forests	To improving enabling framework conditions, including silvicultural and management support, to increase sector yields.
	New Forest Plantations	To improve forest biomass production, effective forest-agro integration, improve protection
	Sustainable Charcoal Value Chain	Efficient charcoal production using efficient kilns
Housing	Energy for Households (Cook stoves, Lighting, Heaters)	To provide affordable energy sources for both cooking and lighting to the people at the bottom of the energy ladder, resulting in substantial socio-economic benefits including reduced levels of indoor air pollution through the use of efficient or clean cook stoves to the

		people and providing a solar powered LED lighting solution.
	Green City	Integration of low GHG emission models for public transport, green buildings, and walkable cities.
	Integrated Sustainable Rural Development	The creation of a 'Rural Productivity Zone' based on an integrated approach to sustainable rural development. This is coupled with Off-Grid Renewables
Industry	Energy Efficiency Improvement in the Tea / Coffee Sector	To improve the downstream activities in the tea and/or coffee sub-sector in Rwanda. The project intends to achieve the objective by improving the existing tea/coffee production technology and optimizing production routines
	Green or Eco Industrial Park	An industrial park in which businesses cooperate with each other and with the local community in an attempt to reduce waste and pollution, to share resources, and to help achieve sustainable development, with the intention of increasing economic gains and improving environmental quality.
Energy	On-Grid Renewables (Hydro and Solar PV)	The Planning, development and implementation, and operation of new grid connected renewable electricity generation capacity in the form of large scale hydro power plants and solar PV power plants.
	Off-Grid Renewables Hydro and Solar PV	The Planning, development and implementation, and operation of solar PV mini-grids in 100 rural communities. Including the application of Rural Productivities Zones ("RPZ") for increasing the income generating potential.
Agriculture	Scaled up One Cow per poor family	Extension / expansion of the one cow per family programme, into larger scale activities.
	Improved Fertilizer	Focus is on improved lime production through cooperative lime grinding facilities, and reduce or eliminated vertical burning of lime for agriculture

Source: Adapted from Table of NAMA Opportunities, NAMA Sectoral Analysis, p 162

5.2.2 Mechanisms for environmental technology transfer

In Rwanda, Science, Technology, Research, and Innovation capacity has expanded over the years. In addition to indigenous knowledge and technologies acquired and disseminated throughout the country, modern technologies are acquired and transferred mainly from off shores. Technologies are acquired in many ways mainly through bilateral and multilateral cooperation as well as external investments in the country. After 1994, Rwanda has opened for external investments and this catalyzed the transfer of technologies in different sectors.

At policy level, since 2005 the country has a National Science, Technology, and Innovation Policy to support the implementation of the Rwanda's Vision 2020, the Economic Development and Poverty Reduction Strategy(EDPRS), as well as support the achievement of the Sustainable Development Goals (SDGs).The National Commission for Science and Technology (NCST) was also established with the mandate to coordinate and monitor all matters related to science, technology, research and innovation and also to manage the national research and innovation fund.

In Environment and Natural Resources Sector, one of the mechanisms established to facilitate innovation and technology is Rwanda's Green Fund (FONERWA).FONERWA is a groundbreaking environment and climate change fund established with purpose to be an engine for the next 50 years of green growth in Rwanda, while serving as a touchstone for Africa and the rest of the world. Its strategy is to provide unheralded technical and financial support to the best public and private projects that align with Rwanda's commitment to a green economy. Through Ministry of Environment, Rwanda has been accredited to the Green Climate Fund and this allows developing and transferring some climate technologies.

5.2.3 Capacity building for technology transfer programmes

Capacity building is crucial for technology transfer. Technology capacity building is a cross-cutting issue and individual Ministries and institutions are responsible for capacity building for the sectors under their mandate on new technologies and practices. The capacity building programs include local and international trainings, exchange and coaching programs.

At National level, the Capacity Development and Employment Board was established to advise the Government on the implementation of institutional capacity-building with special focus on priority sectors of the national development and monitor and assess the impact of capacity building activities across different employment sectors.

In environment and climate change, sector REMA trough is department of environmental education and mainstreaming and other technical departments is involved in providing technical trainings, to local and central government staff on environment and climate change. The similar training have been and are delivered to universities lecturers and students; secondary and primary teachers; civil society and special tasks forces like army and national police. In addition trainings on best practices and in awareness rising have been provided to local community such as farmers, business persons, faith based organizations, etc.

5.3. Climate research and systematic observation

5.3.1. Research related to climate

Notwithstanding with the importance of researches to deal with climate change and their effects, they are still limited in Rwanda. Hence, conjugated efforts from all stakeholders are in call to increase the number of researches and publications related to climate change.

5.3.1.1 National systematic observation

All national climate activities, including research and applications, are primarily based on observations of the state of the atmosphere or weather. All analyses require highly reliable observational data received in a timely manner at analysis centres from a sufficiently dense network or other observation source; Currently, Meteo Rwanda has a network of 317 observing weather stations includes manual and automatic.

Table 5.3 below shows the descriptive type of station as well as the number of operational stations that Meteo Rwanda operates.

Table 5.3 The following is the current status of observation systems

Descriptive type of station	Operational
Surface synoptic stations	5
Agro-meteorological stations	9
Climatic stations	75
Rainfall stations	74
Automatic Weather stations	55
Automatic Rain Gauge	100
Weather Radar	1
Automatic Lightning Detector	1

Source: Rwanda Meteorology Agency (Meteo Rwanda)

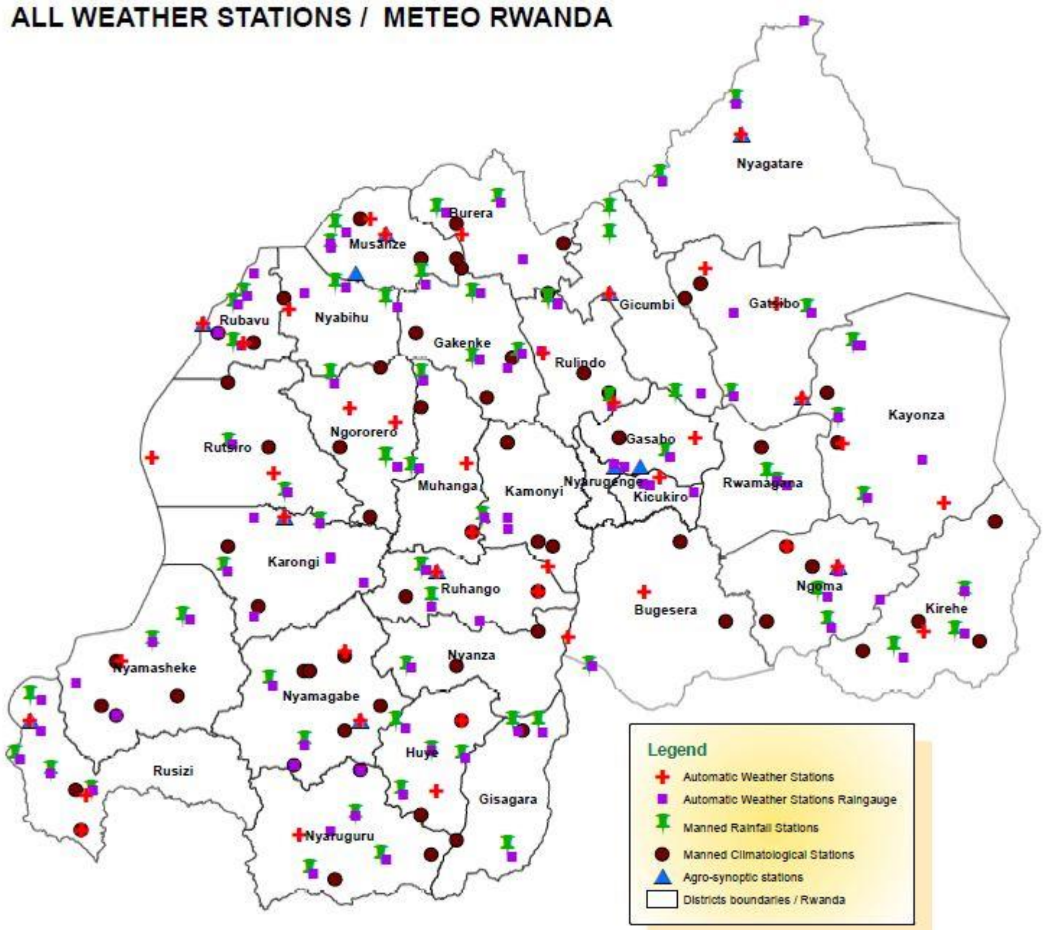


Figure 5.1 Spatial Distribution of both Automatic Weather Stations (AWS) and Manual stations

5.3.2. Recent research on Rwanda climate data

The International Research Institute for Climate and Society (IRI) and partners have been leading an effort to simultaneously improve the availability, access and use of climate information at the national level in African countries. This effort, named “Enhancing National Climate Services (ENACTS)”, has already been implemented in a number of countries in Africa. The foundation of ENACTS is the creation of quality-controlled, spatially and temporally complete climate data set. This involves organization and quality control of station data, and generating historical time series by combining station observations with satellite and other proxies.

This approach has been implemented by Meteo Rwanda to generate over 30 years (1981 to present) of rainfall and over 50 years (1961-2014) temperature time series at decadal (10-daily) time scale and for every 5km grid point across Rwanda.

5.3.3 Data processing and management

Meteorological data collected from manual and automatic weather stations countrywide are checked, managed, processed and archived in Meteorological Databank. Climsoft software is currently used to manage data processing and archiving. It is also used to encode and transmit TDCFs messages to Global Telecommunication System (GTS) via Nairobi Regional Telecommunication Centre (RTC).Currently, the following methods are being used to estimate temperature and rainfall variability.

5.3.3.1. Data access

Historical Meteorological data are accessed free of charge upon presentation of a clear request justifying the utilization of requested data. Data are available in different format (excel spreadsheet, Comma Separated Values (csv) and text).

5.3.3.2 Climate products

Historical meteorological data are used to generate climate products to support other sectors, namely transport (air, marine and road), agricultural, infrastructure, health, environmental and disaster management, climate monitoring, for sustainable development in safe environment.

5.3.3.3 Quality control of Rwanda climate data

Data quality control is a critical component for ENACTS. A significant amount of time is spent on this aspect of the work. Data quality control involves checking station coordinates, identifying outliers as well as checking for the homogeneity of the time series for each station. Currently the number of outliers that are found is relatively small. The homogeneity test revealed some serious problems, particularly with temperature data. These erroneous measurements were either fixed or removed.

Historical rainfall time series in the standard ENACTS approach are generated by combining station observations with satellite estimates for each dekad (ten day period) of each year. However, this approach does not work for Rwanda because of the 15-year gap in observations. Thus, a different approach was needed for Rwanda. The approach adopted removes the mean (climatological) differences (bias) between the satellite rainfall estimate and station data. The mean bias is computed using data between 1981 and 1993. The satellite product used is CHIRP from University of California, Santa Barbara. The generated data are used for the Climate Analysis Map room.

5.4. Education, Training and public awareness

This section covers detailed information on education, training and public awareness activities implemented by the public Institutions and stakeholders to raise awareness for environment management and building resilience to climate change in Rwanda. To promote the integration of environment and climate change issues in the formal and non-formal education and adequate environmental management skills and awareness a department of Environmental Education and Mainstreaming has been established in REMA.

Public awareness and broad national sensitization on environment and climate change has been successfully conducted across the country at central and decentralized levels, and within the private sector, civil society, NGOs, environment clubs, Higher Learning Institutions and schools. Key activities mainly developing and implement a five years strategy of environment education for sustainable development, competitions, creating awareness materials and training modules, integration of national environment/climate priorities and commitments into sector planning, mainstreaming check lists and guidelines targeting planning in sectors and Districts. Trainings for different officials from various institutions have been conducted.

5.4.1 National Education Sector Strategic Plan 2014-2018

This strategy indicates that Sustainable economic growth is dependent upon the quality of the environment and therefore in part on people are understanding of environmental issues and how they engage with their ecosystem. The education sector is influential is raising awareness of environment and climate change and helping to build skills that will help Rwanda achieve sustainable economic growth.

These have been addressed in the new competence based curriculum, to increase understanding of climate change and effective environment management. Opportunities also exist to ensure that the delivery of education is environmentally sustainable, for example including water harvesting systems in school buildings to improve the efficiency of water use and ensure good sanitation, and use of alternative energy sources such as solar panels and biogas (**MINEDUC, Education Sector Strategic Plan 2014 – 2018**).

Also, guidelines of how education for sustainable development can be infused into schools were developed and disseminated to all schools through MINEDUC and Districts. Moreover, best practices in Greening Schools programme and Environmental Education for Sustainable Development (EESD) have been documented and shared with schools for dissemination. A training of trainers on EESD have been organized.

5.4.2 Formal education

In 2015, New Competence Based Curriculum with environment and climate change contents mainstreamed in different subjects was developed and published. It serves as an official document and guide to competency based teaching and learning, and also ensures that there is consistency and coherence in the delivery of education across all levels of general education in Rwandan schools.. Integration of Environment, Climate Change and Sustainability in the curriculum focuses on and advocates for the need to balance economic growth, society well-being and ecological systems.

5.4.2.1 Primary and Secondary schools

Environment and climate change contents were considered as cross cutting contents in all subjects. Many topics were incorporated in Science and Elementary Technology, Social Studies, Geography, Biology, General Studies, Agriculture, Home Science, English, French, Kinyarwanda, Kiswahili, Entrepreneurship, Art and Craft, Economics, ICT, Music, Physics, Chemistry (**REB, Competence Based Curriculum for sustainable development, 2015**). There is a need to train all teachers on the contents related to environment and climate change. Teaching materials, teacher training manual and students reference books will be developed in collaboration with Rwanda Education Board. One tree per child programme has been launched in primary schools.

In secondary schools, many units related to climate change and environment include in the curriculum mainly: climate change in English, Air, wind and sound, Air pollution, Sustainable waste management and Energy management in Science and Elementary Technology, Transforming different wasted articles into craftworks in Creative Arts, Environment impact assessment (EIA) in interpreurnership and Environment and Sustainable Development, Environmentally friendly farming for sustainable food production in General Studies and communication skills.

5.4.2.2. Technical and vocational education

To implement the Green Growth and Climate Resilience Strategy, Technical and Vocational Education and Training (TVET) were expanded to develop skills in energy and water efficiency, renewable energy, agroforestry, passive housing, organic agriculture, waste recycling and Workforce Development Authority (WDA) have been created.

The level of integration of environment, climate change and sustainability into TVETs curricula has been assessed and new contents to address the gap have been proposed. Currently, environment and climate change contents are integrated into complementary module, Health, Safety Security and Environment for level three.

5.4.2.3. Higher Education Institutions

Higher Education Institutions are required to deliver graduates, research, consultancy services and community engagement to support the social and economic development of Rwanda. REMA has planned a continuous programme to train lecturers to enhance the quality and relevance of higher education to respond to local sustainable development challenges. The Management and oversight of Higher Learning Institutions from the central government is, in most cases, from MINEDUC through Higher Education Council which is responsible for ensuring the structure, organization and functioning of higher education institutions, monitoring and evaluating the quality and standard of provision and ensuring the quality enhancement of teaching and research.

Nursing colleges are under administrative control of the Ministry of Health. Lecturers and students have been trained on integration of Education for Sustainable Development into Higher Learning Institutions programmes and plans. REMA supported different HLIs with laboratory equipment for testing water quality. Ministry of Education in collaboration with Rwanda climate observatory project established Masters in Climate Science Program started in 2016, in University of Rwanda, College of Science and Technology (UR-CST) to develop skills in various fields related to climate change and Low Carbon Development. This program has been approved by the Government of Rwanda in 2015 and is offered to East African Community students.

5.4.3 Informal education

Informal education programmes were developed to raise environment and climate change awareness through competitions, debate, public lectures, events commemoration,, field tours and training workshops. A set of trainings on EESD have been delivered to decentralized institutions (District environment and education officers), media and civil society organizations. In collaboration with other institutions and NGOs, REMA has provided technical support (trainers and training manual) to the training and workshops organized in line with environment and climate change. Different social media, TV and radio have disseminated information related to climate change and environment.

5.4.3 Informal education

Informal education programmes were developed to raise environment and climate change awareness through competitions, debate, public lectures, events commemoration,, field tours and training workshops

5.4.4 Greening school programme

In a bid to attract school children in environmental protection and sustainability activities, REMA in collaboration with the Ministry of Education (MINEDUC) and Districts engaged children in hands-on activities, aimed at creating environmental friendly learning conditions at school. Since 2011, greening schools which is a programme working with schools using Education for Sustainable Development (ESD) as a tool for mainstreaming Environment and Climate Change in schools for sustainability within Education system has been implemented.. Countrywide, 191 schools (Nine and Twelve Years Basic of Education)were greened.

Greening schools programme seeks to solve environmental issues facing Rwanda schools, children and adults who spend more time at school. Different activities have been carried out, including but not limited to capacity building targeting students and teachers, tree nurseries making and tree planting, installed water tanks for water harvesting, hygiene and sanitation, activities related to resource efficiency and waste management (REMA, Report 2015).

5.4.5. Environmental clubs

Since 2006, REMA has been involving schools in environment protection activities to equip the youth with necessary skills that would enable them to ensure a sustainable future for our country. Environmental clubs have been established in primary, secondary and higher learning Institution. REMA developed Monitoring and evaluation checklists for environmental clubs activities to ensure that they are active and provide technical support. Clubs in HLIs participated in monthly community work and others have initiated green activities like tree planting in primary and secondary schools and maintenance of water channels.

5.4.6. Training and public awareness

Numerous educational initiatives aimed at creating greater environment and climate change awareness and training programmes to build a future workforce that has the knowledge and skills to protect and restore the country's natural resources and to develop measures for mitigation and adaptation to climate change have been conducted. Trainings for youth, students and NGOs staff, communities and local leaders have been conducted. Public lecturers have been delivered in Higher Learning institutions, schools and Institutions. The EESD strategy considers the media as an important stakeholder in education for sustainable development and awareness creation. REMA works closely with the media to enhance coverage of accurate information in the news, events, programmes and documentaries on topical environmental and climate change issues.

Journalists from different media housed were trained on how to integrate EESD and climate change in Media reporting. Association for Journalists who report regularly on environment and climate change was created. In 2016, The Ministry of Natural resources established Environment and Natural Resource Communication team which report on the environment and climate change. A weekly media review is carried out by the team and an average of 5 articles from national and international newspapers, radio, television are reviewed and reported.

5.4.7. Best Environmental Performance Awards

To raise awareness about environmental sustainability and encourage sustainable practices in all sectors, REMA hands out 'Best Environmental Performance Awards' to deserving entities such as Districts, Community Based Environmental Organizations (CBOs) and media reporters. Merit is based upon their demonstrated progress towards environmental protection and/or climate change adaptation or mitigation. Districts, CBOs and]media reporters received awards (REMA, 2015).

5.5. Capacity building

5.5.1 Capacity building activities at National, Regional and International levels,

To implement the crosscutting issues planned in EDPRSII and Vision 2020, REMA through trainings built capacity of planners from different sector on tools and checklist for mainstreaming environment and climate change into sector strategic plans. Also, District planners and Environment District officers were trained on mainstreaming environment and climate change into District Performance Contracts and District Development plans (DDPs). Local environmental NGOs were equipped with skills to reorient their activities towards the implementation of environment and climate change issues planned in the Vision 2020 and EDPRS II. REMA in collaboration with LVCEEP trained youth in Bugesera and Kirehe on their role in policy advocacy and also empowered them to start up small income generating projects.

They were equipped with skills on agriculture in green house. Station Technical Experts have been given the training by MINEDUC in collaboration with climate observatory project needed to run sensitive scientific instrumentation, perform data analysis and data quality control, and become experts in the field of atmospheric chemistry instrumentation.

AAP and LDCF projects have conducted capacity building to straighten at national, district and community levels to restore and protect ecosystems of national and global importance against potential degradation. The trained cooperatives were equipped with skills to continue the same and similar AAP and LDCF activities, environmental protection, climate change mitigation measures through protection and conservation appropriate technology transfer. The 30% of cooperative members from districts where AAP and LDCF are implemented are female and beneficiated training in order to increase capacity building of local women organizations. Specifically, the training contributed to the amelioration of understanding the linkage between poverty alleviation, environmental management and climate change. Women acquired basic capabilities and self-confidence to counter and challenge existing disparities and barriers against them. They have got knowledge on access to micro-finance services will lead to individual economic empowerment through enabling women's decisions about savings and credit use, enabling women to set up micro-enterprises, and increasing incomes under their control relationship between poverty, environmental degradation and climate change; action plan design of specific activities aiming sustainable environmental management and climate change adaptation towards poverty reduction (UNDP**,** AAP Final Evaluation report, 2013[5]; UNEP,Terminal Evaluation of the Rwanda LDCF Project, 2015[6] **).**

5.5.2. Coordination and sustainability of Capacity-Building activities at National level

Coordination of Capacity-Building activities in environment and natural Resources are under control of Ministry of Natural Resources through REMA. A database of all NGOs involved in environment and climate change has been created and many of them are recorded with their registration certificate from Rwanda Governance Board (RDB). All environmental NGOs are requested to share with REMA the annual action plans and reports. Every year, training for building capacity of staff of these NGOs is conducted by REMA and at least 2 NGOs reported their activities in environment and climate change subsector thematic working Group.

5.5.3. Capacity building gaps

Identified gaps related to climate change, capacity building in programs, policies and strategies are addressed through the efforts and strategies for next actions and steps to be taken to strengthen the implementation of education, technology and research activities related to climate change activities. The capacity building gaps are the following:

1. Lack of basic knowledge on climate data interpretation and provide emergency adaptation strategies by local leaders and farmers;
2. Low level of improved procedures and techniques for issuing warnings to the public, local authorities and emergency services

[5] https://erc.undp.org/evaluation/documents/download/7571

[6] https://wedocs.unep.org/rest/bitstreams/1098/retrieve

3. Insufficient Emergency planning, public awareness campaigns, training, systems improvements and flood risk mitigation at local level;
4. Lack of capacity for responses to climate impact warnings by public, in advance of a flood emergency,
5. Low number of education materials to support climate change issues mainstreamed in the competence based curriculum;
6. Lack of Technical Capacity on Climate change and impact assessment by staff in charge of education and mainstreaming in the Ministry of Natural resources;
7. Shortage of well trained staff at local level which knows the climate change science and dynamics of the climate system to support local authorities and farmers to mitigate and adapt to the impact of climate change;
8. Different Institutions and research companies are working on different aspects of climate change and its impact on various sectors. There is a great probability of duplication of research efforts due to the lack of communication among the researches;
9. Shortage of technical equipment and laboratory facilities as well as the lack of skill of the staff to carry out necessary climate change data analyses;
10. Shortage of academic institutions and programs offering meteorology or climate change science at graduate or post-graduate levels;
11. Lack of national climate change research center for data archived and available for researches.

5.5.4. Capacity building needs

The capacity building needs are the following:

1. Build Capacity of staff of REMA on numerical modeling and climate system dynamics at International organizations to support climate change issues mainstreaming policies, strategies and Districts Development Plans (DDPs);
2. Establishment of National Environment and Climate Change Research Center for climate data archived and available for research. This center should organize the research assignments and research grants should be provided to researchers capable to carry out the given task. Such centres could be universities or existing networks promoting climate change and environment research and information sharing and dissemination;
3. Strengthen capacity building of local authorities to encourage farmers on the importance of using harvested rainwater and modern inputs (improved seeds, pesticides and fungicides) to increase production;
4. Increase climate observation facilities and enhance collection, and compilation of climatic, social and biophysical data;
5. Strengthen information exchange by enhancing technologies transfer and capacities necessary from national to local levels to promote environment and climate change mitigation and adaptation through education and public awareness development.
6. Enhance the ability to gain access to, analysis and effectively use information and knowledge available on climate change and environment.
7. Support Higher Education Instructions and networks for environmental and climate change education. Cross-disciplinary courses could be made available to all students. Existing regional networks and activities and national university actions which promote research and common teaching approaches on sustainable development should be built upon,

8. Promote informal education activities at the local, National, and regional through cooperation and partnership and supporting the efforts developed by NGOs, local entities, media and environmental clubs for informal education;
9. Provide automatic weather station equipment to schools to support teaching and learning of climate sciences in all primary and secondary schools and ensure that teachers are trained on its manipulation;
10. Promotion materials of all kinds and for all audiences should be based on the best available information, including climate change scientific information, adaptation and mitigation measures, existing early warning systems, building climate change resilience by all sectors and climate change technologies;
11. Recognize annually the institution, NGOs, schools and individual persons with excellent participation in climate change adaptation and mitigation implementation in the country;
12. Support University of Rwanda to strengthen the program of Master in Atmospheric and Climate Science, revise it to include the content related to adaptation and mitigation measures and to facilitate this program with scientific equipment and laboratory;
13. Build capacity of media, theatre groups, and entertainment and advertising industries to mobilize their experience in shaping public awareness and increase the active public participation in the climate change adaptation and mitigation debate.
14. To strengthen institutional capacities, to enable staff to meet their environmental climate change objectives mainstreamed in their programs and plans and to facilitate the transfer and assimilation of new environmentally sound and appropriate climate change adaptation technology.

5.6. Information sharing

Rwanda Environment Management Authority (REMA) established an online climate change portal. The portal aims to serve as information hub on climate change in Rwanda and it provides a platform for all climate change practitioners and stakeholders to discuss, network and share climate change knowledge and information.

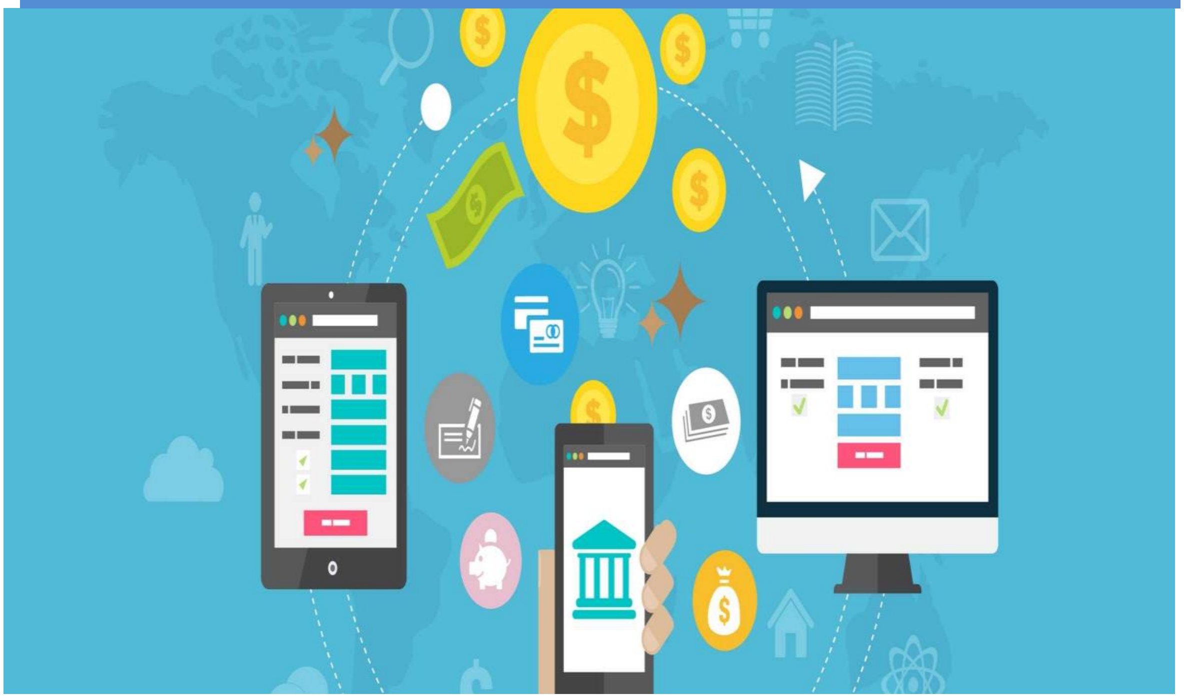
The Portal also aims to encourage more climate change adaptation and mitigation initiatives and innovation by empowering and supporting individuals, institutions, and communities to undertake action. It was established with an objective to raise awareness and promote action on climate change in Rwanda.

In this regard, to keep the portal effective and alive all stakeholders in climate change are invited to contribute to its update by sharing their initiatives, reports and cooperate on studies and events.

The website of Rwanda climate change portal is http://www.rema.gov.rw/climateportal/

CHAPTER 6

CONSTRAINTS, GAPS, AND RELATED FINANCIAL, TECHNICAL AND CAPACITY NEEDS



CHAPTER VI: CONSTRAINTS, GAPS, AND RELATED FINANCIAL, TECHNICAL AND CAPACITY NEEDS

6.0 Introduction

Constraints and gaps for building resilience to climate change identified during climate change activities implementation by different stakeholders including all activities conducted in line with third National Communication are discussed under this chapter. The main gaps were the insufficiency of data for GHG emission Inventory in different sectors, and the constraints are limited financial capacity to mitigate the impacts of climate change and lack of skills and knowledge for local communities to adapt to the climate change impacts. Financial, technical and capacity needs were also discussed and are very important for enabling the country to better respond to climate change issues to increase the resilience and promote green growth.

6.1. Financial constraints, gaps and needs

6.1.1 Financial constraints and gaps

The major financial constraints and gaps for implementing climate activities include the following:

Insufficient funds to ensure effective adaptation strategies

The implementation of climate change activities requires funds coming mainly from public budget. Allocated budget is not enough to fund all climate change activities. More resources from other source like Bilateral and Multilateral Grants are essential to build resilience to climate change. **MIDIMAR (2012)** indicates that the primary source of funding for disaster responses shall come from the local administrations (Districts) in affected areas.When the magnitude of the situation overwhelmed the districts capacity to cope with, the second source will be the next highest level of administration above the affected areas.

Limited budget

It affects the implementation of adaptation and mitigation activities by Districts: The allocation of funds to the activities at the district level has been guided by the priorities set. The budgets that the national government and local authorities have at their disposal for adapting to climate change are limited.

Involvement of private funding of climate change activities

The involvement of private sector in environment and climate change activities is low as their targets are benefits in terms of money. To involve the private sectors into environment and climate change activities implementation, the government of Rwanda has established the National Fund for the Environment (FONERWA) within the Ministry of Environment. FONERWA is limited to providing adaptation and low carbon projects with grant financing and instrumental in leveraging private investment for low carbon initiatives by employing other public financing mechanisms.

The disparity of budget allocations demonstrates at some extent a limited commitment to sectors highly vulnerable to climate change, and subsequent implementation of much needed adaptive activities. Commitment is shown through financial support and engagement in more vulnerable sectors such as agriculture and forest, energy and water sectors. The Ministry of Natural resources (2012) through Environment and Climate Change Sub-Sector Strategic Plan 2013/14 – 2017/2018 indicated that there was a funding gap of approximately Frw 14,211,404,268between funding estimates for sub programmes and budget commitments to the sub-sector (from both the budget and projects).

Table 6.1 List of active development partners in environment and climate change (2013)

Development Partners	Amount(USD)
United Nations	**10,613,499**
Netherlands	**7,758,621**
Sweden	**5,447,118**
UK	**4,013,977**
EU	**2,684,524**
Germany	**1,000,952**
World Bank	**414,151**
Italy	
Total	**31,937,842**

Source: MINICOFIN (2013) OD report 2011/2012

Table 6.2 Funding Gaps

No	Programme outcome	Total 5 Yrs estimates in FRW	Total funds availability	Gap
1	Environment and climate change mainstreaming	4,606,201,886	3987507834	618,694,052
2	Climate Change management	9,333,800,000	3,742,153,186	5,591,646,814
3	Pollution management (Prevention & Control)	6,447,675,060	1,764,942,924	4,682,732,136
4	Environmental research and planning	3,171,568,025	3,066,921,999	104,646,026
5	Environmental governance	9,065,080,859	5,851,395,619	3,213,685,240
	TOTAL	32,624,325,830	18,412,921,562	14,211,404,268
	Gap %			43.6

Source: MINIRENA, Environment and Climate Change Sub-Sector Strategic Plan 2013/14 – 2017/2018, 2012

Furthermore, the budget estimates for the coming period of 2018-2024 shows an increase of the budget (Table 6.3), and this will undoubtedly result into increased gap if partners to not raise their fund according.

Table 6.3 Environmental and Natural Resources sector strategic plan 2018-2024 cost by outcome

S/N	OUTCOME	COST (FRW)
1	Increased sustainability and profitability of forests	31,356,000,000
2	Integrated and sustainable water resources management to maximize reliable, efficient and productive investments	260,783,980,000
3	Integrated and sustainable land management to maximize reliable, efficient and productive investments	10,715,615,800
4	Enhanced reliability of weather and climate services and products for Rwanda's socio-economic development	11,554,280,000
5	Enhanced Environmental management and resilience to climate change	32,366,242,611
6	Vibrant, efficient and responsible mining spurring sustainable economic development	54,666,000,000
TOTAL		**401,442,118,411**

Source: MOE, 2018.

6.1.2 Financial needs

Apart from Government budget for financing climate change activities and reduce the impact of disasters, Bilateral and Multilateral financial support are needed. FONERWA could act as a Public Private Partnership Vehicle and employ public financing mechanisms such as grants, lines of credit, loan guarantees, public venture capital, and equity capital. These mechanisms enable green businesses and consumers to overcome initial investment costs of low carbon technologies, and attract private finance by buying down the risk of low carbon investments.

FONERWA can be accessed by line ministries, Government agencies, Districts, civil society organizations (including academic institutions) and the private sector. At least 20% of total FONERWA resources will be earmarked for the private sector for use across core financing windows (excluding Window 4), and at least 10% of Fund resources will be earmarked for Districts (REMA: 2015).

Key strengths of the FONERWA Fund from a GoR perspective include the national orientation and ownership of the fund. Strengths from a donor perspective include national ownership and an opportunity to pool resources with other donors towards an extra-budgetary climate/environment fund. The primary source of FONERWA financing is bilateral Development Partners who can capitalize the Fund in the short-term (and long-term). DFID Rwanda provided initial seed capital of GBP 22.5 million (**REMA, 2015**). A secondary source is domestic capitalization from the Government of Rwanda. As of January 2014, the GoR has committed counterpart funding of approximately USD$ 3.7 million. FONERWA also seeks to facilitate access to multilateral financing sources, as well as internal and external private sector sources. Towards this, FONERWA has successfully supported the GoR in accessing approximately USD 15 million in external finance, including USD 10 million from the Adaptation Fund, with approximately USD 15 million pending approval from other sources (**REMA: Lessons from National Climate Compatible Development Planning in Rwanda, 2015)**

6.2. Technical and capacity constraints, gaps and needs

The main technical and capacity constraints and gaps identified was the low level of knowledge, skills and awareness of the climate change issues among the national stakeholders. This has led to the absence of climate change aspects from most of the national strategies and policies. Mitigation and adaptation to climate change impacts has to involve a number of government institutions, local NGOs and the private sector. Common objectives and clear roles for each of the stakeholders as well as close cooperation and understanding among are needed to be efficient and successful. Also, the implementation and formulation of mitigation and adaptation action plans cannot be done without cooperative integration of all stakeholders. Climate change programs including long term programs by the sectors, districts and commune institutions are not given sufficient priority in work plans.

For District to translate climate change issues into locally appropriate and adaptive practices and actions, there is a need for better coordinated efforts, well-defined allocation of responsibilities and more effective mechanisms of sharing knowledge. Continuous capacity building for Districts in knowledge, skills, methodologies and measures to support the most affected and vulnerable communities are needed. Coordination between government agencies in climate change, NGOs and Private Sectors should also be enhanced.

There is a need of a detailed integrated process of data gathering and analysis as well as dissemination of data to concerned sectors and stakeholders to incorporate the process into a planning and budgeting. Training and capacity building on mitigation and adaptations measures, disaster preparedness for Districts officials and vulnerable community and mobilization of agencies and resources to enhance the capacity building of the respective ministries and establish disaster preparedness committees at the national and district levels.

Table 6.4 Technical and capacity constraints, gaps and needs

Sector	Technical and capacity constraints and gaps	Technical and capacity needs
GHG Emission Inventory	• To assist in training of experts on national inventory process, climate change mitigation and adaptation technologies as well as raising awareness of the communities on how to mitigate and adapt to climate change. • Provide continuous data collection for GHG Emission Inventory by all sectors according to IPCC 2016 software • Researches and related funds are needed to provide the missing data for instance national emission factors	• To assist in training of experts on national inventory process, climate change mitigation and adaptation technologies as well as raising awareness of the communities on how to mitigate and adapt to climate change • Provide continuous data collection for GHG Emission Inventory by all sectors according to IPCC 2016 software • Researches and related funds are needed to provide the missing data for instance national emission factors which will advance the used methodology at tier 2 level.

	which will advance the used methodology at tier 2 level •	
Energy	• Lack of physical characteristics of various fuels (Peat, liquid fuels and biomass, methane gas, LPG, etc.) • Lack of country specific emission factors for the latter fuels and related technologies • Lack of information on travelled km for vehicles • Lack of methane gas specific emission factor to be considered in the GHG inventory • Limited studies related to energy generation vulnerability assessment Lack of studies on the impact of climate change on the energy end use in the household and institutions	• Mobilize research funds for determination of emission factors and physical characteristics of the fuels used in the energy sector • Conduct surveys for energy consumption and use in the households and institution to fill gaps in data • To conduct surveys to collect data on fuels consumption in transportation sector • To conduct surveys on the biomass use in the charcoal production chain • To support various researches on the climate change impact on the energy generation and use.
IPPU	• The main gaps relate to the limited use of cleaner production measures,the lack of green buildings as well as the lack of technology that use the improved material efficiency in cement production.	• There is a need to use the best available technology and the use of improved material efficiency in cement-to-clinker fractions. This will require further national and international researches to evaluate appropriate substitution materials and to assess their regional availability.
AFOLU	• Lack of specific country data (e.g. emission factors and expansion factors) for estimating GHG emissions • Local agricultural and forestry and other land usemodels are lacking. • Inadequate monitoring of farmers inputs and outputs. The early warning systems for climate conditions are still not usable by the farmers.	• To support research and monitoring of activity data in order to establish specific country data and develop local or national agricultural, forestry and other land use models so as to improve estimation of GHG emissions from AFOLU • To ensure regular collection of activity data for GHG Emission inventory according to IPCC 2006 software. Support and improve early warning systems for agricultural seasons' onsets so as to help farmers to minimize crop failure and other weather hazards.
WASTE	• Unsuitable waste management methods such as collection, disposal and treatment approaches	• To improve waste management practices by considering the waste prevention techniques and other sustainable approaches for waste collection and treatment such as waste source separation, sanitary landfills and energy recovery from waste. This will require large scale capacity building and awareness raising for sustainable waste management.

6.3. Funding for the implementation of climate compatible development activities in Rwanda

6.3.1 Existing funding mechanism for the implementation of climate compatible development activities in Rwanda

Funding for the implementation of climate compatible development activities in Rwanda is mobilized from four main sources:

1) Internal public investment resources: this entails national budget allocation to the environment and climate change through ministries, agencies and districts, through the consolidated budget, and contributions to the FONERWA fund;
2) External development partner resources: Donor funds support on-going climate change activities through direct project support, budget support, sector budget support, and FONERWA contributions;

3) FONERWA Green Fund: This demand-based, GoR-Donor basket fund aims to generate sustainable financing for environment and climate change projects and programmes, build capacity for managing climate finance and supports access to international climate funds, among other initiatives.

4) Non-public sector resources: Additional funds are drawn – directly and indirectly – from non-state actors, e.g. the international NGOs, CSOs; local NGOs and the private sector. The below sub-sections provide details on internal and external resources, as well as the FONERWA fund.

Further details on the extent of non-public sources are not available due to limited data availability.

Table 6.5 List of projects in Rwanda under bilateral and multilateral climate funds update 2014

Name of Project	Name of Fund	Implementing Agency	Approved (USD millions)	Disbursed (USD millions)	Grant
Pilot study examining the feasibility of investment in forest and landscape restoration in Rwanda	Germany's International Climate Initiative	IUCN	0.248		0.248
Preserving Biodiversity in the Nyungwe Forest	Germany's International Climate Initiative	Universität Koblenz-Landau	2.289		2.289
Drafting a National Climate Change and Low Carbon Development Strategy - 647 - 780	UK's International Climate Fund	World Bank	0.37		0.37
Sustainable afforestation and reforestation management of the natural forests of Rwanda.	Congo Basin Forest Fund (CBFF)		5.237	2.026	5.237

Enabling Activities to Facilitate the Preparation of a National Adaptation Plan of Action (NAPA)	Least Developed Country Fund (LDCF)	UNEP	0.195		0.195

Source: REMA, 2014, Lessons from National Climate Compatible Development Planning in Rwanda)

Table 6.6 Sample Detailed Environment and Climate Change Expenditure by Budget Agency – 2013/14 Approved Budget (MINECOFIN)

Line Ministry	Programme	Budget Item	2013/14 Budget (FRW)
MINEDUC	Education, Science and Technology R&D	Research and climate change observatory	375,000,000
MININFRA	Meteorological Operations	Weather/Climate Services	3,394,480,230
	Fuel and Energy	Alternative Energy Sources Promotion	1,399,742,537
		Energy Efficiency and Supply Security	9,579,452,941
MINIRENA, currently MoE	Environmental management and climate change resilience	education and mainstreaming	1,284,747,202
		Climate change vulnerability	791,275,210
		Pollution management	2,562,929,39
		Environmental research and planning	334,926,000
	Land Administration and Land use Management	Land tenure regularization.	931,400,000
		Land use planning and management	-
	Integrated water resource management	Water resource monitoring	1,094,684,173
		Watershed rehabilitation and management	-
	Terrestrial Ecosystems and forest resource management	Forest plantation management and agro-forestry	2,998,283,935
		Mineral and quarry exploration and exploitation	
MINAGRI	Agriculture and Animal Resource Intensification	Soil conservation and land husbandry	23,596,409,033
		Irrigation and Water Management	27,029,012,677

Source: MINECOFIN, http://www.minecofin.gov.rw/uploads/media/ANNEX_II-1_01.pdf

6.3.2 Capacity needs for convention implementation

In 2015, the Rwandan government commissioned a climate change vulnerability index to estimate vulnerability at national and household levels and to assess how investments in climate resilience have thus far paid off. At the national level, the vulnerability index makes 29 policy recommendations, each divided into thematic subsets including strategic cross-sector action, adaptation planning, climate information services, agriculture, water resources management, health, biodiversity as well as transportation and energy infrastructure. The adaptation subset recommends the adoption of a National Adaptation Plan (NAP) in line with the UNFCCC and based on multi-stakeholder consultations and community-based adaptation. The index also specifies which ministries and stakeholders should be involved in the realization of what recommendations. REMA, Rwanda Environmental Management Authority, is quite logically, given a strong role in coordinating and implementing the results of the index.

Rwanda submitted its Intended Nationally Determined Contributions (INDCs) to the UNFCCC ahead of COP21 in September 2015. The INDCs frame the overall goal of transitioning the country into a climate resilient economy based on energy security from low carbon energy supplies. Other goals include the preservation of ecosystem services, food security, enhanced disaster risk management and social security.82 Priority areas of action for adaptation in each sector are based on the Green Growth Strategy from 2011. Sector goals are subdivided into agriculture, forestry, tourism, water, land use and cross cutting issues. Due to its status as a Least Developed country, Rwanda's INDCs put emphasis on urgent adaptation actions. Furthermore, the INDCs call for close cooperation between ministries, sector agencies, research centres and universities.

Table 6.7 Major environmental programs and donor activities

No.	Project	Donor	Type	Tot Fin. (F Cur. In 000, FRW in 000000)	Start	End
1	Lake Victoria environment management project phase ii (LVEMP II)	World Bank	Grant	15,000,000 USD	2012	2017
	Reducing vulnerability to climate change by establishing Early Warning and disaster preparedness System and support for Integrated Watershed Management in Flood Prone Area	UNDP	Grant	3,486,000 USD	2010	2014
3	The SIDA-supported natural resources and environment management in Rwanda (NREP)	SIDA	Grant	5,661,600 USD	2011	2014
4	Forestry sector development project in Rwanda	GoR	CP	320,000,000Frw	2012	2015
5	Forestry sector development project in Rwanda	SIDA	Grant	4,999,000 EUR	2012	2015
6	Decentralization and environment management project (DEMP II)	UNDP	Grant	5,620,200 USD	2008	2012
7	Support program to the reforestation in Rwanda (PAREF I)	Netherlands	Grant	10,000,000 EUR	2009	2012
8	Support program to the reforestation in RWANDA (PAREF II)	Belgium	Grant	6,000,000 EUR	2011	2015

9	Water resources management master plan	GoR	IF	2,400,000,000 Frw	2011	2014
10	Securing community livelihoods through promotion and utilisation of bamboo resources in Rwanda	FAO	Grant	499,000 EUR	2012	2015
11	Projet de gestion durable des boisements et restauration des forets naturelles au Rwanda	GoR	CP	333,000,000 Frw	2012	2015
12	Projet de gestion durable des boisements et restauration des forets naturelles au Rwanda	FFBC	Grant	4,587,000 EUR	2012	2015
13	Systematic Land Regislation(SLR)	DFID	Grant	26,792,000,000 Frw	2010	2015
14	SystematicLand Regislation(SLR)	GoR	CP	10,653,000,000 Frw	2010	2015
15	Strengthening land administration - connecting LAIS to districts	GoR	IF	808,000,000 Frw	2010	2015
16	Land use planning and management project	GoR	IF	1,566,000,000 Frw	2011	2015
17	China Bamboo project	GoR	IF	2,000,000,000 Frw	2010	2015
18	Improved Information on water quantity	GoR	IF	2,223,000,000 Frw	2011	2013
19	Water quality monitoring project	GoR	IF	193,000,000 frw	2011	2013
20	Rainwater harvesting promotion project	GoR	IF	1,164,000,000 Frw	2007	2015
21	Water hyacinth control project	GoR	IF	864,000,000 Frw	2011	2015
22	watersheds rehabilitation project	GoR	IF	1,130,000,000 Frw	2011	2015
23	LDCF	UNEP		642,200,000	-	2016
24	PEI	UNEP		802,060,000	-	2014
25	Reducing Vulnerability to Climate Change in North West Rwanda through Community Based Adaptation	GoR (RNRA)	Grant	9,969,619 USD	2014	Period of 4 years

Source: Olof Drakenberg and Emelie Cesar, Environment and climate change policy brief- Rwanda, final draft, 2013

6.4. Descriptions of contributions from the GEF, through its implementing agencies

GEF is a mechanism for international cooperation for the purpose of providing new, andadditional, grant and concessional funding to meet the agreed incremental costs of measure to achieve agreed global environmental benefits. It is a financial mechanism established to protect the global environment and promote sustainable development (**Yoko Watanabe, GEF Secretariat, Kigali Rwanda, 20th April 2011).** Rwanda is a beneficiary of GEF funding (Table 6.8 and Table 6.9).

GEF Agencies create project proposals and then manage these projects on the ground. In so doing, they help eligible governments and non-governmental organizations (NGOs) to develop, implement and execute their projects. Through collaboration with Agencies, the GEF project portfolio has quickly grown and diversified, serving both developing countries and countries with economies in transition. Such partnership reinforces the individual Agency's efforts to mainstream or incorporate global environment concerns into its internal policies, programs and projects.

Table 6.8 Total GEF Funding Received by Rwanda

No.	Trust Fund	Project Type	Number of Projects	Total Financing	Total Co-Financing
1	GEF	National	11	$16,872,745	$125,990,955
2		Regional/Global	20	$92,664,273	$441,782,546
		Total	**31**	**$109,537,018**	**$567,773,501**
3	LDCF	National	4	$23,810,749	$94,955,600
4		Regional/Global	0	$0	$0
		Total	**4**	**$23,810,749**	**$94,955,600**
5	MTF	National	1	$9,532,000	$51,596,000
6		Regional/Global	0	$0	$0
		Total	**1**	**$9,532,000**	**$51,596,000**
7		Regional/Global	1	$1,762,557	$9,200,000
		Total	**1**	**$1,762,557**	**$9,200,000**

Source: Total GEF Funding Received by Rwanda, available at: *https://www.thegef.org/country/rwanda*, accessed 09/03/2017

GEF funds the following focal areas: Biodiversity, Climate Change, Land Degradation. Other interventions include Sustainable Forest Management (SFM), Funds for Least Developed Countries (LDCF), International waters and persistent organic pollutants (POPs) chemicals.

The main projects financed by GEF in Rwanda include:

- Integrated Management of Critical Ecosystem (Biodiversity);
- Montane Forest Protected Area Management Project (Biodiversity);
- Akagera Basin Management (International Waters);
- Regional Lake Victoria Basin Management (International Waters);
- Reducing Vulnerability to Climate Change (Climate);
- Sustainable Energy Development (Climate);
- Management of PCB Stockpile (POPs);
- Enabling Activities: Preparation of the National Biodiversity Strategy and Action Plan, National Adaptation Plan of Action (NAPA), National Bio-safety Framework Development, National reports to the Conventions.

Table 6.9 Active project through UNDP 2015

Country-project title	Source of Funds	Disbursement (US$)	Grant Amount (US$)	Co-financing (US$)	Project period
Rwanda: $3,077,700					
Reducing Vulnerability to Climate Change by Establishing Early Warning and Disaster Preparedness Systems and Support for Integrated Watershed Management in Flood Prone Areas	LDCF	2,053,738	2,141,000	3,400,000	2010-2015
Management of PCBs stockpiles and equipment containing PCBs	GEF	757,660	936,700	1,050,000	2012-2015

Source: UNDP-GEF Performance report, 2015

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ANNEXES

Annex 1. LIST OF PEOPLE AND EXPERTS PARTICIPATED IN THE VALIDATION AND REVIEW WORKSHOPS

N°	**Names**	**Post/Institution**
1	Alphonse Mutabazi	Climate Change Programme Manager - REMA
2	Patrick Mugabo	Climate Change Adaptation Officer - REMA
3	Prof. Jean Nduwamungu	Professor - UR/CAVM Busogo
4	Dr. Svetlana Gaidashova	Head of Banana Programme - RAB/Karama
5	Dr. Omar Munyaneza	Senior Lecturer - UR/CST Kigali
6	Prof. Donat Nsabimana	Associate Professor - UR/CST Huye
7	Erneste Nkuba	Hydropower Specialist- EDCL - REG
8	Telesphore Ngoga	Analyst in Development of Community Tourism - RDB
9	Dr. Innocent MUHIRE	Senior Lecturer - UR/CE Kigali
10	Joseph Sebaziga Ndakize	Weather Forecaster - Meteo Rwanda
11	Herman Hakuzimana	Ag. Director/ DCCIO – REMA
12	Innocent Nkurikiyimfura	Lecturer - UR/CST Kigali
13	Theoneste Higaniro	Head of Generation Projects & Implementation - EDCL
14	Telesphore Mugwiza	Director Industrial Development Policy - MINICOM
15	Elisée Gashugi	Lecturer - UR/CST Kigali
16	Cyprien Ndayisaba	Environmental Specialist - RTDA
17	Vincent Rwigamba	Director of Housing Planning - RHA
18	Dismas Bakundukize	Director of Forestry Management - RWFA
19	Francois Xavier Tetero	Head of Water Resources Management Dept - RWFA
20	Pius Nishimwe	Operations Manager - COPED Kigali
21	Jean Claude Hafashimana	RWFA/Forestry Dept
22	Pearl Nkusi	Intern CC Program SPIU- REMA
23	Gaspard Uwimana	Director of Livestock - RAB Rubona
24	Emmanuel Twagirayezu	Soil and Water Management Specialist - MINAGRI
25	Samson Twiringire	Chemicals & Pollution Officer - REMA
26	Jacques Nsengiyumva	Environmental Regulations & Standards Officer - REMA
27	Jean Claude Nyamarere	Land Use Monitoring & Evaluation Officer - RLMUA
28	Lambert Uwizeyimana	Forestry and Environmental Statistics Officer - NISR
29	John Mugabo	Waste Management Expert - City of Kigali
30	Immaculée Uwimana	Climate change Mitigation Officer - REMA
31	Marshall Banamwana	Environmental Specialist – Ministry of Environment (MoE)
32	Dr. Florien Nsanganwimana	Lecturer – University of Rwanda – College of Education
33	Jean Felix Ndabarasa	Forecasting Officer – Rwanda Meteorology Agency
34	Aimable Gahigi	Agro-meteorologist - RAB Rubona