Rwanda – State of Environment and Outlook Report 2015

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Greening agriculture with resource efficient, low carbon and climate resilient practices

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Foreword

Vincent BIRUTA

Rwanda has recorded significant progress in all aspects of economic and social development in the past two decades. The recently published report on the 4th Integrated Household Living Conditions Survey (EICV4) for the period 2013/14 reveals that the country maintained a rapid economic growth averaging at 8 per cent for over a decade reducing poverty from 59 per cent to 39 per cent, lifting a million people out of poverty.

The EICV4 also reports Rwanda's achievement of all MDGs, with the exception of the poverty goal that fell short on stunting and poverty targets. The country aims for even higher development targets as pledged in EDPRS II. By 2018, it aims to achieve an economic growth rate of 11.5 per cent, an annual job-creation rate of 200,000 off-farm jobs, a 30 per cent poverty reduction while maintaining high standards of Accountable Governance.

In maintaining the desired rapid economic growth, the country recognizes increasing threats to the hard-earned gains of protection against environmental degradation, but especially from the impacts of climate change.

The key instrument for meeting Rwanda's long-term sustainable development vision is the Green Growth and Climate Resilience Strategy (GGCRS) that was adopted by the Government in 2011. Strategic objectives to maintain rapid economic growth while taking into consideration environmental sustainability and climate resilience were integrated in the updated Vision 2020 and in the Green Economy priority interventions for economic transformation in the second phase of the medium-term Economic Development and Poverty Reduction Strategy (EDPRS II), running from 2013 through to 2018.

The updated Vision 2020 recognizes the three principles of a Green Economy: social cohesion, economic empowerment and environmental intelligence. The three principles will contribute to the country's achievement of the aspiration to become a middle income and knowledge-based economy by 2020 and progressively to be a developed climate-resilient, low carbon economy by 2050. In the medium term EDPRS II framework, the Government of Rwanda sets the priority for a Green Economy approach in its Economic Transformation thematic area that orients economic activities and consumption practices towards resource efficiency, low carbon production and climate change adaptation for resilience.

The theme of the fourth edition of the State of Environment in Rwanda "Greening Agriculture with resource efficient, low carbon and climate resilient practices" is most appropriate and timely as agriculture is a backbone production sector in the country's economy and source of livelihoods for the majority of rural households. It is therefore imperative that the desired rapid growth of the agricultural sector proceeds with efficiency in inputs and operations that produce the minimum possible greenhouse gas emissions and that are adaptive to climate change effects for resilience.

The findings of the fourth State of Environment report demonstrate the determination of the Government and people of Rwanda to put in place mitigation measures that reduce the effects of climate change and to change mindsets and cultural practices in order to adapt to the changing climate conditions.

On behalf of the Government of Rwanda, we wish to congratulate the Rwanda Environment Management Authority (REMA) for meeting its statutory obligations of producing the fourth State of Environment Report. Deep appreciation also goes to our development partner, the Swedish International Development Agency for their financial support.

We also take this opportunity to acknowledge the technical insights provided by policy advisors, technical experts and researchers from concerned institutions with a particular appreciation to those from the Ministry of Agriculture and Animal Resources (MINAGRI) and its technical institution, the Rwanda Agriculture Board (RAB).

It is our expectation and hope that this report will harness your knowledge of the state of Rwanda's environment and great opportunities for the necessary green growth of the agricultural sector.

Enjoy the reading,

Vincent BIRUTA
Minister of Natural Resources

Gerardine MUKESHIMANA
Minister of Agriculture and Animal Resources

Dr. Gerardine MUKESHIMANA

Preface

Dr. Rose MUKANKOMEJE

This State of the Environment and Outlook Report (SEOR) fulfills REMA's mandate to conduct a thorough inspection of environmental management and publish a stock taking of environmental conditions every two years, as directed by Article 3 of law No 63/2013 to 27/08/2013. As the fourth such report to be released by REMA, it continues the process of integrating environment and natural resources management into national planning for economic development that began with the first SEOR in 2009. That report provided baseline data on the state of Rwanda's ecosystems to inform Rwanda's Vision 2020, the EDPRS and Rwanda's progress on the environment related to the MDGs; subsequent SEORs have built upon these data and updated the indicators.

At the same time, each report focused on a special issue or topic of particular salience to Rwanda's environmental and development goals for the future. The special theme of the 2009 issue was Our Environment for Economic Development. It established the importance of recognizing the link between natural resources and national economic growth. The special focus of the 2011 report, the Atlas of Rwanda's Changing Environment, was Implications for Climate Change Resilience. It provided compelling visual documentation of the impacts of human activities and the changing climate on the country's lands and waters. The last report, published in 2013, concentrated on the state of Kigali City's environment and future outlook, with the theme of sustainable urban development. Finally, the special feature focus of this 2015 edition is Greening Agriculture with Resource Efficient, Low Carbon and Climate Resilient Practices.

As with all its previous reports, this SEOR was planned and produced through a highly participatory process that included visioning, planning, advice and oversight from inception though to validation by a broad spectrum of stakeholders. These included representatives from all levels of government and all departments with any influence over environmental and agricultural matters, as well as development partners and non-governmental organizations.

The authoritative and widely-used Driving Forces-Pressure-State-Impact-Response (DPSIR) methodology provided the organizational and analytical framework. Several hotspot to hopespot case studies using change pairs of satellite images, as were used in the Atlas, punctuate the report with dynamic illustrations of on-the-ground evidence of how Rwanda is succeeding in restoring degraded landscapes.

The green economy is a thread running through the report, showing the challenges inherent in achieving the twin goals of economic growth and "green" or sustainable environmental development. This theme is guided and informed by the goals and targets in Rwanda's Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development.

A special feature chapter focuses on greening agriculture in Rwanda. It notes the country's impressive progress in increasing agricultural production over the past decade and asks how the sector might continue to contribute substantially to growing the national economy without degrading its soils, polluting its waters and significantly increasing its greenhouse gas emissions. To reply, it describes a suite of tried and true sustainable farming practices that conserve and improve soils so they continue to be productive, among other environmental advantages. Historically, Rwandan farmers have been engaging in many of these practices. With population growth and poverty, however, they are often forced to take short cuts: land parcels diminish in size, fallow periods are reduced, erosion controls are abandoned, etc. This is why Rwanda needs green growth — both economic growth and environmental protection.

The report also presents calculations on the costs of business as usual compared to two scenarios that increasingly invest in protecting the land, natural resources and water. Unsurprisingly, it becomes evident that the more we invest in protecting our natural heritage now, the more we can reap from it into the future. Only this way can Rwanda realize a fully modern agricultural sector that can sustain its population and bring economic growth.

REMA is extremely grateful to the Swedish International Development Agency (SIDA) for their financial support in producing this report, to all the stakeholders and key contacts from government departments who supplied the data and reports to inform it and who enthusiastically participated in the inception and validation meetings (their names are listed with gratitude in the Acknowlegements). It also thanks the Environmental Pulse Institute for its excellent work and collaboration in research and writing.

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Acronyms

AAP Africa Adaptation Programme
ABS Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization
AMSL Above mean sea level
ANP Akagera National Park
A/R Afforestation and Reforestation
ARAMA Association de Recherche et d'Appui aux Mouvements Associatifs or Association for Research and Support to Associations
ASARECA Association for Strengthening Agricultural Research in Eastern and Central Africa
ASIP Agriculture Sector Investment Plan
ASM Artisanal and Small-scale Mining
Au Gold
AZE Alliance for Zero Extinction
BAU Business-As-Usual
BEST Biomass Energy Strategy
BOD Biochemical Oxygen Demand
CBD Central Business District
CBD Convention on Biological Diversity
CDM Clean Development Mechanism
CER Certified Emission Reduction
CH_4 Methane
CIAT International Center for Tropical Agriculture
CIP Crop Intensification Programme
CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS Convention on the Conservation of Migratory Species of Wild Animals
CO_2 Carbon dioxide
COD Chemical Oxygen Demand
COOCEN Coopérative pour la conservation de l'environnement
CSA Climate Smart Agriculture
CTC Certified Trading Chain
DHS Demographic and Health Survey
DLUP District Land Use Plans
DPSIR Driving Forces-Pressure-State-Impact-Response
DRC Democratic Republic of the Congo
DRR Disaster Risk Reduction
DSM Demand-Side Management
E-waste Electronic waste
EAC East African Community
EARP Electricity Access Roll-out Program
EARS Eastern African Rift System
EBFM Ecosystem Based Fisheries Management
EDCL Energy Utility Corporation Limited
EDPRS Economic Development and Poverty Reduction Strategy
EE Energy Efficiency
EESD Environmental Education for Sustainable Development
EIA Environmental Impact Assessments
EICV Integrated Household Living Conditions Survey (Enquête Intégrale sur les Conditions de Vie des Ménages)
ENR Environment and Natural Resources
EPI Environmental Pulse Institute
ESSP Energy Sector Strategic Plan
EST Environmentally Sound Technologies
EWSA Energy, Water and Sanitation Authority
FAO Food and Agriculture Organization
FFS Farmers Field School
FHA Forest of Hope Association
FMNR Farmer Managed Natural Regeneration
FONERWA Rwanda National Climate and Environment Fund
FSDS Foundation Saint Dominique Savio
GACP Gishwati Area Conservation Programme
GCF Green Climate Fund
GDP Gross Domestic Product
GEI Green Economy Indicators
GEO Global Environment Outlook
GGCR Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development
GGEI Global Green Economy Index
GGGI Global Green Growth Institute
GHG Greenhouse Gas(ses)
GII Gender Inequality Index
GIS Geographical Information System
GoR Government of Rwanda
GPS Global Positioning System
HDI Human Development Index
HFA Hyogo Framework for Action
ICDP Integrated Conservation and Development Projects
ICT Information and Communication Technologies
IDP Integrated Development Programme
IFAD International Fund for Agricultural Development
IISD International Institute for Sustainable Development
IMTA Integrated Multi-Trophic Aquaculture
IPCC Intergovernmental Panel on Climate Change
IPM Integrated Pest Management
ISFM Integrated Soil Fertility Management
IUCN International Union for Conservation of Nature and Natural Resources
IWRM Integrated Water Resources Management
KCMP Kigali City Master Plan
LAFREC Landscape Approach to Forest Restoration and Conservation
LDC Least Developed Country
LEIA Low External Input Agriculture
LPG Liquefied petroleum gas
LULUCF Land Use, Land-Use Change and Forestry
LWH Land husbandry, Water harvesting and Hillside irrigation
MAB Man and the Biosphere
MDG Millennium Development Goals
MEA Multilateral Environmental Agreements
MHPP Mini/Micro Hydropower Plants
MIDIMAR Rwanda Ministry of Disaster Management and Refugee Affairs
MINAGRI Ministry of Agriculture of Rwanda
MINALOC Rwanda Ministry of Local Government
MINECOFIN Rwanda Ministry of Finance and Economic Planning
MININFRA Rwanda Ministry of Infrastructure
MINIRENA Rwanda Ministry of Natural Resources

MINISANTE Rwanda Ministry of Health
MPAIS Marketplace for Agricultural Information and Services
MPI Multidimensional Poverty Index
MUS Multiple-Use Services
N Nitrogen
N_2O Nitrous oxide
NAEB Rwanda National Agriculture Export Board
NBSAP National Biodiversity Strategy and Action Plan
Nb-Ta Niobium-tantalum
NC National Communication
NCA Natural Capital Accounting
ND-GAIN Notre Dame Global Adaptation Index
NDBP National Domestic Biogas Programme
NGO Non-Governmental Organization
NISR National Institute of Statistics of Rwanda
NLUMP Rwanda National Land Use and Development Master Plan
NPDRR National Platform for Disaster Risk Reduction
NPP Nyungwe National Park
NR National Roadmap
NWRMP Rwanda National Water Resources Master Plan
P Phosphorus
PEI Poverty and Environment Initiative
PES Payment for Ecosystem Services
PGRFA Plant Genetic Resources For Food and Agriculture
pH Power of hydrogen
PoA Programmes of Action
PPP Public Private Partnership
PSDS Private Sector Development Strategy
PSTA Rwanda Strategic Plan for the Transformation of Agriculture
PV Photovoltaic
RDB Rwanda Development Board
REC Rwanda Energy Company
RECP Resource Efficient and Cleaner Production
REDD Reducing Emissions from Deforestation and Forest Degradation
REG Rwanda Energy Group
REMA Rwanda Environment Management Authority
REP Rwanda Energy Policy
RIG Rwanda Investment Group
RNRA Rwanda Natural Resources Authority
ROAM Rwanda Organic Agricultural Movement
RoR Republic of Rwanda
RRECPC Resource Efficient and Cleaner Production Centre
RSB Rwanda Standards Board
RURA Rwanda Utility Regulatory Agency
RWH Rainwater Harvesting
SAS Seasonal Agricultural Survey
SE4ALL Sustainable Energy For All
SEA Strategic Environmental Assessments
SEOR State of the Environment and Outlook Report
SEZ Special Economic Zone
SFM Sustainable Forest Management
SMART Service oriented, Modern, Accountable, and Real-Time
SME Small and Medium-sized Enterprises
SMN Small Micro Nutrients
SMS Short Message Service
Sn Tin
SnO_2 Cassiterite
SOM Soil Organic Matter
SSP Sector Strategic Plan
STI Science, Technology, and Innovation
Ta Tantalum
TNA Technology Needs Assessment
TVET Technical and Vocational Education and Training
UNCCD United Nations Convention to Combat Desertification and Land Degradation
UNCSD United Nations Conference on Sustainable Development
UNDP United Nations Development Programme
UNEP United Nations Environment Programme
UNFCCC United Nations Framework Convention on Climate Change
UNIDO United Nations Industrial Development Organization
UNISDR United Nations Office for Disaster Risk Reduction
VCM Voluntary Carbon Marketing
VNP Volcanoes National Park
W Tungsten
WASAC Rwanda Water and Sanitation Corporation
WAVES Wealth Accounting and Valuation of Ecosystem Services
WDPA World Database on Protected Areas
WDR World Development Report
WISDOM Wood fuel Integrated Supply/Demand Overview Mapping
WO_4 Wolframite
WRM Water Resources Management

Units of measurement

CO_2e carbon dioxide equivalent
GWh Gigawatt hour
Gg Gigagram
h hour
ha hectares
Kcal kilocalorie
kg kilogram
km kilometre
km^2 square kilometre
Kt kilotonne
kWh kilowatt hour
kWp kilowatt-peak
L litre
m^2 square metre
m^3 cubic metre
mg milligram
mm millimetre
Mt megatonne
MW megawatt

Symbols

± plus or minus
< less than
> greater than
≈ approximately

Introduction

This report is in continuation of previous State of the Environment and Outlook Reports published by REMA every two years as a part of its mandate. The report is primarily organized in two parts. Part I provides the geographical context and describes the main drivers of environmental change. It then assesses the status and trends in environmental conditions in Rwanda. Part II focuses on greening Rwanda's agricultural sector with resource efficient, low carbon and climate resilient practices, provides an outlook for the future of the nation's agriculture sector and explores opportunities for agriculture to contribute to greening the Rwandan economy. The main findings are summarized below.

Part I: The State of the Environment in Rwanda

Chapter 1: Geographical, Socioeconomic and Environmental Context

1.1: Geography

This section provides context by describing and illustrating Rwanda's geography (location, climate, topography, etc.), population distribution and density, as well as administrative units. The next sections provide background information on the institutional and socioeconomic drivers or underlying forces that influence environmental change.

1.2: Governance

This section presents the key policies and strategies that oversee Rwanda's development, focusing on the environmental aspects. These include Vision 2020, which aims for Rwanda to become a knowledge-based economy and middle-income country; the Economic Development and Poverty Reduction Strategy II (EDPRS), which is the main vehicle for delivering the Vision's long-term development goals and has the targets of reaching sustained growth of 11.5 per cent and reducing poverty to less than 30 per cent of the population; and the Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development (GGCR strategy) and its 14 Programmes of Action that set Rwanda on a path to becoming a climate-resilient, low carbon economy, with a strong service sector, low unemployment and low levels of poverty by 2050. It also describes the Ministry of Natural Resources (MINIRENA) and the Rwanda Environment Management Authority (REMA), mentions some of Rwanda's high-profile laws that protect the environment and lists the Multilateral Environmental Agreements (MEAs) the country has ratified.

1.3: Demographics

Population numbers and density, migration, and gender and the environment are highly correlated with poverty, food security and ecosystem degradation. Rwanda's population is 10,515,973 (4th Population and Housing Census, 2012), of which more than 40 per cent is under the age of 15; 83 per cent of the population lives in rural areas and 51.8 per cent is female. Rwanda's population density is 415 inhabitants/km^2, the highest in Africa.

1.4: Economy

Between 2001 and 2014, GDP doubled as Rwanda's economy grew at an average rate of almost 7 per cent to reach about 4.69 trillion RWF. Per capita GDP rose from 207 thousand RWF to 387 thousand RWF over that time. Close to one-third of the country's economy depends mainly on agriculture, but the service sector's share of GDP has been growing and between 2001-2014, it was the main contributor to the country's GDP. Rwanda is a member of the World Bank led global Wealth Accounting and Valuation of Ecosystem Services (WAVES) partnership, which aims to mainstream natural capital in development planning and national economic accounting systems. It is also committed to greening its economy and has developed a set of Green Economy Indicators. According to the Global Green Economy Index (GGEI), in 2014, Rwanda ranked 27th out of 60 countries in its performance in greening its economy.

1.5: Poverty

There are numerous methods of measuring poverty. A useful table in this chapter lists five key methods of defining poverty and gives Rwanda's status according

to each one. For example, according to the World Bank, 63.17 per cent of the population lives in extreme poverty while according to UNDP's multidimensional definition, 49.7 per cent of the population is poor. Using Rwanda's definition measured by household consumption, between 2000 and 2014, the share of the national population living below the poverty line dropped from 59 per cent to 39.1 per cent , surpassing EDPR I's objective to reduce the share of the population living in poverty from 56.9 per cent in 2005/6 to 46 per cent in 2012/13. Thus, although poverty in Rwanda is still pervasive, its severity is declining, mostly due to increases in non-farm employment, farm productivity and the number of livelihood activities in which an individual engages. It has also been aided by Ubudehe, the long-standing Rwandan practice and culture of collective action and mutual support to solve problems within a community.

1.6: Education

Rwanda has numerous educational initiatives aimed at creating greater awareness of environmental issues, and training and capacity building programmes to build a future workforce that has the knowledge and tools to protect and restore the country's natural resources and environmental assets. These include a strategy for Environmental Education for Sustainable Development (EESD) and a five-year Action Plan. The Greening Schools Programme uses EESD as a tool to mainstream environment and climate change for sustainability within the education system. Two civil society organizations are also piloting Eco-school programmes in 100 schools. In addition, the GoR is preparing a comprehensive capacity building plan in environmental management related programmes, including renewable energy, and is expanding the Technical and Vocational Education and Training (TVET) programme, with the number of students enrolled more than doubling from 2010 to 2013. There are also Farmer Field Schools (FFS) in all 30 Districts and to date, there are 2,897 FFS groups benefitting a total of 80,000 farmers.

1.7: Technology

The EDPRS II prioritizes improving technology, especially through sustainable green innovations, and Technology, Innovation and Infrastructure is one of the GGCR strategy's five Enabling Pillars. Rwanda is one of the fastest growing African countries in Information and Communication Technologies (ICT) and is committed to greening the sector. Through FONERWA, Africa's biggest environment and climate change fund, Rwanda funds green technologies and its Resource Efficient and Cleaner Production Centre (RRECPC) builds capacity among industries, manufacturers and hotels to reduce energy, water use and pollution, which also saves money.

1.8: Climate change

Although Rwanda has one of the world's lowest per capita emissions of greenhouse gases, it is highly vulnerable to the impacts of temperature and rainfall changes due to climate change since it relies heavily on rain-fed agriculture for subsistence livelihoods and tea and coffee cash crops. As well, half of its electricity generation, a significant driver of economic growth, depends largely on hydropower. The country's average temperature increased by 1.4°C since 1970, higher than the global average, and by the 2050s, it is likely to rise by up to 2.5°C from the 1970 average, while in the future, it could experience increased rainfall intensity during both rainy seasons. Already, Rwanda feels the impacts of global climate change, in the form of flooding and droughts, which cost lives and resources and adversely affect agricultural output. With higher temperatures in the future, crop pests could expand their ranges but so could coffee and tea crops, among other potential impacts. Rwanda is developing a set of indicators to measure vulnerability to climate change impacts and reducing its contributions and building resilience to climate change are key priorities as reflected in EDPRS II and the GGCR strategy.

1.9: Natural hazards

Human activity that degrades the environment exacerbates natural hazards such as landslides and floods, heightening their intensity, severity and frequency. Rwanda is subject to droughts, floods and various types of storms as well as earthquakes and landslides. In 2015, Rwanda published *The National Risk Atlas of Rwanda*, a comprehensive assessment of existing risks at national and local levels illustrated with maps showing hazard prone areas and vulnerable populations. It reports that over the last decade, the frequency and severity of natural disasters,

particularly floods and droughts, have significantly increased, raising the toll of human casualties as well as economic and environmental losses. Over the past two decades, floods and droughts have affected over 2 million people. The Ministry of Disaster Management and Refugee Affairs (MIDIMAR) has put in place various tools to tackle natural hazards and their impacts and has developed a 5-Year Strategic Plan for 2012–2017.

Chapter 2: Forests

Rwanda has a wide variety of forested landscapes, including Afro-montane rainforests, forest patches in savannahs, tree plantations and scattered stands of agroforestry species. Since about 2007, it has stemmed forest loss and significantly increased the area under forest cover by banning timber felling in indigenous forests and state plantations and through an aggressive tree-planting programme. By 2015, 29.2 per cent of the country was covered in forest; Vision 2020's goal is to increase forest cover to 30 per cent of its land area. Natural forests, which cover 10.8 per cent 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 agroforestry plantations cover 18.4 per cent and represent nearly 63 per cent of all forest cover.

Planted forests supply almost all fuelwood, with charcoal accounting for about 15.2 per cent of households' primary energy sources. Rwanda is actively promoting agroforestry to provide wood for fuel during the transition to available and affordable electricity for all. Agroforesty also controls erosion, provides fodder, improves soil fertility and contributes to social well-being and green economic growth. Vision 2020 aims to reduce the percentage of households using wood for energy from 86.3 in 2012 to 50 per cent. In 2011, Rwanda's National Forest Policy, which aims to make the forestry sector a 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, representing the proportionally highest national commitment to date.

Chapter 3: Biodiversity and Protected Areas

Rwanda is one of Africa's most biologically rich regions, with some 2,150 known plant species, 151 mammal species (representing 40 per cent of Africa's mammalian species), 87 species of amphibians and reptiles and 670 bird species. It is home to about 30 per cent of the global population of mountain gorillas. It also provides habitat for a large troupe of 500 chimpanzees as well as many other monkey species. Rwanda's growing tourism industry brought in US$293.6 million in 2013, a significant proportion of which was generated by gorilla tourism, which not only protects the species and its habitat, but generates jobs and combats poverty through revenue sharing schemes. Likewise, incomes from Akagera and Nyungwe National Parks continue to grow (increasing by 65 per cent a year in the former) as Rwanda improves biodiversity protection and tourist infrastructure, and increases forest cover as well as local community involvement.

In 2012, 10.13 per cent of the national territory was set aside as protected areas, consisting of National Parks, Forest Reserves, Forests of cultural importance, and Wetlands of global importance. The GoR is also establishing a National List of Threatened Terrestrial Ecosystems and Species in Need of Protection.

There are three National Parks: Akagera, Nyungwe and Volcanoes and the GoR recently created a fourth: the Gishwati-Mukura National Park, which will further protect the forests from encroachment and increase tourism revenues. Already, forest expansion and regeneration efforts have led to an increase in forest cover in the Gishwati Forest Reserve, which grew from 600 ha in 2005 to 1,913 ha by 2014, resulting in fewer floods, landslides and river siltation, and improved soil fertility, water quality and local livelihoods. This chapter features a special hotspot to hopespot case study of the Gishwati forest, which is a stellar example of ecosystem restoration, illustrated with a series of satellite images from 1986 to 2015.

Chapter 4: Water Resources

Rwanda is endowed with abundant water resources, but they are unevenly distributed over the country's area and throughout the year. The main watersheds are the Congo and Nile River Basins. The former lies west of the Congo-Nile divide, includes Lake Kivu, shared with the DRC, covers 33 per cent of Rwanda's territory and receives 10 per cent of its total water. The Nile basin lies to the east of the divide, includes the Akagera River which is the main source of the White Nile, covers 67 per cent of the total national territory and drains 90 per cent of Rwandan waters. Rwanda is covered by a dense hydrographical network of 101 lakes, 861 rivers and 860 wetlands. The country's natural water towers, which feed its rivers, are the highlands in the Albertine region, Nyungwe Mountain Forest and Volcanoes National Park as well as the Rugezi wetland. Wetlands cover a total of 10.6 per cent of Rwanda's territory, of which 53 per cent has been converted to agriculture and 41 per cent remains covered by natural vegetation.

Rwanda often suffers from per capita water stress or water scarcity due to the unequal distribution of rainfall and poor water resource management. Nevertheless, it uses only about two per cent of its renewable freshwater, of which irrigation uses the most. There is room to accelerate water resources development to provide the Rwandan population with adequate improved water supplies and sanitation, increase the sustainable use of water for irrigation to boost agricultural output (the EDPRS II goal is to increase irrigated areas from 24,000 ha in 2012 to 100,000 ha in 2018) and to supply water for new hydro developments, businesses and industrial opportunities to further green the Rwandan economy. The GoR's vision, targets and strategies, including the National Water Resources Master Plan (NWRMP), are all aligned towards the goals of addressing flooding, drought and erosion and improving agricultural livelihoods, focusing especially on Integrated Water Resource Management (IWRM). In addition to strategies to collect and store water, especially through rainwater harvesting, action plans include addressing water quality and the causes and impacts of pollution as well as adaptation to climate change.

Chapter 5: Urban Areas

Rwanda's annual urban growth rate far exceeds the worldwide average, and population density, at 415 inhabitants/km^2, is the highest in Africa. By 2020, its urban population will have grown from 1.5 million today to about 4.5 million. Kigali is the main urban area, assimilating most rural-urban migration, providing about a third of all jobs and accounting for one-tenth of the country's entire population and almost half of its urban population. In the last five years, the proportion of the migrant population moving to Kigali increased from 19 to 27 per cent.

Ninety per cent of urban households have access to an improved water source, compared with 83.7 per cent of households in rural areas; municipal solid waste collection services in urban areas have improved substantially, growing from 23 per cent of houses served in 2006 to 30 per cent by 2011; 67.4 of urban households use charcoal for cooking, followed by firewood; and 83.4 per cent have access to improved sanitation at the national level.

Because there are already housing and basic infrastructure shortages in Kigali (which requires about 34,000 new dwellings annually), its waste-water, sanitation and solid waste systems as well as treatment plants for industrial effluents and storm-water drainage systems are still inadequate, and traffic and air pollution are growing problems, the GoR has made the development of six secondary cities a priority. Currently, only about a quarter of the country's total urban population is distributed among these cities and Rubavu, Rwanda's second-largest city, is only one-fifth the size of Kigali. The government is committed to encouraging urban and economic growth in these urban centres to take the pressure off Kigali and more evenly distribute employment opportunities.

Vision 2020, EDPRS II, the GGCR strategy and the Urbanization and Rural Settlement Sector Strategic plan for 2013 to 2018 aim to implement Land Use and Development Master Plans and district plans to create low carbon, high density and walkable cities. In collaboration with the Global Green Growth Institute (GGGI), Rwanda is moving forward with plans to develop Green Model Cities with Green Economic

Opportunities. Rwanda also intends to pilot a green city and is investigating the costs of implementing various practices that could be introduced in Kigali under the Climate Smart Cities programme. Already, it has ambitious Master Plans for Kigali that aim to make it a world-class sustainable city.

Chapter 6: Mining and Industry

6.1: Mining

Although Rwanda's mining industry is still small, its role in the world's production of tin, tungsten and tantalum is significant, it employs more people than both the tourism and services sectors and it is the country's largest foreign exchange earner, representing 38 per cent of the total. The mining sector is characterized by private sector and small-scale/artisanal mining operations, usually organized as cooperatives and covering surface areas of less than 4 ha; it contributes about 2 per cent of Rwanda's GDP. In recent years, Rwanda's mining sector has improved in terms of production, exports and contribution to the economy as well as in legislating and limiting its environmental impacts. The GoR intends to increase the mining sector's contribution to GDP and exports, foreign investments in the sector and mining employment opportunities. Mining production could triple by 2020. The GoR also recognizes the potential environmental and human threats of industrializing its mining sector, however, and is promoting a state-of-the-art "green" mining sector and intends to pilot a model "green" mine and engage in Climate Compatible Mining.

6.2: Industry

Although agriculture remains Rwanda's largest GDP contributor, industry and services have been growing at a faster rate over the past 15 years. Industry (excluding agriculture and services) contributes 14 per cent of GDP. The manufacturing sector, including agro-processing, currently constitutes 34 per cent of the industrial sector and contributes 5 per cent to GDP. The construction industry is booming. Between 2010 and 2012, manufacturing investments, excluding agro-processing, grew from US$20 million to US$155 million. Most industry is located in and around Kigali, which has been increasingly addressing the environmental impacts of industrial activities. The RRECPC is extremely influential in mainstreaming cleaner production in policies and strategies and in promoting, teaching and implementing resource efficiency and waste reduction in industries and businesses. As off-farm work opportunities increase, especially in agro-processing, local industries will grow in importance for both livelihoods and the national economy. Vision 2020's goal is to increase the annual industrial growth rate to 8 per cent and the sector's contribution to GDP to more than 20 per cent. As it develops its industrial sector, Rwanda's vision is to ensure that it contributes to greening the economy by using resources efficiently and reducing waste production and energy consumption, which also have important long-term cost saving benefits.

Chapter 7: Energy

Presently, Rwanda imports all of its oil-based products, which fuel about 40 per cent of its electricity generation, 27.8 per cent of its diesel and the entire transport sector. Increased oil prices would thus have a significant economic impact. However, Rwanda is endowed with ample non-renewable and renewable energy resources, including peat and methane deposits, and hydro, geothermal, solar and sustainable biomass. Biomass accounts for about 85 per cent of Rwanda's primary energy use and its production, transport, and combustion have important environmental impacts, including the release of methane. Hydro developments can also be socially and environmentally costly.

Only 23 per cent of Rwanda's households (500,000 customers) are connected to the grid and its per capita electricity, at 42 kWh per year, is one of the world's lowest by far. This chapter includes a box that describes the resource base for potential power generation from hydropower, geothermal, methane, peat, solar, wind and biomass, which together amount to about 1,500 MW, most of which has yet to be fully exploited. For example, overall hydropower potential is estimated at about 400 MW, but currently the utilized hydro capacity is 98.5 MW. Also, Lake Kivu, shared with the DRC, contains high concentrations of naturally occurring methane gas, sufficient to generate 700 MW of electricity over a period of 55 years, of which Rwanda's potential share would be 350 MW.

The GoR is aggressively increasing access to electricity and between 2006 (EICV 2) and 2014 (EICV 4), the percentage of households with electricity as the main source of lighting grew from 4.3 to 19.8 per cent. The 2015 Energy Sector Strategic Plan (ESSP) aims to increase household access to grid electricity to 48 per cent and access to off-grid electricity to 22 per cent. It has also produced the SE4ALL Action Agenda under the Sustainable Energy For All framework (SE4ALL), which sets specific targets for access to sustainable energy sources. Using renewable energy generation sources, such as hydro (especially mini/micro hydropower plants) geothermal and solar together could exceed Rwanda's electricity needs by 2020 and replace oil-fuelled power plants. Such advancement would significantly help Rwanda attain the economic and environmental goals in Vision 2020 and the EDPRS II and achieve the resource-efficient and low carbon targets in the GGCR strategy.

Part II: Greening Agriculture

Chapter 8: Agriculture

Agriculture, especially rain-fed subsistence farming, continues to be the most important economic sector in Rwanda: it contributes 33 per cent of GDP, is currently growing at an average annual rate of over 5 per cent, represents 55 per cent of the country's exports, employs 70 per cent of working people and with about 70 per cent of cultivated land covered with food crops, it provides 80 per cent of national food needs. Rwanda's climate, growing seasons and diversity of agro-ecological regions are conducive to a wide variety of crops. In order of their share of food crops, these include roots and tubers, bananas, fruits and vegetables, and cereals and pulses (beans and peas). Coffee, tea, sugar cane and pyrethrum are the most important cash crops.

The lack of available land is a major constraint to increasing production and the area of arable land has remained fairly stable over the past decade. As the population grows, this has led to increasingly fragmented plots. Nevertheless, between 2000 and 2015, agricultural production almost doubled and coffee production rose by 20 per cent, driven by the impacts of the Crop Intensification Programme (CIP) and land consolidation (the rearrangement and regulation of land to form larger and more rational holdings, which has affected about 27 per cent of households), increased fertilizer use (which rose from 6 kg/ha to 29 kg/ha on cropland) and soil conservation practices. The national livestock herd grew, and just over two-thirds of households keep livestock; 47 per cent of farm households have at least one cow and 53 per cent have at least one goat. The One-Cow-per-Poor-Family programme, or Girinka, which has benefitted over 177,000 families, is helping to increase agricultural livelihoods by supplying manure, improving household incomes and reducing childhood malnutrition. Rice is a vital crop grown on developed wetlands and Rwanda is helping rice cooperatives to improve sustainable rice cultivation.

Increasing agricultural production can come at the expense of the environment, with impacts including land scarcity, erosion, loss of soil fertility, water pollution from agro-chemicals and greenhouse gas emissions, among others. Beginning in 2007, chemical fertilizer use increased through the CIP. Over-cultivation and land degradation leading to erosion have been significant problems, addressed through anti-erosion practices, which are now practised on 87 per cent of agricultural land. Rain-fed farming will feel the impacts of global climate change, with temperature rises potentially affecting harvests and in turn, food security.

Chapter 9: Greening Agriculture — Policies and Practices

"Green" or sustainable agriculture integrates environmental health, economic profitability and social and economic equity. It is guided by a set of principles and associated with a plethora of best practices that build, restore and enhance soil fertility; apply agro-ecological approaches; reduce and prevent soil erosion; manage water use; naturally protect plants from pests and weeds; integrate climate resilience; and reduce food spoilage and loss.

Rwanda's Vision 2020, EDPRS II and the Strategic Plan for the Transformation of Agriculture in Rwanda (PSTA 3) aim for the agriculture sector to make the

major contribution to growing the economy and reducing poverty by becoming fully commercialized and increasing agricultural productivity by 8.5 per cent per year. Recognizing the challenge of modernizing agriculture without jeopardizing ecosystem goods and services, the GGCR strategy guides Rwanda towards a green economy by mainstreaming climate resilience, low carbon development and other environmental protection practices into agriculture and other key economic sectors. Four of the strategy's Programmes of Action focus on greening agriculture:

- Sustainable intensification of small-scale farming;
- Agricultural diversity for local and export markets;
- Integrated Water Resource Management and Planning; and
- Sustainable forestry, agroforestry and biomass.

This chapter describes a number of key farming approaches and practices that Rwanda is pursuing or might consider implementing to lower carbon emissions, increase resilience to the impacts of climate change and use resources more efficiently, using illustrative case studies and examples. It organizes the practices under the following guidelines related to the GGCR's Programmes of Actions:

- Build, restore and enhance soil fertility
- Apply agro-ecological approaches
- Reduce and prevent soil erosion
- Manage irrigation sustainably
- Protect plants from pests
- Integrate climate resilience
- Add value through niche products
- Reduce post harvest losses
- Increase access to markets

The chapter amply illustrates how Rwanda is already implementing many of the best practices in sustainable agriculture. Resource efficient, low carbon and climate resilient practices need to be upscaled and expanded from pilot projects and exemplary case studies to become the new business as usual to both reduce poverty and improve the ecosystem goods and services that are the very foundations of economic development.

Chapter 10: Greening Agriculture — Successes, Outlook and Proposals

This chapter summarizes the progress Rwanda has made in creating a more productive and sustainable agricultural sector, looks into the future at the costs of further greening agriculture and proposes some ways that it might support and strengthen the transition to a fully modern agricultural sector that is economically and environmentally sustainable.

Interventions to move agriculture from a subsistence economy to a market economy were largely responsible for the fall in extreme rural poverty from 35.8 per cent to 16.3 per cent over the eight years between 2005/06 and 2013/14. By 2010, agricultural GDP was growing by 8 per cent a year and represented 47 per cent of GDP and 40 per cent of land was under modernized agriculture. To assess how well Rwanda is performing in greening agriculture, however, it is necessary to systematically and periodically measure its progress through the use of indicators. The GGCR suggests a number of key, mostly qualitative, indicators to measure progress in its Programmes of Action and REMA has proposed a list of specific mostly quantitative indicators to measure how the agriculture sector is becoming more productive as well as increasingly resource efficient, low carbon and climate resilient.

Accurate and timely statistics are needed to populate the indicators, however, as well as technical expertise and finances to monitor, measure and report on indicators on a regular cyclical basis.

To assess the financial output needed to implement green growth priorities, the GoR commissioned technical assistance to conduct an exercise in scenario building in the agriculture and natural resources, water and energy sectors, with scenarios of other sectors to be executed in the future. It proposed three potential outcomes, based on the degree to which certain green growth and climate resilient criteria were adhered to: 1. Business as Usual (BAU); 2. medium green growth; and 3. high green growth. For the agriculture and related water sectors, the results show that the BAU scenario results in environmental degradation and adverse social impacts and practices that could limit Rwanda's long-term growth potential. The capital cost for the BAU scenario for agriculture would be US$920 million. On the other hand, the medium and high green growth scenarios would result in significant financial, social and environmental benefits, including increased climate resilience and water supply reliability. The capital costs of executing the high green growth scenario for agriculture, over and above the costs of the BAU path, would be US$0.6 billion between 2015 and 2030.

The chapter makes a number of recommendations to the GoR, including the following: set up an environmental measuring and monitoring programme; introduce green technologies in the CIP, including agroecology; invest more in researching new techniques, and reform agricultural policies to accommodate and disseminate them; achieve 100 per cent coverage in land conservation practices; strengthen the National Post Harvest and Value Addition capacity; integrate new niche markets for sustainably produced and organic products, including supporting organic certification schemes and compliance with international food safety standards; reduce irrigation in marshlands and rehabilitate and optimize existing irrigation schemes; increase to 100 per cent the collection and treatment of urban and industrial wastewater; introduce Payment for Ecological Services (PES) in the agriculture sector; and develop a robust and vibrant private sector to provide jobs for youth in rural areas. Finally, it suggests that MINAGRI should consider adjusting existing programmes and projects and developing new ones to implement and mainstream the green growth scenarios.

The chapter concludes by noting that Rwanda is already eminently equipped with the policies, strategies, action plans and financial instruments to further upscale and expand green agricultural practices that will both increase food production and protect and sustain the ecosystem services that underpin economic development. It is essential that Rwanda moves beyond business as usual and invests in high green growth in its agriculture sector as a major contribution to achieving Vision 2020 and the GGCR strategy.

Emphasized terrain Eugene Apindi Ochieng

Rwanda, the Land of a Thousand Hills

Introduction to this report

This is the fourth in a series of reports on the state of the environment in Rwanda produced by the Rwanda Environment Management Authority (REMA). These reports fulfill its obligation to release a national report on the state of environment every two years (RoR, 2013). This fourth report follows on from and updates the first *Rwanda State of Environment and Outlook Report* (SEOR), produced in 2009 (REMA, 2009), the subtitle of which was *Our Environment for Economic Development*. It also complements the two subsequent SOER reports: the 2011 *Atlas of Rwanda's Changing Environment* (REMA, 2011), which focuses on the implications of climate change, and the *Kigali: State of Environment and Outlook Report 2013* (REMA, 2013), which discusses the theme of sustainable urban development.

This SOER report begins in Part I by analyzing the status and trends in environmental conditions in Rwanda. Part II is a special focus on *Greening Rwanda's Agricultural Sector with Resource Efficient, Low carbon and Climate Resilient Practices*. Part II also provides an outlook for the nation's agriculture sector and explores opportunities for Rwanda to further invest in greening the sector (RoR, 2012). This is in keeping with the goals outlined in Rwanda's 2011 *Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development* (RoR, 2011), henceforth referred to as the GGCR national strategy.

Methodology

The evidence in this report was gathered through a number of rigorous methods, including the following:

- An extensive literature review of government sources, reports by international organizations and peer-reviewed scientific papers;
- Stakeholder consultations in Kigali at an Inception Workshop to identify data sources

with officials and other stakeholders and to launch the work;

- Personal interviews with experts and officials from various government departments and environmental organizations and institutions in Kigali;
- Field work to collect "evidence" in specific places experiencing noticeable environmental change; and
- A Validation Workshop held in Kigali to solicit comments on draft chapters and validate the first draft.

The approach to preparing and presenting the data and information in the report is based on the following:

- A special focus on how agriculture can contribute to greening the economy through resource efficient, low carbon and climate resilient practices;
- The use of the Driving Forces-Pressure-State-Impact-Response (DPSIR) methodology as the organizational and analytical framework;
- The compilation, analysis and visualization of statistical and geo-spatial data, including the presentation of visually compelling ways to present the data: satellite images, maps, graphs and charts, boxes with case studies and ground photos;
- The identification and presentation of *hotspots, hopespots* and *change pairs*, i.e., places where significant environmental change is identified using current and historical satellite images;
- The updating of relevant content of the three previous SEOR reports, which provide the baseline data; and
- An understanding that resilient ecosystem services are the basis of life, the economy and human well-being.

Terms and concepts used in this report

The green economy and green growth

According to UNEP (2011), a green economy results in improved wellbeing and social equity while significantly reducing environmental risks and ecological scarcities. A green economy focuses on achieving qualitative growth rather than simply increasing GDP (RoR, 2011). It recognizes that protecting and conserving environmental resources can be a significant driver of economic growth. It promotes growth in income and employment that is driven by reducing carbon emissions and pollution, enhancing energy and resource efficiency and preventing the loss of biodiversity and ecosystem services (UNEP, 2011).

Box 1: Resource efficient, low carbon and climate resilient development

Resource efficiency ensures natural resources are extracted, transformed, processed, transported and consumed sustainably, by reducing the environmental impact of products over their full life cycles.

Low carbon development is a new economic, technological and social system of production and consumption that conserves energy and reduces greenhouse gas emissions, while maintaining momentum towards economic and social development. In some cases, the low carbon option is the best development option for low-income countries.

Climate resilience is the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity of self-organization and the capacity to adapt to stress and change. Climate resilience activities strengthen the ability to cope with climate variability now and in the future.

Sources: (UNEP, 2010) (RoR, 2011) (IPCC, 2007)

In 2011, Rwanda adopted its GGCR national strategy to guide the process of mainstreaming resource efficiency, climate resilience and low carbon development into key sectors of the economy (Box 1). To build a low carbon and climate-resilient agricultural sector, Rwanda aims to sustainably intensify small-scale production by strengthening and adding best practices that reduce the sector's dependence on fossil fuels and its carbon emissions, use resources more efficiently and are more resilient to the vagaries of a changing climate.

DPSIR framework

The report uses the Driving Forces-Pressures-State-Impacts-Response (DPSIR) approach to measure and assess environmental conditions and trends. This framework helps to order the data and information in such a way as to tell the story of environmental change in an integrated fashion, linking causes and effects. *Drivers* describe the socioeconomic driving forces, such as population growth, poverty and consumption that contribute to the direct

Pressures that impinge on the environment, including pollution and resource extraction. The *State* of the environment refers to data and descriptions of trends in environmental conditions over time and space. These three aspects of the framework answer the question "what is happening to the environment?" The approach allows for analysis of the *Impacts* of environmental problems on the country's ecosystem goods and services, society, the economy and human health and well being, answering "What are the consequences for the environment and humanity?" Finally, *Responses* refers to how societal actors are addressing environmental and climate issues and with what results, responding to the question "What is being done and how effective is it?" The DPSIR is informed by indicators of environmental change that use a variety of visual means, including graphs, pie charts, tables, maps, and remote sensing from satellites and aircraft to graphically display the data.

Hotspots and Hopespots

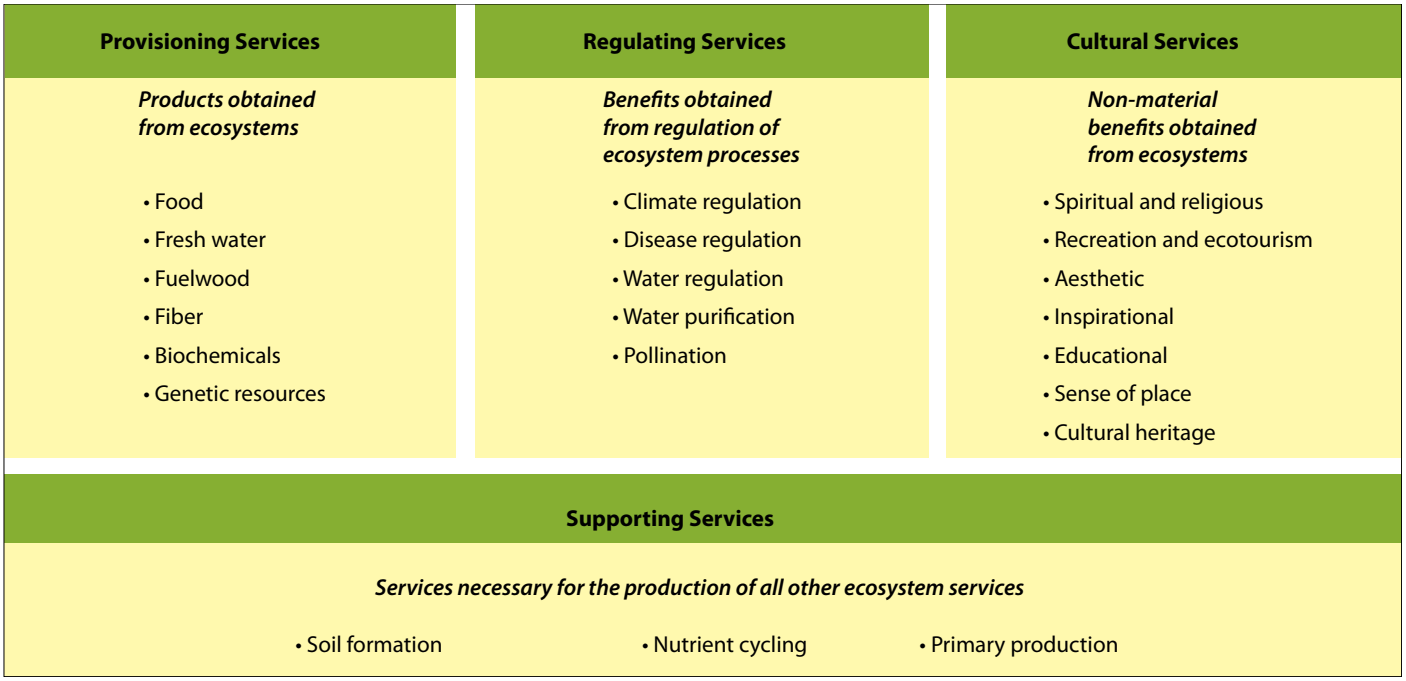
Scientific articles assessing environmental change can be complex and challenging for non-scientists and decision-makers to visualise and comprehend. Time-series satellite imagery provides a way to monitor the environment's resource base and visually document the extent to which humans and natural processes have had an impact on the environment. This report uses selected satellite images to visually tell the story of environmental change. A significant area of the Earth's surface that is susceptible to slow-onset or rapid environmental change is referred to here as a "*hotspot*" and is explained through the use of two or more satellite images showing the change over time. A positive outlook for the future is captured through the concept of a "*hopespot*", which refers to areas where actions have led to, or are leading to, positive changes, such as restoration and rehabilitation (UNEP, 2013).

Two images that display landscape modification that has not been determined to be either "good" or "bad", but rather a transformation, is called a "*change-pair*". The hotspots, hopespots and change-pairs that feature in this report were first identified by scanning both medium and high resolution satellite images from the region as well as reports and publications focusing on Rwanda's environment and noting areas of particularly significant visual change in the physical environment. The final selection was made in collaboration with REMA during an Inception Workshop that took place in Kigali in April 2015 and the selected sites were visited to confirm the changes.

Terraced hillside

Eugene Apindi Ochieng

Figure 1: Ecosystem services



Source: (MA 2003, 57)

Ecosystem services

The Millennium Ecosystem Assessment reminds us that while culture and technology buffer us against environmental immediacies, we are ultimately fully dependent on the flow of ecosystem services. It defines them as "the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits" (MA, 2003, p. 3) (Figure 1). They are referred to throughout this report.

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Part I
The State of the Environment in Rwanda

Rwanda Government / Flickr / CC BY-ND 2.0

Chapter 1: Geographical, Socioeconomic and Environmental Context

Environmental change is influenced by underlying geographic and climatic conditions as well as socioeconomic factors and patterns such as economic activity, poverty, consumption, technology and governance. These drivers are described in this chapter to provide context for the assessment of the status and trends of Rwanda's environmental assets and because many of the indicators provided here are referred to throughout the report.

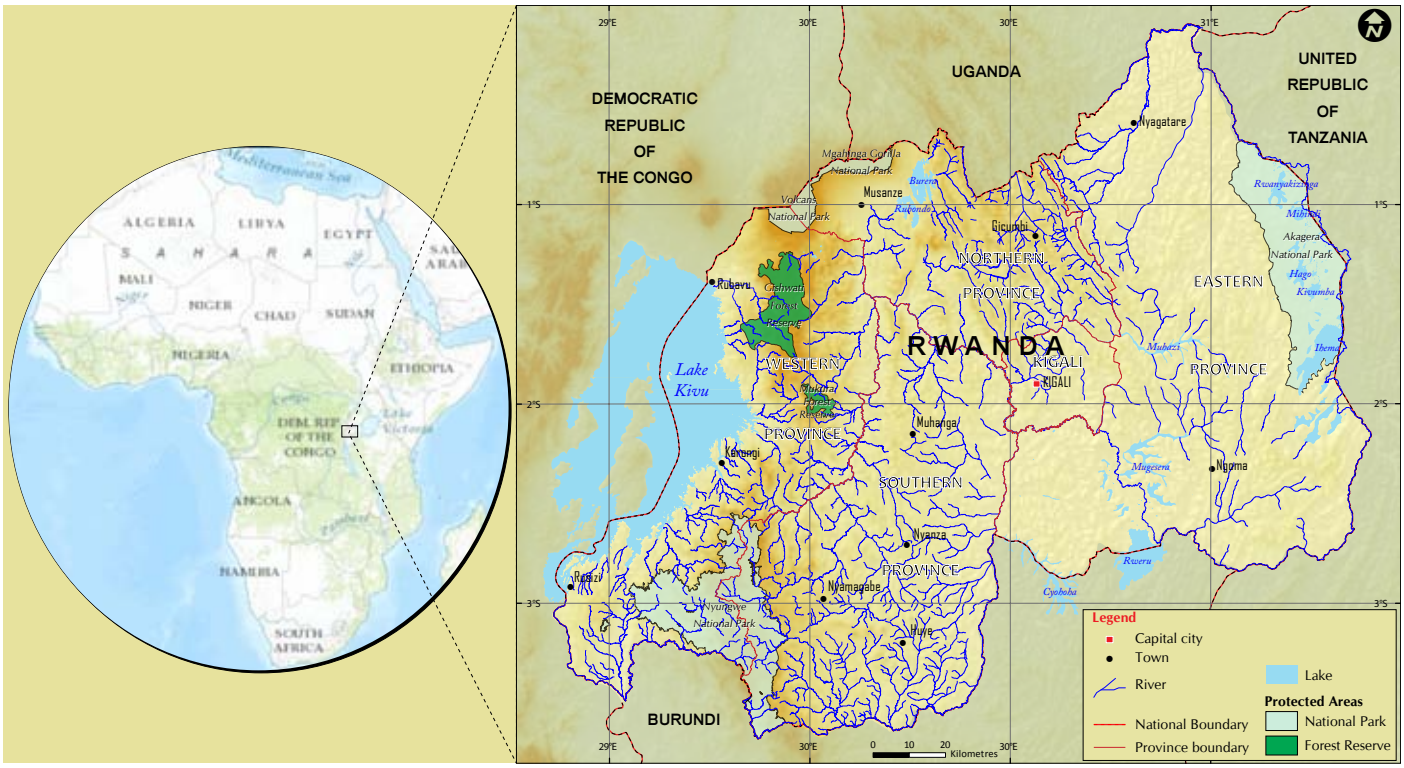
Land of a thousand hills

1.1 Geography

Rwanda's economy and its people's livelihoods and well-being are underpinned by the land base upon which they dwell and the natural resources it provides. This introduction presents Rwanda's geographical endowments and challenges to set the context for the state of environment report and for an assessment of how Rwanda can green its agricultural sector with resource efficient, low carbon and climate resilient practices.

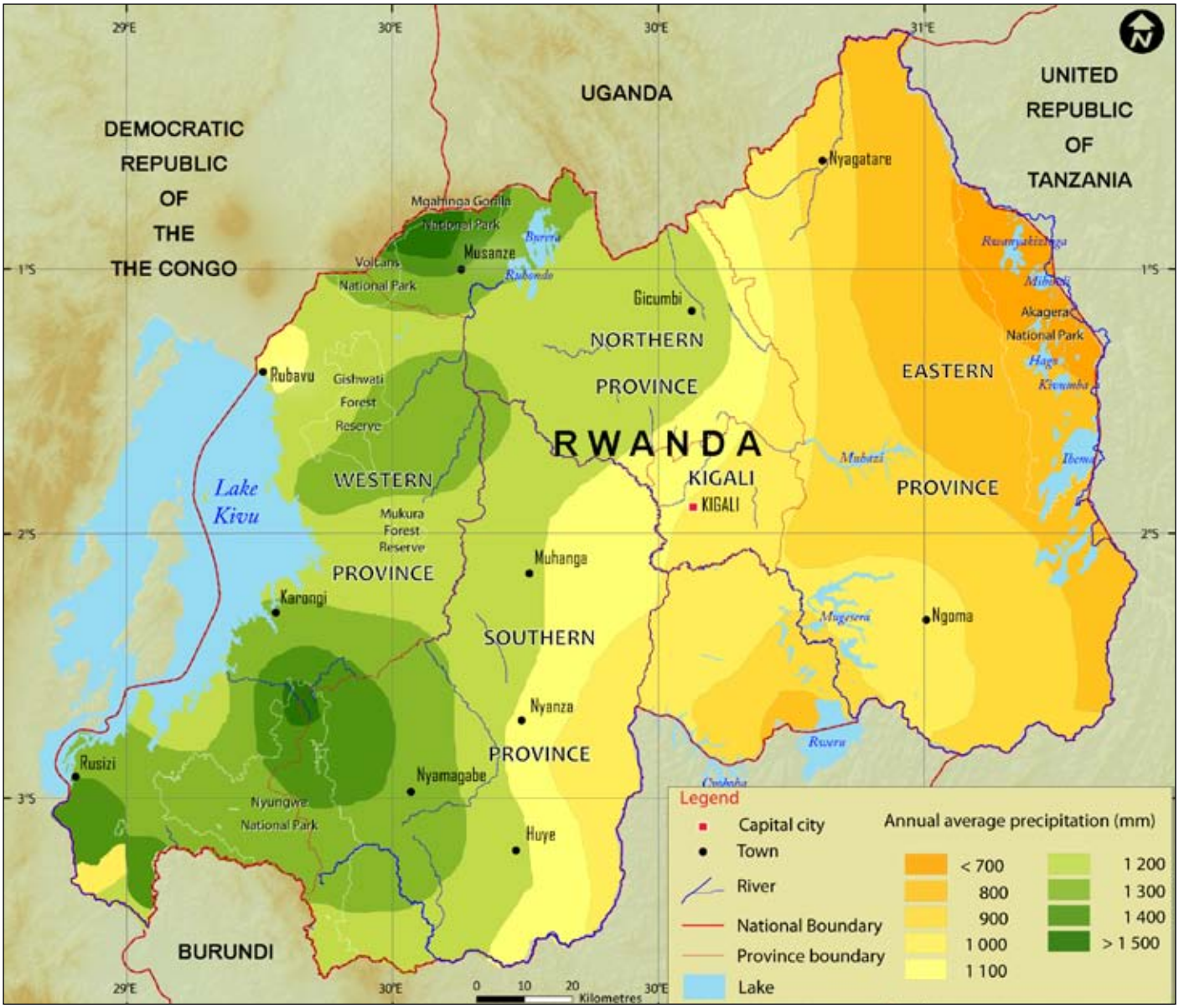
Rwanda, known as the "land of a thousand hills", is a small, fertile country in the heart of Africa. It covers

Figure 1: Rwanda's location



Source : Adapted from REMA, 2011

Figure 2: Annual average precipitation

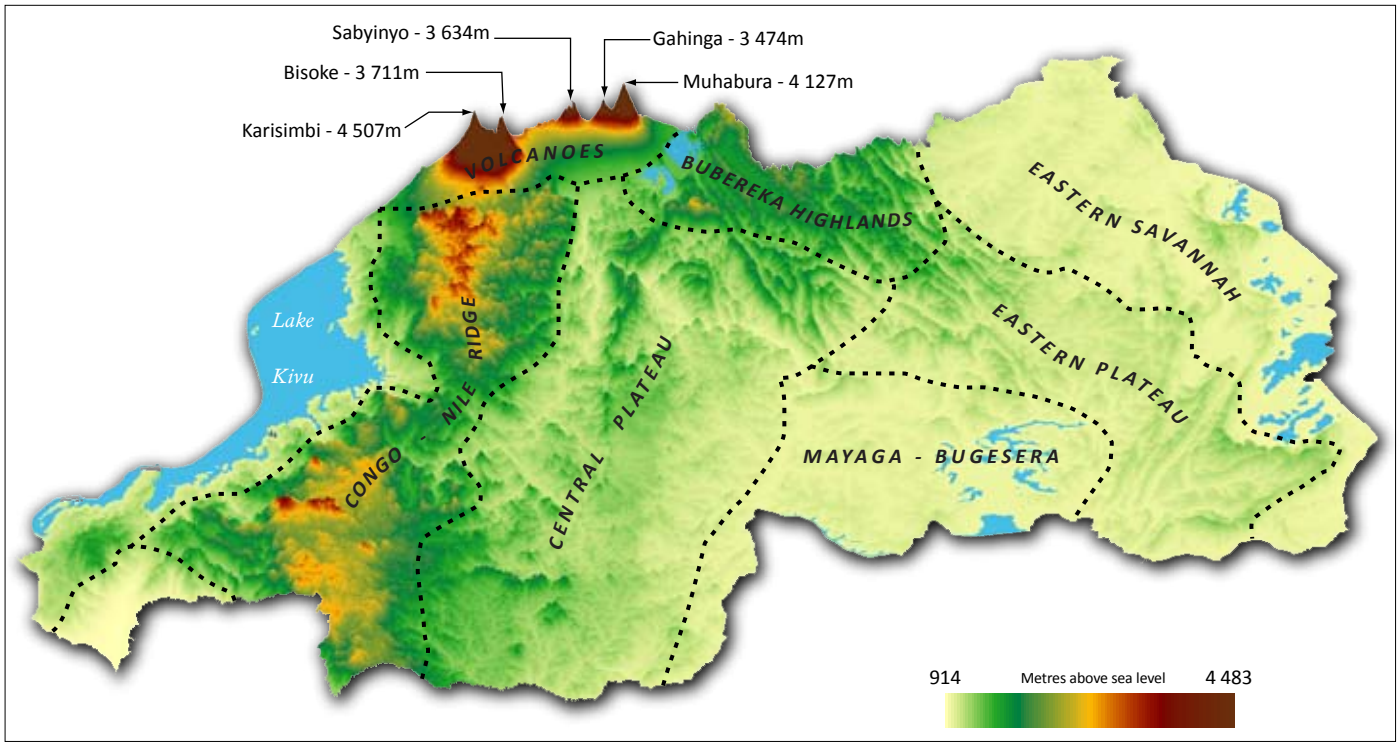


Source: (REMA, 2011)

26,338 km^2 in a position 121 km south of the equator, 1,416 km west of the Indian Ocean and 2,012 km east of the Atlantic Ocean. Rwanda is bordered by Uganda to the north, Tanzania to the east, Burundi to the south and the Democratic Republic of the Congo to the west (RDB, n.d.a) (Figure 1).

Rwanda is entirely situated within the equatorial zone, but it enjoys a moderate tropical climate due to its high altitude, which ranges from 900 m to 4,500 m above mean sea level (AMSL). The average temperature is 20°C but it falls as low as 0°C in some areas of the volcanoes region and rises as high as 19°C to 29°C in intermediate altitude zones. The higher regions of the Congo-Nile divide experience temperatures between 15°C and 17°C. There are two rainy seasons, a short one in October and November and a longer one from February to May. Rainfall is abundant throughout the year in the western parts of the country, while the east has frequent dry spells (Figure 2).

Figure 3: The major topographic regions



Source: (REMA, 2011)

The Upper Nile Basin covers 67 per cent of Rwanda and drains 90 per cent of its surface waters; the remaining 10 per cent drains into the Congo Basin. At 4,507 m above sea level, Karisimbi Volcano in the Virunga Mountains is the highest point; the lowest point is in the southwest, at 900 m. The average elevation is 1,250 m (Figure 3) (REMA, 2011).

Rwanda is endowed with a rich diversity of ecosystems and species. It is home to more endemic mammals, birds, reptiles and amphibians than any other East African country (RoR, 2011).

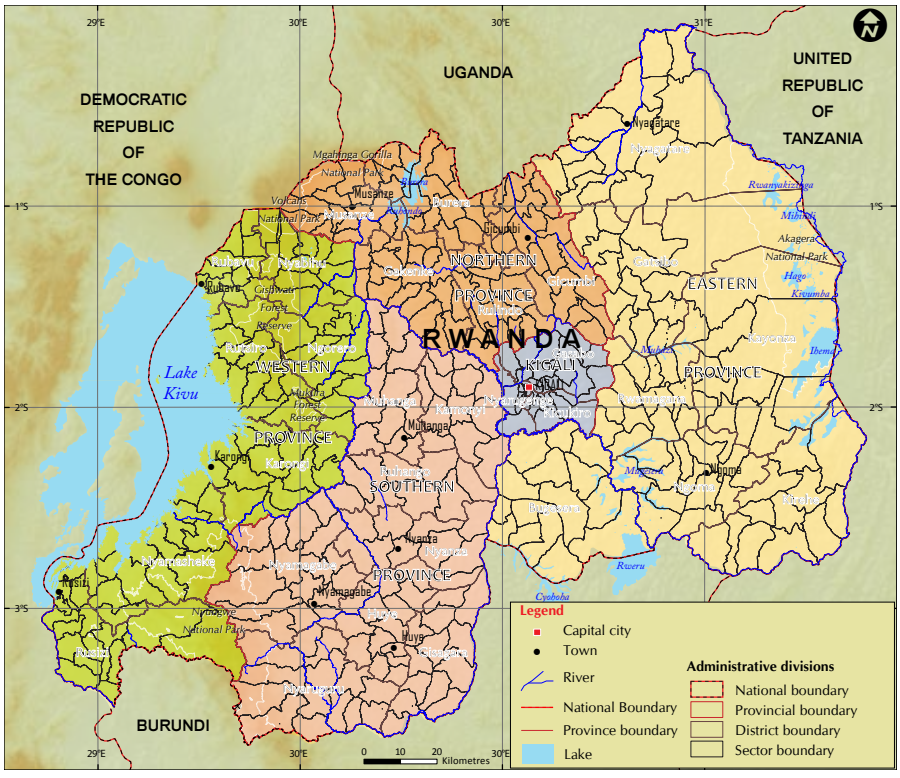
Rwanda is Africa's most densely populated country and its population is growing at about 2.4 per cent a year. About 83 per cent of the population, which is approaching 11 million people, live in rural areas, most of them farming small hillside plots (NISR, 2014a) (Table 1). Urbanization, however, is increasing at 4.5 per cent per year (MININFRA, 2013). Figure 4 shows the country's main population centres and administrative divisions (Provinces and Districts).

Table 1: Population characteristics, 1978-2012

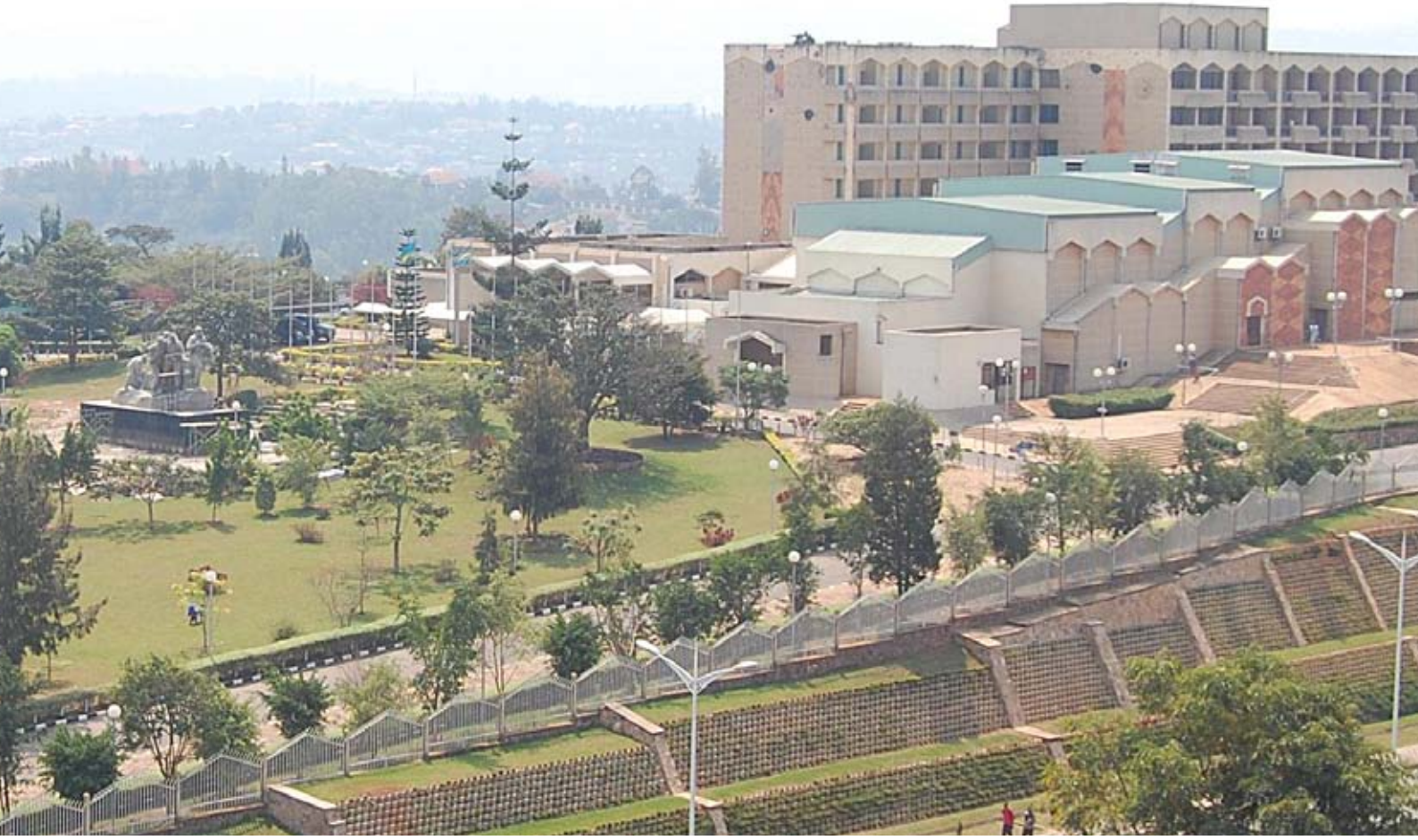
Year	Total population	Population density (habitats/km²)	Population growth rate (%)	Population in urban areas (%)
1978	4,831,527	183		
1992	7,157,551	272	3.2	5
2002	8,128,553	321	2.6	16
2012	10,515,973	415	2.37	16.5

Sources: (NISR, 1992) (NISR, 2012a) (NISR, 2012b) (NISR, 2014a)
**data unavailable*

Figure 4: Administrative map of Rwanda



Source: (REMA, 2011)



Rwanda parliament building

©Rwanda Parliament

1.2 Governance

Governance and the environment

Effective environmental governance at all levels is critical for finding solutions to environmental challenges. UNEP defines environmental governance as interactions at local, national and international levels between the state, the market and civil society, among other actors, which interact with one another in formal and informal ways to formulate and implement policies in response to environment-related demands and inputs from society. The interactions are bound by rules, procedures, processes, and widely-accepted behaviour and possess the characteristics of "good governance" oriented to attaining environmentally-sustainable development (UNEP, 2008).

Table 2: Key Vision 2020 targets

Objectives	Vision 2020 targets
Rapid economic growth to Middle Income status	• GDP per capita of $1,240 • Average GDP growth of 11.5%
Increased poverty reduction	• Poverty reduced to 20% • Extreme poverty eliminated
More off-farm jobs, more urbanisation	• 1.8 million new off-farm jobs • 35% of population urban
Reduced external dependency	• Exports growth of 28% p.a.
Private sector as engine of growth	• Private sector takes dominant share of investment

Source: (RoR, 2012)

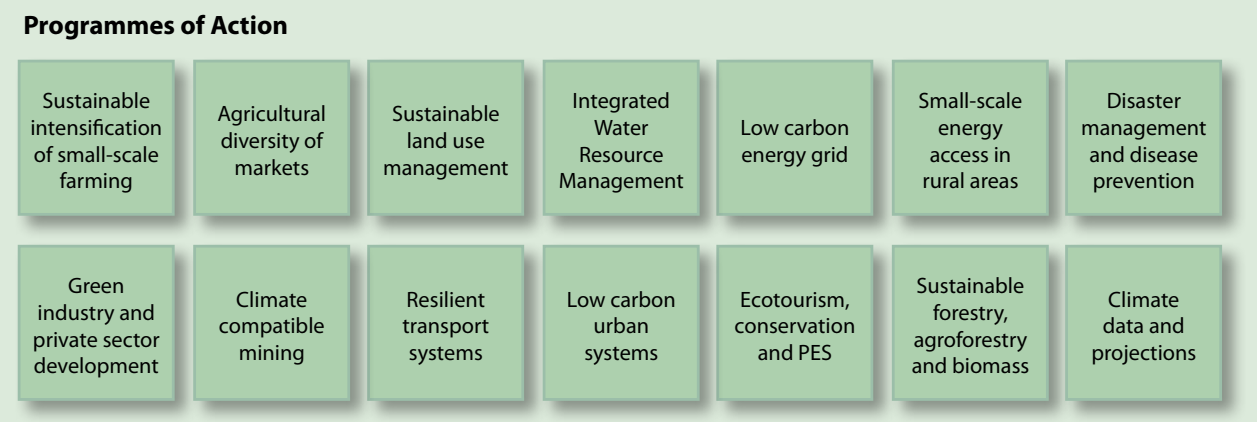
Vision 2020

Vision 2020 is the overarching framework guiding Rwanda's future development. Its ultimate goal is to achieve middle-income status by 2020 and transform Rwanda into a knowledge-based economy. It supports a clear Rwandan identity, whilst showing ambition and imagination in overcoming poverty and division and attaining the United Nations Millennium Development Goals (MDGs). Sustainable environmental and natural resource management is one of its cross-cutting themes. To align the Vision 2020 targets with the progress achieved in the last ten years and to reflect the country's ambition featured in its long-term development goals, a revised version of Vision 2020 was adopted in May 2012, with forty-eight indicators (RoR, 2012). Table 2 summarizes its key targets.

Economic Development and Poverty Reduction Strategy (EDPRS II) (2013-2018)

The Economic Development and Poverty Reduction Strategy (EDPRS) is the primary medium-term vehicle

Figure 5: The GGCR strategy's 14 Programmes of Action



Note: PES - Payment for Ecosystem Services
Source: (RoR, 2011)

for delivering the long-term development goals embodied in Vision 2020 and the MDGs. The second Economic Development and Poverty Reduction Strategy (EDPRS II) is a five-year plan designed to accelerate the progress already achieved and to shape Rwanda's development in the future. It builds on EDPRS I policies, which effectively accelerated growth, created employment and generated exports (IMF, 2013). In addition, EDPRS II will strengthen policy and strategy approaches in innovative ways and ensure continued progress by enhancing the private sector's engagement. The overarching goal for EDPRS II, derived from Vision 2020's long-term goal of "creating a productive middle class and fostering entrepreneurship" is "Accelerating progress to middle income status and better quality of life for all Rwandans through sustained growth of 11.5 per cent and accelerated reduction of poverty to less than 30 per cent of the population" (RoR, 2013).

EDPRS II places a high priority on addressing environmental and climate change issues, reflected by naming them specifically as cross-cutting issues. Other EDPRS priorities related explicitly to the themes of this report include transforming Rwanda's economic geography by managing urbanization and promoting secondary cities; pursuing a "green economy" approach to economic transformation; and addressing rural development by improving land use and increasing the productivity of agriculture, among others. This report's chapters outline the relevant EDPRS strategies in greater depth.

The Green Growth and Climate Resilience Strategy (GGCRS)

In 2011, the Cabinet approved Rwanda's *Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development* (GGCR) (RoR, 2011). It lays out a Vision for 2050, foreseeing Rwanda as a climate resilient, low carbon economy, with a strong services sector, low unemployment and low levels of poverty. The guiding principles include:

1. Economic growth and poverty reduction;
2. Good regional and global citizenship;
3. Sustainability of the environment and natural resources;
4. Gender equality and equity; and
5. Welfare and wellness of all citizens in a growing population.

The GGCR strategy's strategic objectives are

1. To achieve energy security and a low carbon energy supply that supports the development of green industry and services;
2. To achieve sustainable land use and water resource management that results in food security, appropriate urban development and preservation of biodiversity and ecosystem services; and
3. To achieve social protection, improved health and disaster risk reduction that reduces vulnerability to climate change (RoR, 2011).

The strategy's 14 Programmes of Action (Figure 5) are referred to in the relevant chapters of this report.

A special fund for environment and climate change called FONERWA supports the GGCR strategy (RoR, 2013). It provides technical and financial support to the best public and private projects that align with Rwanda's commitment to a green economy (FONERWA, n.d.a).

REMA

Ministry of Natural Resources (MINIRENA)

Rwanda has a relatively comprehensive and progressive legislative framework and has established agencies to work cross-sectorally to support natural resource management, notably the Rwanda Environment Management Authority (REMA), and the Rwanda Natural Resources Authority (RNRA) and the Rwanda Meteorology Agency (RMA), both within the Ministry of Natural Resources (MINIRENA).

The mandate of MINIRENA is to "ensure the protection and conservation of the environment and ensure optimal and rational utilization of natural resources for sustainable national development" (MINIRENA, 2013). MINIRENA oversees matters related to the environment, water resources, lands, forestry and mining. It executes its mandate through the development and dissemination of relevant policies, strategies and programmes that promote the following:

1. An efficient land administration and management system that enhances a national strategy that secures transparent land ownership and encourages investment in land for the durable benefits of people;
2. A national development process that inflicts minimal damage on the environment and builds resilience to the impacts of climate change in all activities;
3. Sustainable management of ecosystems and forest resources to optimize their economic as well as ecological functions;
4. Lasting water quantity and quality security that meets all future needs of a growing population and industrial development to perpetuate economic and social advancement;
5. An improved geology and mines system for optimal and sustainable income and community welfare through the adoption of technologies and measures that protect the environment while increasing revenue from mineral exports and transformation; and
6. The provision of improved and coordinated weather and climate information for better planning and decision making (MINIRENA, 2013).

Rwanda Environment Management Authority (REMA)

REMA is non-sectorial institution mandated to facilitate coordination and oversight of the implementation of national environmental policy and the subsequent

legislation. REMA has a key role to play towards achieving the national goal of sustainable development as set out in Vision 2020. REMA operates under the Ministry of Natural Resources (MINIRENA) and is responsible for implementing policy and framework legislation relating to the environment. To achieve its objectives, REMA works with and through public, private sector and civil societies; its structure supports two types of environmental management functions:

1. Sectoral environmental management functions relating to specific natural resources or environmental services such as agriculture, water, mining, forestry, waste management etc;

2. Coordination and integration of environmental management functions in relation to cross-cutting issues such as monitoring and evaluation of environmental policy and implementation of environmental legislation (REMA, 2014b).

Policies and legislation

Rwanda has promulgated an important number of policies to govern the various aspects of environmental management, including the following: Rwanda Environmental Policy; Land Policy; Forestry Policy; Mine and Geology Policy; the Rwanda Biodiversity Policy; Water and Sanitation; Five Year Strategic Plan for the Environment and Natural Resources Sector, 2013-2018; Environment and Climate Change Sub-Sector Strategic Plan 2013–2018; Wildlife Policy; National Policy for Water Resources Management; and the National Policy and Strategy for Water Supply and Sanitation Services.

There are also laws governing economic and other sectors to promote a sustainable and low carbon development, including, but not limited to the Organic Law on environment, Land Law, Forestry Law, Mining Law, Water Law, Biodiversity Law, legislation governing Environmental Impact Assessments (EIA) and guidelines for Strategic Environmental Assessments (SEA) (pending a ministerial order making SEA mandatory).

Rwanda is well-known internationally for its proactive stance on plastic bags. In 2008, it introduced the Law relating to the prohibition of manufacturing, importation, use and sale of polythene bags in Rwanda, making it a world leader in protecting the environment from the pollution these bags cause and in reducing the use of energy to manufacture and transport them.

Multilateral Environmental Agreements (MEAs)

REMA coordinates all Multilateral Environmental Agreements (MEAs) ratified by Rwanda and advises the Government on policies, strategies and legislation related to environmental management.

Multilateral Environmental Agreements (MEAs) ratified by Rwanda include: the United Nations Framework Convention on Climate Change (UNFCCC); the Kyoto Protocol, which is linked to the UNFCCC and which sets internationally binding emission reduction targets; the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (the Basel Convention); the Montreal Protocol on Substances that Deplete the Ozone Layer, which is associated with the Vienna Convention for the Protection of the Ozone Layer (Vienna Convention); the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (Rotterdam Convention); the Cartagena Protocol on Biosafety; the Convention on Wetlands of International Importance (Ramsar Convention); the UN Convention to Combat Desertification and Land Degradation (UNCCD); the Convention on Biological Diversity (CBD); the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) to the CBD; the Convention on the Conservation of Migratory Species of Wild Animals (CMS Convention); and the Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention).

One-laptop-per-child workshop REMA

1.3 Demographics

Population and the environment

Population numbers and densities act as drivers of environmental pressures when they grow beyond the ecosystem's carrying capacity. The number of people dependent on natural resources in a given area is often proportional to the environmental damage, although advanced technologies can mitigate individual impacts as can the way human societies organize themselves in various communities, such as villages and cities (UNEP, 2012).

Poverty and food security are highly correlated with demography, health and education indicators, with direct links between life expectancy, maternal and child health and the rise in population numbers.

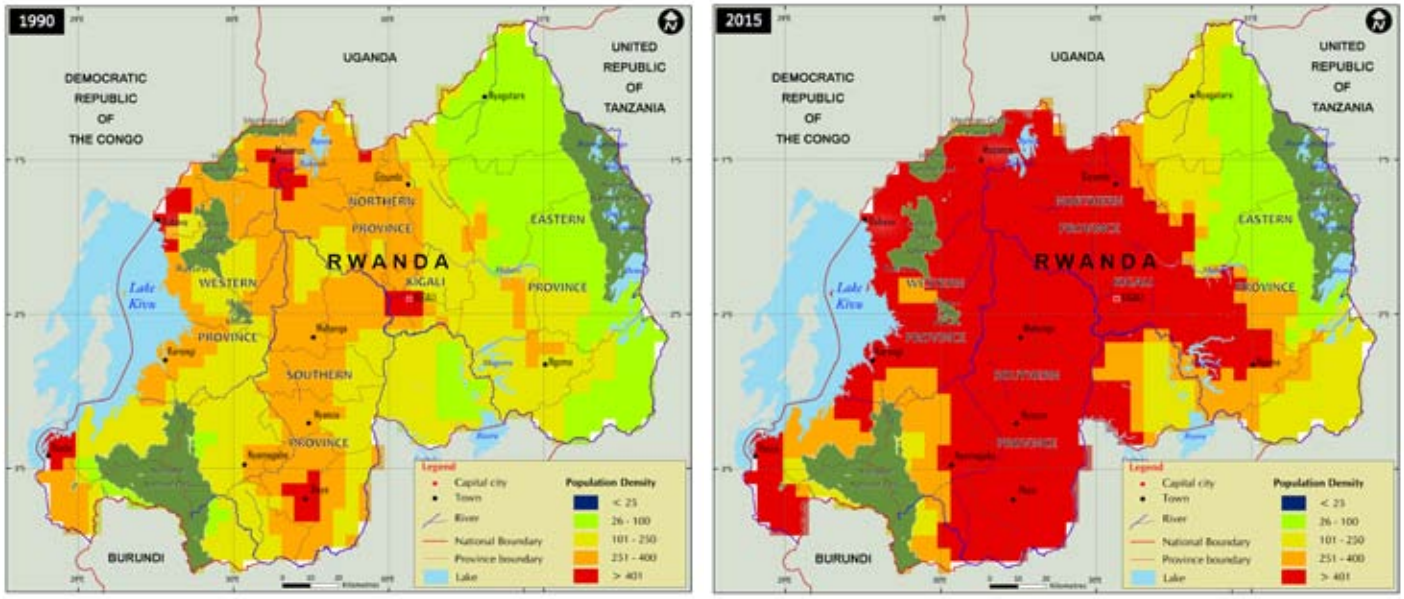
Migration is another demographic factor that has environmental consequences, usually associated with increasing wealth. Rural–to-urban migration, as well as international migration that results in remittances back home, usually increase wealth, which leads to higher energy, meat and dairy consumption with impacts on the environment. For example, with incoming people and rising incomes in urbanizing areas, the number of homes often increases while household size shrinks, as occurs with suburbanization. As a result, land availability for agriculture declines and energy consumption for household goods and services and transport rises (UNEP, 2012).

On the other hand, as shown in the urban chapter of this report, planning and building denser and "greener" cities ensures both environmental protection and wiser economic growth. Similarly, as apparent in Rwanda's GGCR strategy, rural-to-urban migration in the face of increasing population pressure on agricultural areas can both ease environmental pressures and grow the economy (green growth): as people are forced off the land, opportunities for off-farm jobs in green industries and services in well-planned urban centres can lead to increased prosperity (RoR, 2011).

Trends in population numbers and density

Some 11 million people (more precisely, 10,515,973, according to the 2012 Census) live on Rwanda's land surface (of 26 338 km^2), most of them spread over

Figure 6: Population density, 1990-2015



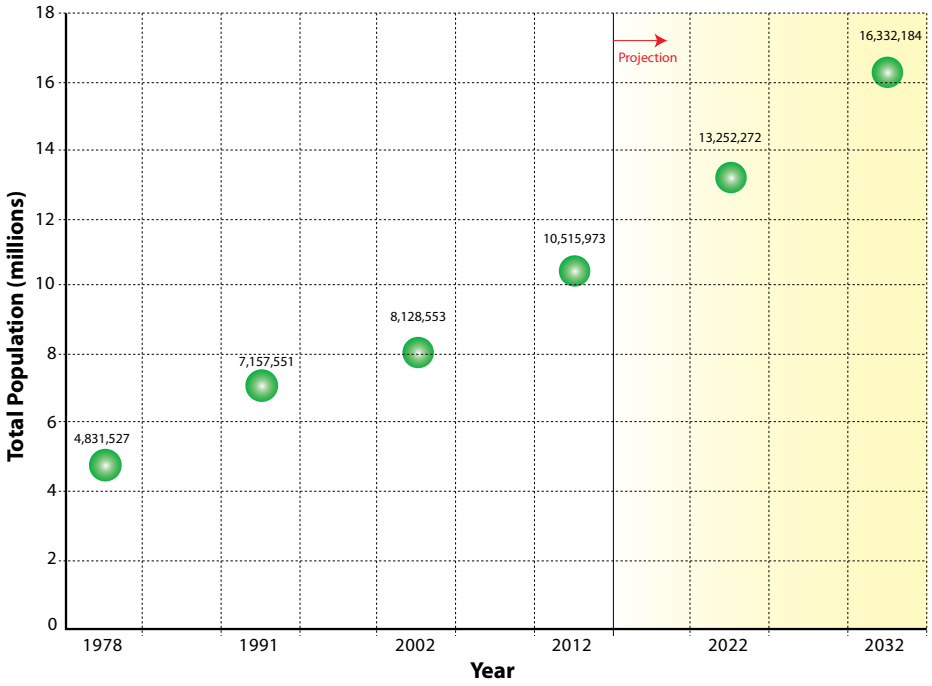
1990 **2015**

Source: updated from (REMA, 2011)

the rural countryside (83 per cent live in rural areas) (NISR, 2014a). The revised Vision 2020 goal is that 35 per cent of the population lives in urban areas by 2020 (RoR, 2012).

The annual population growth rate has slowed from 2.9 in 2000 to 2.8 per cent per year in 2012; if the present rate continues, however, the total population will more than double by 2050 (to 26 million) (RoR, 2011). The population goal in Vision 2020 is to decrease the growth rate to 2.2 per cent per year by 2020 (RoR, 2012). Figure 6 maps population density in 1990 and 2015. Figure 7 shows population growth from 1978 to 2012, with the projection to 2032.

Figure 7: Trend in population growth, 1978 projected to 2032



Sources: (NISR, 2014a) (NISR; MINECOFIN, 2012)

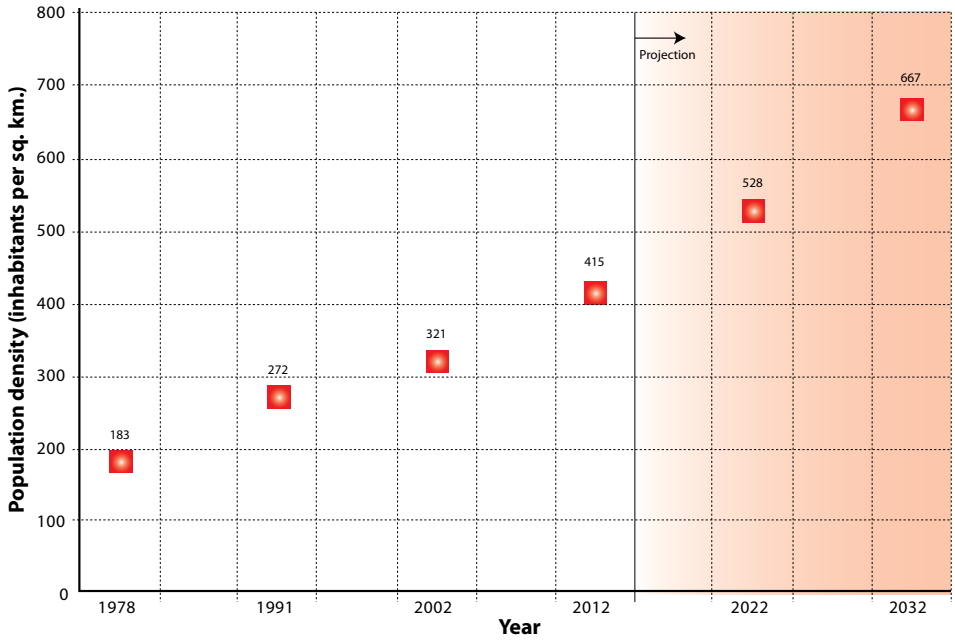
One of the factors that contributed to this increase has been the rise in life expectancy, which increased from 46 in 1978 to 64 in 2012, along with associated indicators such as declining fertility, poverty and maternal and child mortality (NISR, 2014a). For example, in 2012, Rwandan women were having an average of 4 children, down from 5.9 just ten years earlier and from 8.6 in 1978. Vision 2020's goal is to further reduce it to 3 children by 2020 (RoR, 2012). Urban women in Rwanda have fewer children than those living in the countryside: 3.4 children on average for the former, compared with 4.8 children per woman in rural areas. As well, fertility usually varies with the mother's education and economic status; international statistics reveal that on average, women with no education have almost twice as many children as educated women and the poorest women on average have two more children than women who live in the wealthiest households (NISR and ICF International, 2012).

With 415 people per square kilometre (inhabitants/km^2) and a physiological density (number of people per unit area of arable land) of 441 inhabitants/km^2 in 2012, Rwanda's population density is the highest in Africa (NISR, 2014a). This is almost double the density in 1991 (Figure 8). If the trend continues, density

will increase to 987 inhabitants/km^2 by 2050 (RoR, 2011). Figure 9 shows the distribution of population density by District.

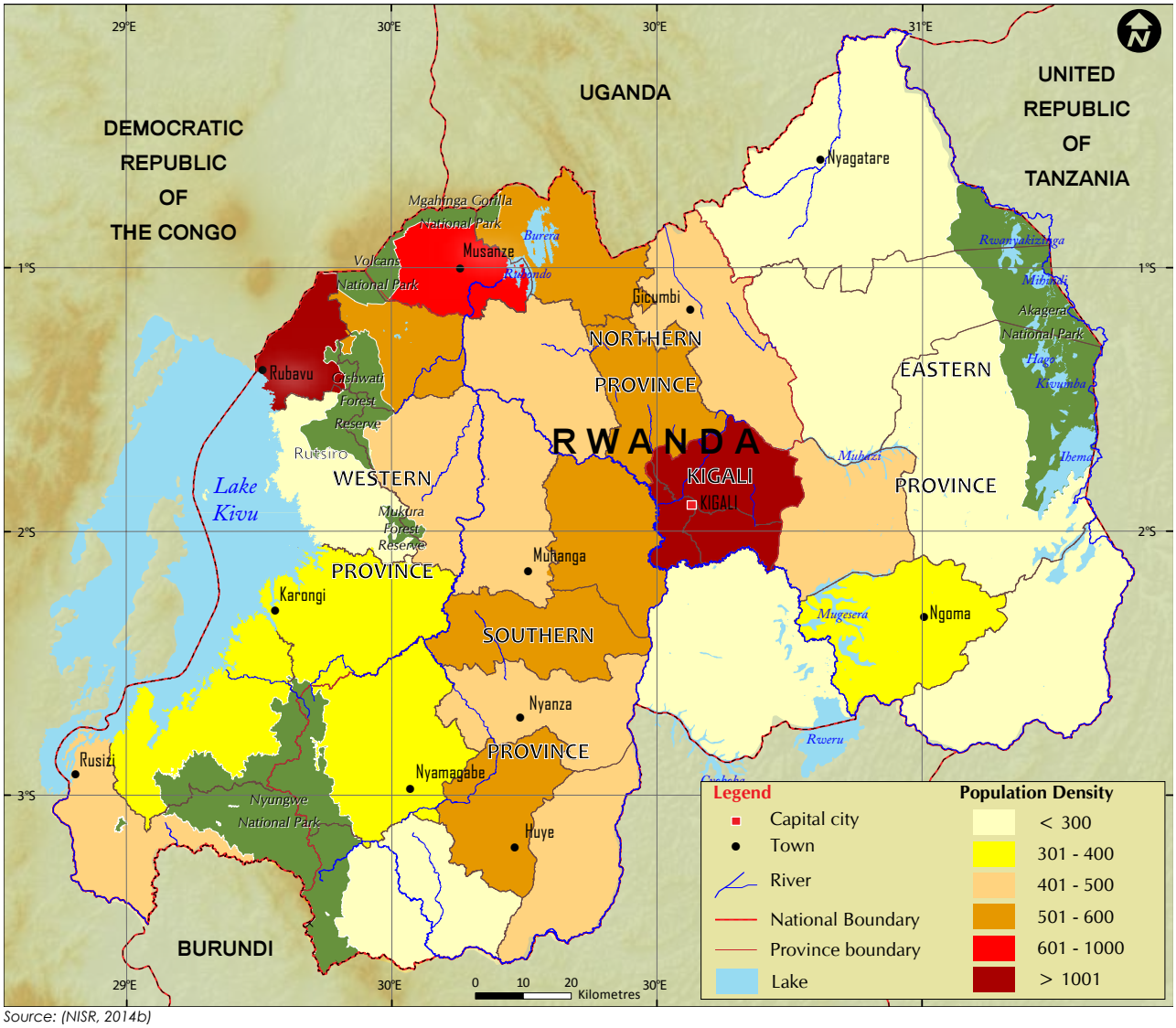
Rwanda is a country of youth. Today more than 40 per cent of the population is under age 15. Although they usually own no land, most of Rwanda's young men are engaged in farming-related activities, doing casual labour, contract farming and trading agricultural produce. Young women are mostly active in the homestead, gaining income by raising poultry and livestock, and growing vegetables, for example. Both female and male youths also earn extra money by fattening livestock, planting trees, building irrigation canals, constructing roof catchments and collecting sand and stone for construction purposes. They generally shun traditional farming, preferring to seek off-farm job opportunities (World Bank, 2014). Young adults are migrating to urban areas to study or seek jobs; 34 per cent of the urban population is now aged

Figure 8: Trend in population density, 1978 projected to 2032



Source: (NISR, 2014b)

Figure 9: Population density by District



Source: (NISR, 2014b)

Dense housing in Kigali is a feature of green urbanization REMA

between 20 and 34 years, compared to 24 per cent of the rural population (NISR, 2014b).

By 2030, the proportion of the population under 15 years old will still be over 35 per cent (PRB, 2012). Thus, productive employment opportunities need to be created, and a competent and skilled youth workforce has to be developed (RoR, 2013). Vision 2020 includes goals that should bridge the gap between the large youth population and unemployment by developing human resources to transition to a knowledge-based economy, matching skills to labour market needs and fostering an entrepreneurial shift in the mindset (RoR, 2012). In particular, the GGCR strategy promotes new jobs in agribusinesses to foster the transition to off-farm employment (RoR, 2011).

Gender and the environment

In 2012, females represented 51.8 per cent of the total population and women headed almost 30 per cent of Rwandan households. Women outnumbered men in rural areas (53 per cent), while the opposite was the case in urban areas, where 49 per cent are female (NISR, 2014c).

Rural women in Rwanda, especially the poor, are intimately involved with their natural environments, depending on ecosystem goods and services for the survival of their families. When these natural resources are lost or degraded, they and their children suffer. They often walk long distances to collect water, fuelwood, wild foods, medicinal herbs, building supplies and other materials for their households, particularly when the natural resources closer to home have already been removed, exhausted, degraded or polluted. In urban areas, they must often wait in line for long hours at communal water points. All these activities leave less time for other productive, social and educational pursuits (REMA, 2010a).

Most rural Rwandan women are subsistence farmers. Because of this close connection to the land and its plants and animals they are a store of local knowledge (REMA, 2010b) that should be valued, especially in light of the need to adapt farming to a changing climate.

Downtown Kigali

1.4 The Economy

The economy and the environment

The environmental impact of economic growth can be positive or negative and both can occur simultaneously, making it difficult to assess the ultimate gains. There is the conundrum of economic growth, which allows greater investments in improving and protecting the environment, but increases consumption, waste and greenhouse gas emissions. The way forward is to "green" the economy, which will improve "human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011a).

Size of the economy and economic growth

Rwanda's Gross Domestic Product (GPD) in 2001 was about 1.8 trillion RWF at 2011 constant prices. The country's economy grew at an average growth rate of almost 7 per cent between 2001 and 2014. As a result, the size of the economy reached about 4.69 trillion RWF at 2005 constant prices, which is more than double the GDP in 2001 (Figure 10).

Figure 10: Rwanda's GDP and GDP growth rate, 2001-2014

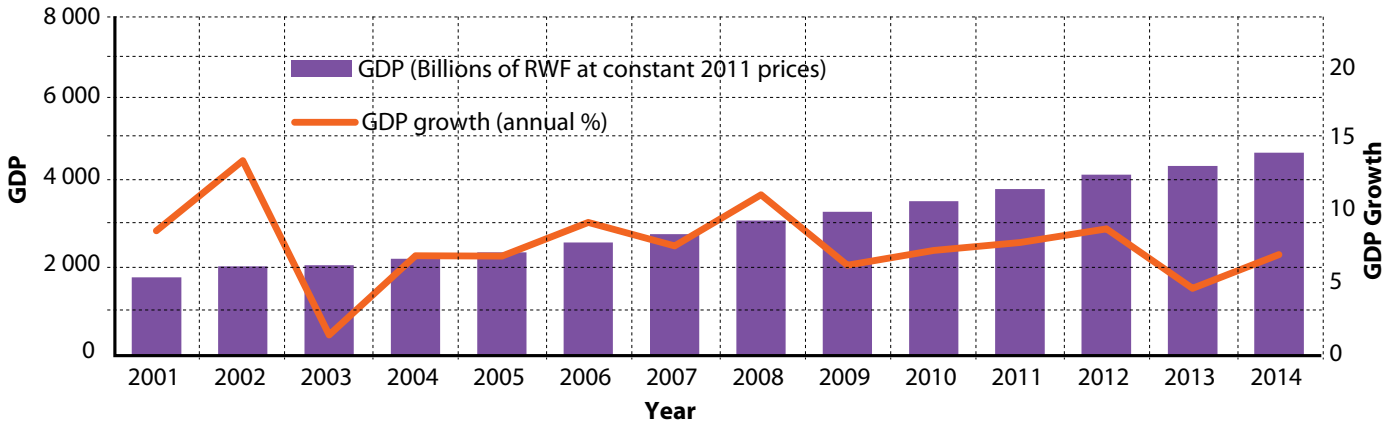
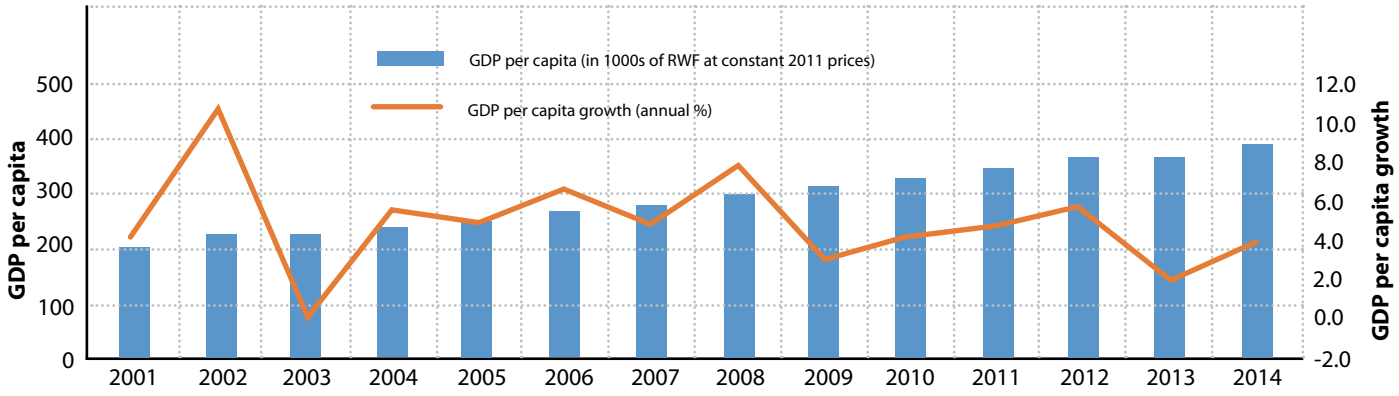


Figure 11: Trend in GDP per capita, 2001-2014



Source: Based on World Bank Database (Word Bank, 2015a)

Per capita GDP

GDP per capita at constant 2011 prices grew at an average annual rate of 4.92 per cent over the period 2001-14, rising from 207,000 RWF to 387,000 RWF over that time (Figure 11).

Although Rwanda enjoyed an encouraging growth in GDP per capita, the distribution of income is highly uneven. In 2011, income of the poorest 20 per cent of the population accounted for 5.16 per cent of the national income, while the income of the richest 20 per cent of the population accounted for 56.84 per cent of the national income.

Structure of the economy by sector and expenditure

The primary sector's share of GDP was 37 per cent in 2001 but declined to 33 per cent by 2013. Its average share of value added to total GDP over the period 2001-2013 was about 35.35 per cent. In other words, close to one-third of the country's economy depends mainly on agriculture, which itself primarily depends on the natural environment and ecosystem services.

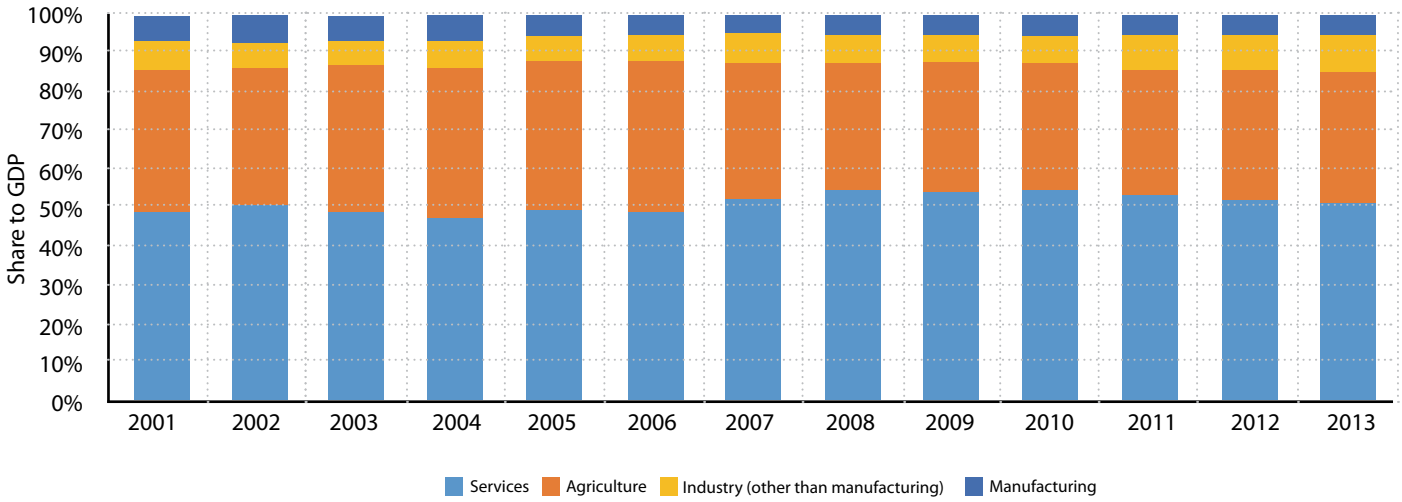
The service or tertiary sector was the main contributor to the country's GDP over the period 2001-2014 and its share to GDP has been growing (Figure 12). From 2001 to 2005, the average share of value added to total GDP in the tertiary sector was about 49 per cent; from 2006 to 2013, it grew to 53 per cent. The value added in the secondary sector (manufacturing and non-manufacturing industries), contributed an average of about 13.2 per cent of Rwanda's GDP over the period 2001-2013 (Figure 12).

Accounting for natural wealth

Gross Domestic Product (GDP), as illustrated above, only measures income as a proxy for economic performance and national wealth. It does not account for the ecosystem goods and services that underlie this income. Natural capital is a critical asset, especially for developing countries where it accounts for an average 36 per cent of total wealth (World Bank, 2015b). According to GDP measures of wealth, mineral exploitation, timber harvests and agricultural outputs increase GDP; on the other hand, these activities deplete the natural wealth of other ecosystem goods and services these resources provide, such as carbon sequestration, air and water filtration and biological diversity (World Bank, 2015b).

The link between the economy and ecosystem services is illustrated by the fact that nutrient depletion through soil erosion on Rwanda's agricultural lands is causing a decline in crop productivity. A recent ongoing study by the Economic Valuation of Options (Scenarios) working group of the Economics of Land Degradation Initiative — a global initiative for sustainable land management — focuses on the Economics of Agricultural Land Degradation in Africa (UNEP, 2015). Preliminary findings reveal that nutrient loss through erosion is causing a considerable loss in productivity of cereal crops in Rwanda. It was estimated that in the cropping seasons of 2010-2012, there had been a loss of about 11,300 tonnes of NPK nutrients per year from about 400,000 ha of land cultivated with cereal crops. The loss in cereal crops due to soil erosion-induced nutrient depletion was estimated at about 406,700 tonnes/year or 1.02 tonnes/ha/year (UNEP, 2015). The gross value of the crop loss was equivalent to about

Figure 12: Value added by sector as a percentage of Rwanda's GDP, 2001-2013



Source: Based on World Bank Database (Word Bank, 2015a)

8.94 per cent of the country's agricultural GDP for the same period (2010-2012) (UNEP, 2015).

Thus, GDP is a misleading gauge of a country's economic performance and well–being and needs to be adjusted to account for resource depletion, pollution and declining ecosystem services (UNEP, 2011a). One way to include natural wealth in economic terms is through natural capital accounting.

Natural Capital Accounting

In 2012, the UN Statistical Commission adopted a System for Environmental and Economic Accounts (SEEA). This provides an internationally–agreed upon method to account for material natural resources like minerals, timber and fisheries (World Bank, 2015b). Rwanda recognizes that Natural Capital Accounting (NCA) can add value to the national development planning process by focusing attention on economically important natural resource sectors and providing consistent, reliable data to support economic assessments (WAVES, 2015a).

Rwanda has thus recently joined the Wealth Accounting and Valuation of Ecosystem Services (WAVES), a global partnership led by the World Bank that aims to mainstream natural capital in development planning and national economic accounting systems (WAVES, 2015b). Rwanda is committed to implementing Natural Capital Accounting and now has an NCA Steering Committee and a Technical Working Group. It has completed a scoping phase and approved sectoral priorities and a work plan for implementation. During the first year, it will focus on land and water accounts (WAVES, 2015a).

Land and water accounts will contribute to assessing Rwanda's progress towards greening its agriculture sector because land availability and productivity and water supplies are potential constraints to agricultural growth, a key pillar of Rwanda's development agenda (WAVES, 2015a).

Green growth

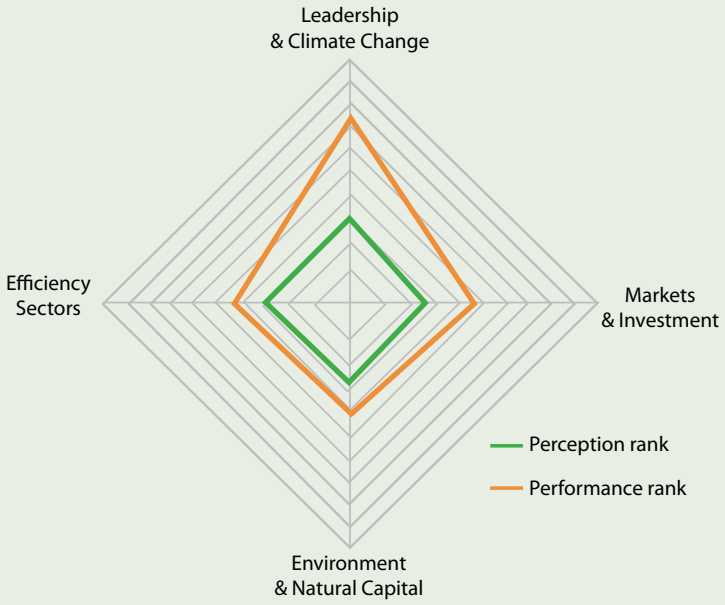
The move towards promoting "green" growth, instead of economic growth for growth's sake, is an important development in the international community towards accounting for the environmental resources that underpin the economy and measuring well-being in more human terms. The Global Green Growth Institute (GGGI) defines green growth as "balanced economic growth that results in a broad based improvement in key aspects of social performance, such as poverty reduction, job creation and social inclusion, and environmental sustainability, such as mitigation of climate change, conservation of biodiversity and security of access to clean energy and water" (GGGI, n.d.).

In short, the Green Economy improves "human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011a). In its 2011 Green Economy Report, UNEP reports that compared to conducting "Business As Usual" or "BAU", investing in the green economy produces more growth and jobs and provides clean water and

Box 1: Rwanda could become the top performing African nation on the GGEI

Rwanda's performance in advancing the green economy greatly exceeds the general perception of its progress (Figure 13). The authors of the Global Green Economy Index suggest that Rwanda should improve the communication of its stellar progress in green growth to advance a global understanding of its green economy and associated market opportunities. They note that although Rwanda ranks as the top African performing nation on the Markets & Investment dimension, its corresponding perception rank is extremely low. The same is true for the Leadership and Climate Change and Efficiency Sectors. They suggest that with continued focus on green economic growth, Rwanda could quickly become the top performing African nation on the GGEI (Dual Citizen LLC, 2014).

Figure 13: Rwanda's GGEI ranking



Source: (Dual Citizen LLC, 2014)

energy services to more people while also reducing greenhouse gas emissions (GHG) and improving the environment in many ways in the medium and long terms. The United Nations Conference on Sustainable Development (UNCSD) or the Rio+20 Summit in 2012 endorsed the green economy as an important mechanism for achieving sustainable development (Barr, 2013).

Rwanda is committed to greening its economy, as outlined in its Green Growth and Climate Resilience Strategy, the National Strategy for Climate Change and Low Carbon Development (RoR, 2011). It also participates in UNEP's Green Economy initiative. Indeed, UNEP has developed a set of Green Economy Indicators (GEI) to enable member nations to measure their progress in transitioning to a green economy (UNEP, 2014). Accordingly, Rwanda has recently developed a set of national indicators for sectors that are critical to transitioning to a green economy: agriculture, forestry, water, energy, mining and extractive industries, transport and sanitation and urban development, and will be using these to measure its progress in the future.

Rwanda's ranking on the Global Green Economy Index

The Global Green Economy Index (GGEI) is an innovative method to assess a country's progress towards greening its economy. The 2014 GGEI performance index is based on gauging performance in four main dimensions: 1. Leadership and Climate Change; 2. Efficiency Sectors; 3. Markets and Investment; and 4. Environment and Natural Capital. These dimensions are measured through 32 underlying indicators and datasets. The GGEI produces two rankings: one for actual performance, and another, the perception rank, which is the result of polling targeted respondents asking them to assess national green performance on the four main dimensions. According to the 2014 GGEI, Rwanda ranks 27th out of 60 countries in the performance rank but 48th in the perception ranking. Rwanda's performance score exceeds its perception one significantly – "signaling significant opportunities for improved green country branding and strategic communications" (Box 1) (Dual Citizen LLC, 2014).

Small-scale agroforestry REMA

1.5 Poverty

Poverty and the environment

The poor, who for the most part live close to the land, are directly dependent on their immediate environments. Poor households in particular rely heavily on expenditure-saving, labour-intensive activities for their subsistence and survival, such as growing food, collecting water and fuel wood or grazing animals.

About 83 per cent of Rwandans live in rural areas and depend on the resources they can eke out of the land and waters for their sustenance and livelihoods. Agriculture accounts for almost half of aggregate household income, and much more for poor households (Hernandez, 2013). Any degradation of their land deepens their poverty.

Given the right circumstances, however, the poor are able to nurture their environments on a sustainable basis, improving material and social well-being for themselves and their offspring. Thus, rather than linear and causal, the poverty – environment connection is a very complex, multifaceted, multidimensional and context-specific one, varying over time and space (Koziell & Saunders, 2001).

Definitions of poverty

Poverty can be measured in many ways. The World Bank uses absolute terms, such as its definition of extreme poverty as living on less than US$1.25 per day and moderate poverty as less than $2 a day. The meaning of poverty, however, has evolved to a broader and more nuanced understanding that describes a condition of deprivation (Box 2).

Box 2: Multidimensional definition of poverty

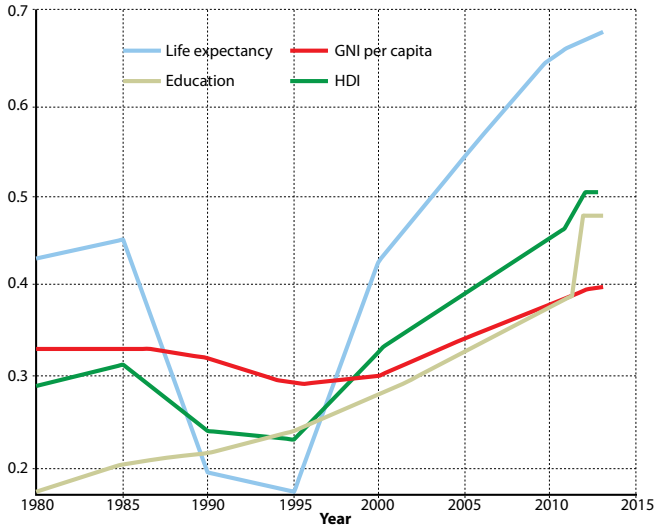
A multidimensional definition of poverty includes "*lack of opportunities* (such as unacceptable low levels of consumption or income and low levels of productive assets), *low capabilities* (low levels of health and educational achievements), *low security* (high uncertainty and great risks of natural, environmental, social, and economic shocks), and *low level of empowerment* (limited access to and participation in decision making and social processes)" (Henninger & Hammond, 2002).

Table 3: Definitions of poverty and inequality and Rwanda's status

Agency/method	Definition	Rwanda's status
World Bank: World Development Report (WDR) on Poverty	Extreme poverty: living on less than US$1.25 per day Moderate poverty: living on less than US $2 a day	• Extreme poverty: 63.17 per cent of the population (2002-2012)
UNDP: Multidimensional Poverty Index (MPI)	Indicators: monetary, health, education and living standards	• Multidimensional poverty: 49.7 per cent of the population (2010)
UNDP: Human Development Index (HDI)	Indicators: life expectancy at birth, years of schooling and Gross National Income per capita	• Ranked 151 out of 187 countries and territories (2013) • Average annual increase of about 1.69 per cent (1980- 2013)
National Institute of Statistics for Rwanda (NISR): Household consumption	Indicators: purchases of food and non-food as well as consumption of home-production of food and non-food (education, health, housing, utilities); value of in-kind wages and transfers	• Household consumption per adult equivalent grew at 2.5 per cent per year • Poverty headcount: 44.9 per cent (2000-2011) • Percentage of poor female-headed households: decline from 66 to 47 per cent (2000-2011)
UNDP: Gender Inequality Index (GII)	Indicators: reproductive health, empowerment, and economic activity	• Ranked 79 out of 149 countries and territories (2013)

Sources: (UNDP, 2014a) (UNDP, 2014b) (NISR, 2012c) (NISR, 2014c)

Figure 14: Trends in Rwanda's HDI component indices, 1980-2013



Source: (UNDP, 2014b)

Table 3 shows various methods of defining and measuring poverty and Rwanda's poverty status and trends according to each scheme.

Rwanda has made significant progress in reducing the proportion of its population defined as poor. Figure 14, for example, shows the progress Rwanda has made on the Human Development Index from 1980 to 2013.

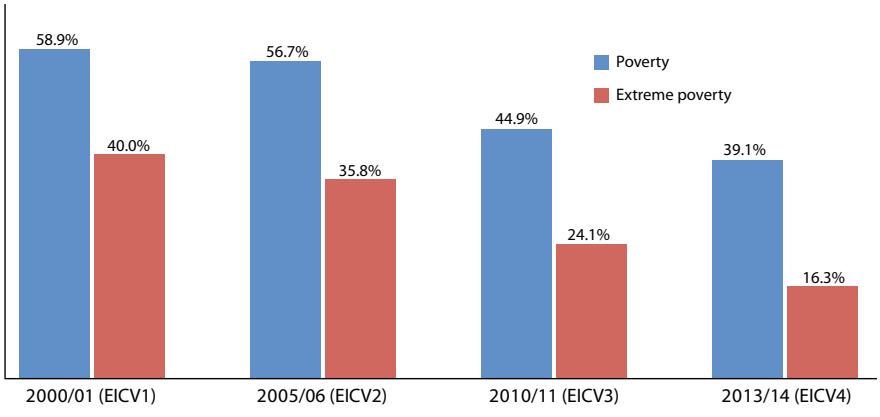
Figure 15 shows that the share of the national population living below Rwanda's poverty line, defined by household consumption, dropped from 59 per cent in 2000/01 to 39.1 per cent in 2013/14.

Table 4 (see next page) shows Rwanda's Gender Inequality Index (GII) values and compares them to the average of low human development countries, highlighting its remarkable progress towards gender equality and development. The proportion of women holding parliamentary seats continues to rise: after the 2013 Rwandan Parliamentary elections, it rose to 64 per cent (One UN, 2013).

Food insecurity

Food insecurity is another indicator of poverty since it is largely a function of poverty and low incomes (RoR, 2009). It is intimately linked to the environment and health through the level of access to the goods and services offered by agriculture (MINAGRI, 2013). Generally, food security depends on food availability

Figure 15: Trend in the percentage of people living below the poverty line, 2001-2014



Source: (NISR, 2015)

Table 4: Gender Inequality Index (GII) for Rwanda, 2013

	GII value	GII rank	Maternal mortality ratio	Adolescent birth rate	Female seats in parliament (%)	Population with at least some secondary education (%)		Labour force participation (%)	
						Female	Male	Female	Male
Rwanda	0.4	79.0	340.0	33.6	51.9	7.4	8.0	86.5	85.5
Low HDI	0.6	-	427.0	91.1	20.0	15.2	29.1	55.7	78.4

Source: (UNDP, 2014b)

Table 5: Perceived causes of poverty in Rwanda in 2007

Cause	Share of respondents (%)
Lack of land	49.5
Poor soils	10.9
Drought/weather	8.7
Lack of livestock	6.5
Ignorance	4.3
Inadequate infrastructure	3
Inadequate technology	1.7
Sickness	1.7
Polygamy	1.2
Lack of access to water	1.1
Population pressure	0.7
Others	10.6
TOTAL	**100**

Source: (REMA, 2009)

and stability (sufficient quantity and quality, available on a consistent basis where needed), accessibility (sufficient and appropriate food resources for a nutritious diet), and use (for basic nutrition) (Caouette, Taylor, Trowell, & Buckles, n.d.). Food security can be defined as the state in which all persons obtain a nutritionally adequate, culturally acceptable diet at all times through local non-emergency sources (Parikh & Parikh, 1996).

Poor rural households with very small plots of land are the most food insecure and are also the most vulnerable to shocks that disrupt food production. The 2012 Household Survey (EICV) found that 21 per cent of households have inadequate levels of food provision (NISR, 2012c).

As a result of food insecurity, households are also vulnerable to malnutrition, illustrating the link between poverty and human and environmental health (MINAGRI, 2013).

Causes of poverty in Rwanda

The 2009 SEOR report provided a table showing the causes of poverty as identified through the first EDPRS Poverty Analysis of Ubudehe. It is reproduced here for its valuable information, although a new survey would undoubtably find fresh results given the progress in addressing soil erosion and improving health and education and other factors (Table 5).

Land related poverty

Poor soils and low agricultural productivity, lack of control over land management and competition from other users are some of the conditions that threaten household food security, which is a symptom of poverty (Parikh & Parikh, 1996). Land related poverty refers to the inability of a farmer's land to provide basic food security. Lack of access to land or landlessness deprives rural people of the opportunity to produce surplus agricultural products for storage and the market, which affects the ability to meet basic needs (Musahara, Nyamulinda, Claude, & Niyonzima, 2014).

Between the two Integrated Household Living Conditions surveys of 2000/01 and 2005/06, land shortage for cultivation was the major impediment in Rwanda's agriculture sector and one of the main contributors to poverty (MINECOFIN, 2012).

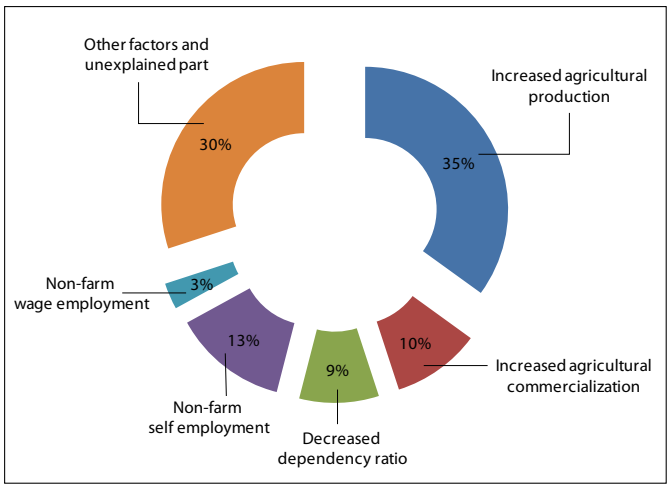
The Economic Development and Poverty Reduction strategies have found that prevalence of poverty is associated with low productivity in subsistence agriculture. Poverty is highest by far (76.6 per cent) among households (often landless) who obtain more than half their income from working on other people's farms. The next poorest group is those with diversified livelihoods who obtain more than 30 per cent of their income from farm wage work (76.2 per cent) (RoR, 2013).

Drivers of poverty reduction

Although there has been a significant decline in the proportion of Rwandans living in poverty, the absolute number of poor people has only declined marginally because of population growth. While the poverty headcount dropped by 24 per cent between 2001 and 2011, the absolute number of people living in poverty dropped by only 1 per cent. Although poverty in Rwanda is still pervasive, its severity is declining and the outlook for further poverty reduction is

Figure 16: World Bank's interpretation of the factors that contributed to poverty reduction

(Contribution of the various factors to poverty reduction between 2001 and 2011, percentage)



Source: (Hernandez, 2013) [from EICV 1 and EICV 3 and World Bank staff calculations]

encouraging (Hernandez, 2013).

Increased farm productivity, non-farm employment and livelihood activities

An analysis of EICV 3 by UN Rwanda attributes the decline in poverty to three main reasons: "an increase in non-farm employment, which is most likely to pay a non-poverty wage; an increase in farm productivity; and an increase in the number of livelihood activities in which an individual engages, such as running small businesses" (One UN, n.d.).

The second EDPRS confirms this reasoning, noting the significance of the Crop Intensification Programme (CIP) that leads to increased agricultural productivity, despite the decline in the size of cultivated plots (RoR, 2013). Data also show that production increases had a role to play in the reduction in the proportion of underweight children under 5 from 29 per cent to 11 per cent between 1990 and 2010/11, and the decline in maternal and under-five mortality rates (MINAGRI, 2013).

Another factor was the successful marketing of produce. Between 2005 and 2011, for example, the sale of household output grew from 18 per cent to about 25 per cent of the output. These two factors have meant higher incomes for the average agricultural household. The EDPRS II also points to the increased contribution of off-farm income to rural households, particularly wage and self-employed income. Finally, the decline in average household size lead to reduced consumption needs (RoR, 2013).

Figure 16 shows the World Bank's calculation of the proportion each of these factors contributed to poverty alleviation between 2001 and 2011, suggesting that increased agricultural productivity accounted for 35 per cent and non-farm employment explains 16 per cent.

Rwanda's One-Cow-per-Poor-Family Programme (Girinka), implemented since 2006, has also contributed to food security and nutrition, since it led to increased milk production and consumption as well as additional income from milk sales with which to buy food (IFAD, 2014).

Ubudehe

Rwanda has had enormous success in assessing and addressing poverty at the community level through one of its "homegrown" solutions called Ubudehe. It refers to the long-standing Rwandan practice and culture of collective action and mutual support to solve problems within a community (Ubudehe, n.d.). Box 3 provides a case study of this remarkable programme, which has won the celebrated UN Public Service Award because of high participation levels and Rwanda's significant efforts to alleviate poverty (Niringiye & Ayebale, 2012).

Goals and targets for reducing poverty

The Millennium Development Goals (MDGs)

In 2000, the world community agreed on a framework for measuring development progress called The Millennium Development Goals, with a 2015 deadline. There are eight overarching goals, together comprising 18 targets and 48 indicators. The first six goals are mutually reinforcing and focus on reducing poverty, hunger, inequality, ill-health, and other manifestations of poverty. The seventh goal is for the achievement of environmental sustainability, and the last one calls for a global partnership for development, outlining the means to achieve the first seven. The goals are addressed to all countries, rich and poor. The MDGs have specific targets, most of which have quantifiable, time-bound values to measure progress against the goals. Rwanda adopted the MDGs along with 191 other countries.

The first MDG is to eradicate extreme poverty and hunger. Three years ahead of 2015, Rwanda has achieved or was on track to achieving all the MDGs, with the exception of MDG1. As is evident in Rwanda, the poor more than any others depend on environmental resources for an important part of their food supply and as the basis of income-generating activities. Thus, one of the most powerful ways to help achieve the first MDG is to ensure environmental quality and quantity is maintained in

the long term (through the sustainable management of land, water and biodiversity resources and the adequate provision of urban sanitation, potable water and waste management), which is the aim of the 7th goal. Minimizing the exposure to environmental risks, such as polluted water, indirectly contributes to reducing poverty, because many environmentally-related diseases lead to lost earnings (Prüss-Üstün & Corvalán, 2006).

According to the 2013 MDG Report prepared by the United Nations Development Programme (UNDP) in Rwanda, though not yet published, Rwanda is doing well overall on MDG 7.

Vision 2020 and EDPRS

The poverty target for Vision 2020 is to reduce the proportion of the population under the poverty line to 20 per cent (from 45 per cent in 2012) (RoR, 2012). The EDPRS's overall objective was to reduce the share of the population living in poverty from 56.9 per cent in 2005/6 to 46 per cent in 2012/13. This target was surpassed one year ahead of time; by 2010/11, 44.9 per cent of the population was living under the poverty line and since then, to 39.1 per cent by 2013/14 (NISR, 2015). The extreme poverty target of 24 per cent was also almost met, with 24.1 per cent under that poverty level in 2011, having declined from 37 per cent in 2005/6 (MINECOFIN, 2012).

Box 3: Identifying and addressing poverty and inequality in Rwanda with Ubudehe

Ubudehe fosters participatory community development and empowerment, democracy, reconciliation, unity and local solutions to local problems. Its objectives are as follows:

- To assist people to classify the level and type of poverty that exists in their community and reach a common understanding of this classification
- To help communities define their development priorities
- To bring communities together to discuss and decide upon the most effective and efficient ways to achieve poverty reduction and their development priorities
- To help communities establish ways of funding their development plans, at a group and individual level

The Ubudehe process involves the following steps:

1. Determine the poverty profile as perceived by the people themselves
2. Determine the causes and consequences of poverty
3. Draw up the social map of the cell showing the names of household heads, their social category (different categories are again decided by the people themselves) and development infrastructure
4. Identify and analyse the problems facing the community and determine a priority problem to be addressed
5. Plan the activities and resources needed for addressing the prioritised problem through a collective action plan (Ubudehe)
6. Put in place a system to manage the identified collective action
7. Submit the action plan to an applicability test for all stakeholders to see if the strategies are the best to solve the identified problem
8. Check if collective action principles are respected
9. The management committee, elected by the community, local technicians, local authorities and other stakeholders approve the execution of the collective action and engage to safeguard and respect the principles of collective action
10. After this process, funds are made available to support the identified Ubudehe collective action

Under the programme, households are put in categories based on their socioeconomic status, their property and other belongings and their employment. The categories, as redefined in 2014, are as follows:

Category 1: Families who do not own a house and can hardly afford basic needs.

Category 2: Those who have a dwelling of their own or are able to rent one but rarely get full time jobs.

Category 3: Those who have a job and farmers who go beyond subsistence farming to produce a surplus, which can be sold. The latter also includes those with small and medium enterprises who can provide employment to dozens of people.

Category 4: Those who own a large-scale business, individuals working with international organisations and industries, as well as public servants (RoR, 2015).

An independent study of Ubudehe conducted in 2012 found that at least 1.4 million people have directly benefitted from the programme through improved incomes, and unintended changes such as job creation and the construction of class-rooms, health centres, roads and bridges, mills, electricity and water infrastructures and radical terraces (Niringiye & Ayebale, 2012).

Rwanda is moving towards e-based learning. REMA

1.6 Education

Education and the environment

The United Nations Environment Programme notes that an educated society has the wherewithal to advocate on behalf of the environment (UNEP, 2012). Providing environmental education in schools, higher education and extra curricular programmes produces a society with the knowledge to address environmental concerns, while vocational and farmer training builds technical capacity to directly improve environmental conditions, especially given Rwanda's dependence on agriculture for people's livelihoods. Educating women is also of prime importance in Rwanda; since more women participate in subsistence agriculture than men (RoR, 2012), they can have an important influence on greening farming techniques and bettering livelihoods for a green economy.

Environmental awareness and care for our immediate surroundings is cultivated in families and by cultural values before it is learned in formal educational settings such as schools and universities, or in other social settings oriented to bringing attention to environmental issues, such as groups that advocate for protecting nature. Thus, environmental education "includes the provision of information in a systematic and structured way, but usually goes further, encouraging deeper understanding and, perhaps, values and norms regarding behaviors" (Dietz & Stern, 2002) (Box 4).

Box 4: Environmental education

Environmental education was formally recognized at the 1972 UN Conference on the Human Environment in Stockholm, Sweden. In 1975, the Belgrade Charter was signed, defining environmental education as a "comprehensive lifelong education, one responsive to changes in a rapidly changing world. It should prepare the individual for life through an understanding of the major problems of the contemporary world, and the provision of skills and attributes needed to play a productive role towards improving life and protecting the environment with due regard given to ethical values" (UNESCO, 1975).

Environmental information and education plays three roles:

1. It informs "responsible citizenship: to help close a gap between what people know or are able to know on their own and what they need to know in order to make well-informed voluntary decisions";
2. It responds "to the citizen's right to know by ensuring that information to which the citizen has a legal and/or moral right is made available"; and
3. It increases "the efficiency of consumers' and producers' responses to economic and other signals of the need to change behavior to reduce environmental costs" (Wilbanks & Stern, 2002).

Thus, the goal of environmental education is to "develop a … population that is aware of, and concerned about, the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations, and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones" (UNESCO, 1975).

Rwanda has numerous educational initiatives aimed at creating greater awareness of environmental issues, and training and capacity building programmes to build a future workforce that has the knowledge and tools to protect and restore the country's natural resources and environmental assets.

Education for sustainable development

The Rwandan government has prepared a strategy for Environmental Education for Sustainable Development (EESD) and developed a five-year Action Plan and implementation framework. It sees Education for Sustainable Development as an opportunity to continuously build its citizens' capacity to implement healthy ways of using the country's resources and to lead productive livelihoods with improved quality of life (REMA, 2010c).

The EESD strategy's specific objectives are as follows:

- Education and awareness to increase public participation in sustainable development;
- Capacity build future leaders to have the commitment, expertise and leadership to ensure sustainable development;
- Integrate Environment and Sustainability issues in the School Curriculum to improve the quality of learning and make it relevant to the needs of the society;
- Capacity build the media to report and communicate sustainable development by providing information required to address pertinent sustainable developmental challenges;
- Enhance the quality and relevance of Technical and Higher education to respond to local sustainable development challenges (REMA, 2010c).

Greening Schools Programme

Initiated in 2011 by REMA in partnership with the Ministry of Education and Districts, the Greening Schools Programme implements the EESD strategy by using EESD as a tool to mainstream environment and climate change for sustainability within the education system (REMA, 2015a). It improves environmental conditions in schools, raises environmental awareness and inculcates environmental and health values among school children. So far, more than 205 schools have benefited from this programme. Through it, children are engaged in hands-on activities to create environmental friendly learning conditions at school, such as agroforestry tree planting, greening school grounds and using improved handwashing facilities, among others. The schools are also provided with various green infrastructures, including water-harvesting tanks, compost pits to manage waste and hygiene and sanitation facilities (REMA, 2014a). A 2015

Children watering the school garden. ARAMA

review of the state of EESD mainstreaming in schools and Higher Learning Institutes revealed that capacity building and the availability of resource materials are still a challenge in most schools. Regional Centres of Expertise are still lacking and there is a need to clearly define implementing agencies and design a better resource mobilization strategy (REMA, 2015a).

Eco-Schools

To address environmental and health conditions in many schools, alleviate poverty and to provide some environmental protection and climate change adaptation and mitigation in the education sector, eco-school programmes are being piloted in 100 schools in 4 Northern and Eastern Districts: Gatsibo, Gicumbi, Ngoma and Kirehe. Initiated in January 2013 at the same time as EDPRS II, they are implemented by a consortium of two Rwandan civil society organizations, ARAMA and FSDS (Association de Recherche et d'Appui aux Mouvements Associatifs or Association for Research and Support to Associations and the Foundation Saint Dominique Savio) (Eco-Schools, 2013)(Box 5).

Capacity building in the transition to a green economy

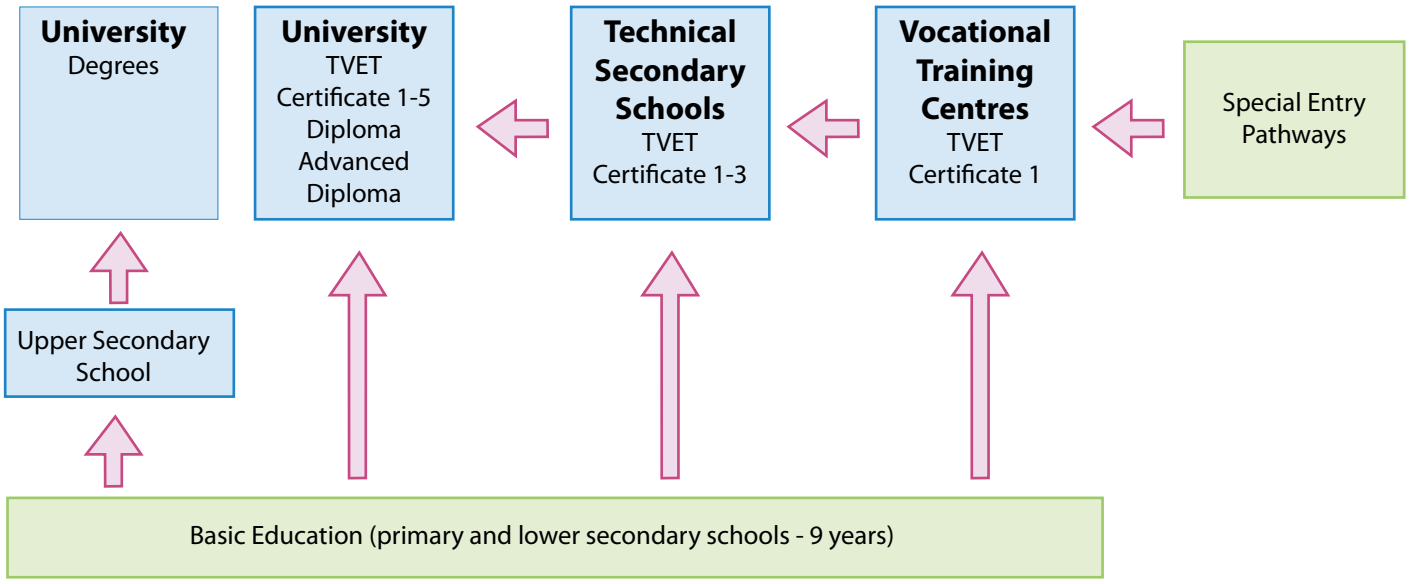
Education is not just for children. In Rwanda's march towards its Vision 2020 goals and those of the GGCR strategy, one of its greatest challenges is building Rwanda's human resource capacity. Many of the strategy's programmes of action are knowledge intensive and require new skills across sectors and management levels (RoR, 2011). School education is the foundation for capacity building, since it increases the number of children who can go on to technical or university training. This is reflected in the GGCR strategy's education framework, illustrated in Figure 17.

Rwanda is preparing a comprehensive capacity building plan. In addition to supporting short courses with international experts, on-the-job experience and training, it provides graduate scholarships to international courses in climatology, meteorology, climate finance, sustainable natural resource management, green engineering, geographical information systems and climate sensitive diseases (RoR, 2011). Creative radio programming, demonstration projects, community exchange visits and farmer field schools (see Box 6) are all critical for building capacity in rural areas.

Box 5: Eco-Schools: environmental literacy and poverty alleviation

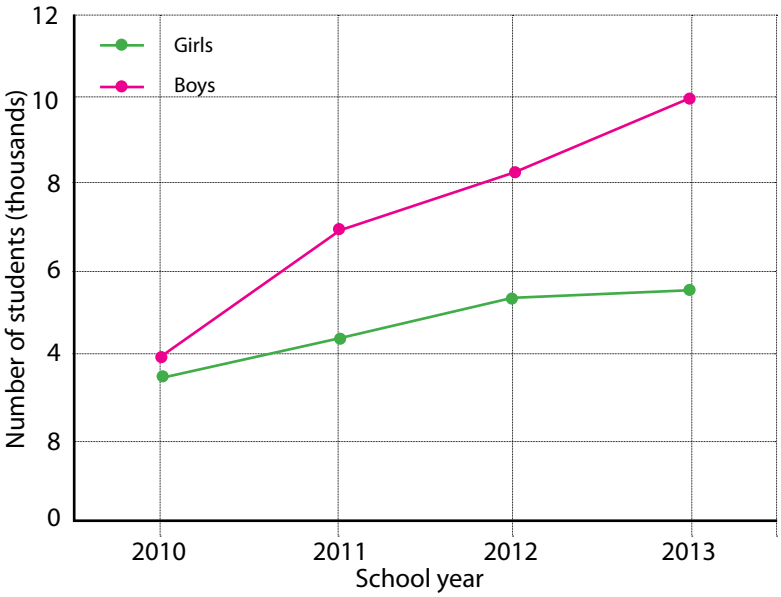
The Eco-schools involve students in environmental education and activities (planting lawns and trees, saving water and energy, practicing litter and waste management and conserving biodiversity) and improve their health through a school feeding programme with food the students grow in the schools' gardens (ARAMA, 2014). By 2014, 343 teachers and head teachers had been trained on Eco-schools and 119,019 primary school students and 9,941 secondary school students had benefited from the programme. Initiatives to scale up eco-schools are underway in the four districts to foster sustainable thinking and action among Rwandan students with the goal of "making the world a better place to live and learn" (ARAMA, 2014).

Figure 17: Education framework for the GGCR strategy



Source: (RoR 2011)

Figure 18: Trend in enrolment in Vocational Training Centres (VTCs), 2010-2013



Source: (MINEDUC 2014)

Capacity Building and Knowledge Management is one of five enabling pillars in the GGCR strategy. Its priorities are as follows:

1. Improve education by expanding school curricula, tertiary education, technical and vocational training and farmer field schools to address climate resilience and low carbon development;
2. Develop capacity within national and sub-national governments through exchange programmes, university partnerships, training focal points, professional development and pilot villages;
3. Improve knowledge management and public awareness through an online Climate Portal, creative radio programming, short training courses, demonstrations of best practice in communities and community exchange visits;
4. Engage in regional and international forums and partnerships on climate and sustainable development topics;
5. Ensure adequate education and training is provided for women and girls (RoR, 2011).

Vocational education

To implement the GGCR strategy, Technical and Vocational Education and Training (TVET) will be expanded to develop skills in energy and water efficiency, renewable energy, agroforestry, passive housing, organic agriculture, waste recycling and drip irrigation (RoR, 2011). Student numbers, staffing and infrastructure have already risen in Rwanda's Technical Vocational Education and Training sub-sector as shown in Figure 18 (MINEDUC, 2014).

Extension services and farmer field schools

Education enhances the ability of farmers to access accurate information on their products, agricultural inputs and practices and better educated farmers are more likely to contact an extension agent to address problems. A 2011 study on the Modernization of Extension and Advisory Services in Rwanda concluded that the country has the needed elements to implement a strong, well-trained and competent farmer-driven extension system, which in turn will help to increase agricultural productivity and reduce rural poverty (Swanson, Mutimba, & Remington, 2011).

Farmer Field Schools (FFS) is a non-formal adult education method used as a participatory agricultural extension approach (Box 6).

Box 6: Farmer Field Schools (FFS)

Farmer Field Schools (FFS) teach farmers to better understand the production system and improve their decision making capacity. "Learning by doing" occurs in season-long experimental trials by farmers in FFS groups where they address the various constraints they encounter with locally appropriate solutions (Busogoro, 2013). This helps to create resilience to the impacts of climate change. Since its beginning in 2009, 80,000 farmers have joined a FFS group, which are located in all Rwanda's 30 districts, covering 12 different commodities.

The impact of the FFS is very significant. Overall, 92 per cent of 2,897 FFS groups report an increase in productivity of at least 50 per cent, but in some crops the results are even more impressive. The farmers' average income has more than doubled (+164 per cent). Furthermore, FFS farmers use less pesticides and conserve local genetic resources (BDA, 2014) making their practices less carbon intensive and more resource efficient while contributing to greening the agricultural economy.

Solar charging kiosks are popular in Kigali

1.7 Technology

Technology and the environment

Technology is needed to produce goods and services; it is also important because it can both contribute to, or decrease, the environmental impact of human activities. It has been argued that over time, economic growth will eventually lead to environmental improvements because accompanying technological innovation will improve production intensity or quality, which may more than compensate for the adverse effects of the rise in population (UNEP 2012). There are intervening variables and trade-offs related to externalities, however, that confound linear cause and effect between technologies and their environmental consequences.

There are many methods to assess the impacts of specific technologies on ecosystem services, human health and well-being and the economy, including Environmental Impact Assessments (EIA), Environmental Risk Assessments and cost-benefit analyses, among many others. Box 7 defines Environmentally Sound Technologies (ESTs). The GoR has undertaken a Technology Needs Assessment (TNA) to identify and facilitate access to and the transfer of appropriate technologies to support economic sectors and the country in general in mitigating and adapting to climate change impacts. These technologies form the basis for a portfolio of Environmentally Sound Technology (EST) projects and programmes (MINIRENA, 2012).

It has also been argued that humans are the "ultimate resource" since their innovations can be the solutions to resource scarcity and environmental problems, with the theory's most well-known proponent declaring that "our growing ability to create new resources has more than made up for temporary setbacks due to local resource exhaustion, pollution,

Box 7: Environmentally Sound Technologies (ESTs)

Agenda 21, the roadmap that was issued from the United Nations Conference on Environment and Development in Rio de Janerio in 1992, defines Environmentally Sound Technologies (ESTs) as having "the potential for significantly improved environmental performance relative to other technologies. Broadly speaking, these technologies protect the environment, are less polluting, use resources in a sustainable manner, recycle more of their wastes and products, handle all residual wastes in a more environmentally acceptable way than the technologies for which they are substitutes" (UNEP, 1992).

Table 6: EDPRS II focus on Green Growth in technologies

Thematic priority	Thematic outcome	Interventions	Lead sectors/ institutions
PRIORITY AREA 5: Green Growth	5.2 High environmental standards and sustainable green innovations in the industrial and private sectors incentivised	• Develop an Environmental and Climate Change Innovation Centre • Build a regulatory environment that incentivises green technologies and innovation • Pilot promising "green" technologies • Pilot a "model" mine	MINERANA, REMA FONERWA

Source: (RoR, 2013)

population growth, and so on" (Simon, 1998). This view supports the idea that with its youthful population and its dedication to fostering innovation, Rwanda has the potential to create and implement ESTs or "green technologies" that can indeed contribute to environmental sustainability and a green economy.

An analysis of Rwanda's national science, technology, and innovation (STI) context affirms that the country's most valuable assets are its people. "National leadership and passion for STI distinguish the country and bode well for the implementation of intended reforms. With the vitality and commitment of Rwandans and Vision 2020 offering a roadmap toward a more prosperous future, the ingredients exist to propel Rwanda toward becoming not just an engine of innovation for Africa, but for the world" (GKI, 2012).

Rwanda's goals for green technology

The EDPRS II places a strong focus on improving technology, especially through sustainable green innovations. Table 6 provides the aims of its Priority Area 5, oriented to the Green Economy, under the thematic area of Rapid Economic Transformation.

The specific outcomes are as follows:

Outcome 5.1: Increased level of "green" investment and environmentally sustainable urban development that exploits "green" economic opportunities; and

Outcome 5.2: High environmental standards and sustainable green innovation in the industrial and private sectors (RoR, 2013).

Technology, Innovation and Infrastructure is one of the GGCR strategy's five Enabling Pillars and Rwanda continues to be one of the fastest growing African countries in ICT, with a mobile phone network covering 99.79 per cent of the country, 54 per cent of households owning a cell phone and 2.4 per cent owning a computer in 2013 (RDB, n.d.a).

Rwanda's ICT Sector Strategic Plan (SSP) 2013 -2018 contains the SMART Rwanda Master Plan 2015-2020 to further improve Rwanda's economic environment to accelerate ICT growth by creating a Service-oriented, Modern, Accountable, and Real-Time

Largest utility-scale solar project in East Africa opened in Rwanda in 2015

Box 8: Managing electronic waste (E-waste)

E-waste (Electronic waste) refers to discarded office and household electronic and electrical equipment and components destined for reuse, resale, salvage, recycling or disposal. It includes computers, entertainment electronic devices, mobile phones, television sets, refrigerators, etc. It is some of the fastest growing waste in the world, making up five per cent of all municipal waste worldwide or nearly as much as all plastic packaging —but it is much more hazardous (EACO, 2012). When electronic equipment is improperly disposed of, they release harmful toxins to the environment contaminating drinking water, soil and the air. Lead, mercury, cadmium and flame-retardants cause birth defects and damage respiratory, coronary, nervous and skeletal system function (Rubicon, 2015). The components of electronic equipment are valuable and scarce commodities, however, so although e-waste is a problem, it is also a resource and its valuable components can be recycled and re-used (Asiimwe, 2011).

There are a number of recycling plants in Rwanda as well as informal collectors and refurbishers (Ooro, 2015). To increase such enterprises and foster proper e-waste management, Rwanda has instituted an E-Waste Management Policy and Bill, that

- Promotes sustainable E-waste management processes and systems;
- Develops Small and Medium-sized Enterprises (SMEs) and creates jobs by investing in E-waste management;
- Protects the environment from E-waste pollution and hazardous materials by establishing an adequate E-waste legal and regulatory framework; and
- Develops a skilled workforce in E-Waste management (MINECOFIN, 2015).

(SMART) government to drive the country's global competitiveness and create jobs. The SMART plan includes a policy orientation to deal with electronic waste (E-waste), an essential process to greening the ICT sector as it grows in size and significance (Box 8).

The SMART plan will also implement five key technologies, one of which is "Green ICT" (the others are a Cloud Data Center, a Wireless Network, Cyber Security and Big Data). This technology involves "greening ICT" by making environmental commitments along the entire life cycle of ICT products and services, as well as "greening by ICT", which addresses energy related problems by applying ICT technologies, such as ICT-enabled energy efficiency enhancement and a SMART Grid. It suggests starting with SMART building management, SMART manufacturing and SMART eco-friendly street lighting (MINECOFIN, 2015).

E-waste

Box 9: FONERWA's goals

By 2016

- Scaling up "green villages" and "green district" programmes
- Supporting expansion of green financing and products available to Rwanda's private sector
- FONERWA accreditation under the Green Climate Fund (GCF) for enhanced direct access
- Private Sector support has included a Credit Line facility that has to date provided funding for a 500 kW mini-hydro power production project

By 2020

- Donor and GoR capitalisation commitments of US$100 million
- 30,000 Rwandan citizens (among them 15,000 women and girls) with increased resilience to climate change
- 580 tonnes of CO_2 emissions equivalent avoided
- 5,000 "green jobs" created
- FONERWA-like approaches adopted by other countries

Source: (FONERWA, n.d.b)

FONERWA

FONERWA is Africa's biggest environment and climate change fund. The purpose of this groundbreaking fund is to drive Rwanda's green growth for the next 50 years and serve as a standard for Africa and the rest of the world. It provides technical and financial support to the best public and private projects selected for their alignment with Rwanda's commitment to green economic growth and climate resilience (FONERWA, n.d.b). Examples of green technologies funded by FONERWA to date include expanding innovative rainwater harvesting; a Green and Smart Village modeling natural resource conservation and management as well as the utilization of sustainable and clean renewable energy sources; and renewable energy projects including a rice husk gasification power plant and a mini-hydro power initiative (FONERWA, n.d.b). Box 9 highlights FONERWA's goals for the future.

Resource Efficient and Cleaner Production Centre (RRECPC)

One of the key means towards achieving a low carbon economy is to introduce technologies that increase the efficiency with which energy is used in production processes. Established in 2008, the Rwanda Resource Efficient and Cleaner Production Centre (RRECPC) is a joint project between the United Nations Industrial Development Organization (UNIDO) and Rwanda's Ministry of Industry and Commerce (MINICOM) (UNEP, 2011b). The Centre works with small and medium-sized enterprises (SMEs) to build capacity among industries, manufacturers and hotels to prevent wastewater generation and harmful emissions and to enhance their productivity and competitiveness (MINICOM, 2014). It has succeeded in raising awareness of the value of resource efficiency, undertaken domestic waste assessments, operated a mobile briquette-making demonstration machine and introduced Resource Efficient and Cleaner Production (RECP) management strategies in some pilot industries (UNEP, 2011b). By January 2014, more than 500 people had undertaken RECP related activities; 130 persons from different government and private institutions had been trained on the programme's best practices and 40 national local experts were trained as trainers. As well, more than 40 industries and SMEs are now implementing resource efficiency and cleaner production methods in their daily businesses (MINICOM, 2014).

In 2015, Rwanda introduced the National Cleaner Production Awards and recognized seven industries that embraced the Resource Efficient and Cleaner Production technologies as a way of preserving the environment. The criteria considered the amount of energy, water and raw materials saved per unit of product and service, the amount of renewable energy adopted and reducing pollution at the source. The award also recognized the level of management's commitment and leadership toward reaping benefits and adhering to standards and social responsibility (MINICOM, 2015).

New housing with rainwater collection

Eugene Apindi Ochieng

Tools for technology transfer

As a final example of the ways in which Rwanda is promoting green technologies, in 2010, the Rwanda Environment Management Authority (REMA) produced a set of very practical technology transfer tools that introduce green technologies that are important to health, agriculture and the environment, as follows:

1. Practical Tools for Sectoral Environmental Planning Final Version 17-07-2010.
2. Practical Tools on Land Management - GPS, Mapping and GIS Final Version 17-07-2010.
3. Practical Tools on Restoration and Conservation of Protected Wetlands Final Version 17-07-2010.
4. Practical Tools on Sustainable Agriculture Final Version 16-07-2010 # Paper A4.
5. Practical Tools on Soil and Water Conservation Measures Final Version 16-07-2010 # Paper A4.
6. Practical Tools on Agroforestry Final Version 17-07-2010.
7. Practical Tools on Irrigated Agriculture on Non-protected Wetlands Final Version 16-07-2010 # Paper A4.
8. Practical Tools on Soil Productivity and Crop Protection Final Version 17-07-2010.
9. Practical Technical Information on Low-cost Technologies - Composting Latrines & Rainwater Harvesting Infrastructure Final Version 17-07-2010
10. Practical Tools on Water Monitoring Methods and Instrumentation Final Version 17-07-2010.
11. Practical Tools on Small-scale Incinerators for Biomedical waste management.
12. Practical Tools on Solid Waste Management of Imidugudu, Towns and Cities Final Version 17-07- 2010.
13. General guidelines and procedures for Environmental Impact Assessment (EIA).

Muyebe green village rainwater harvesting underground storage manholes REMA

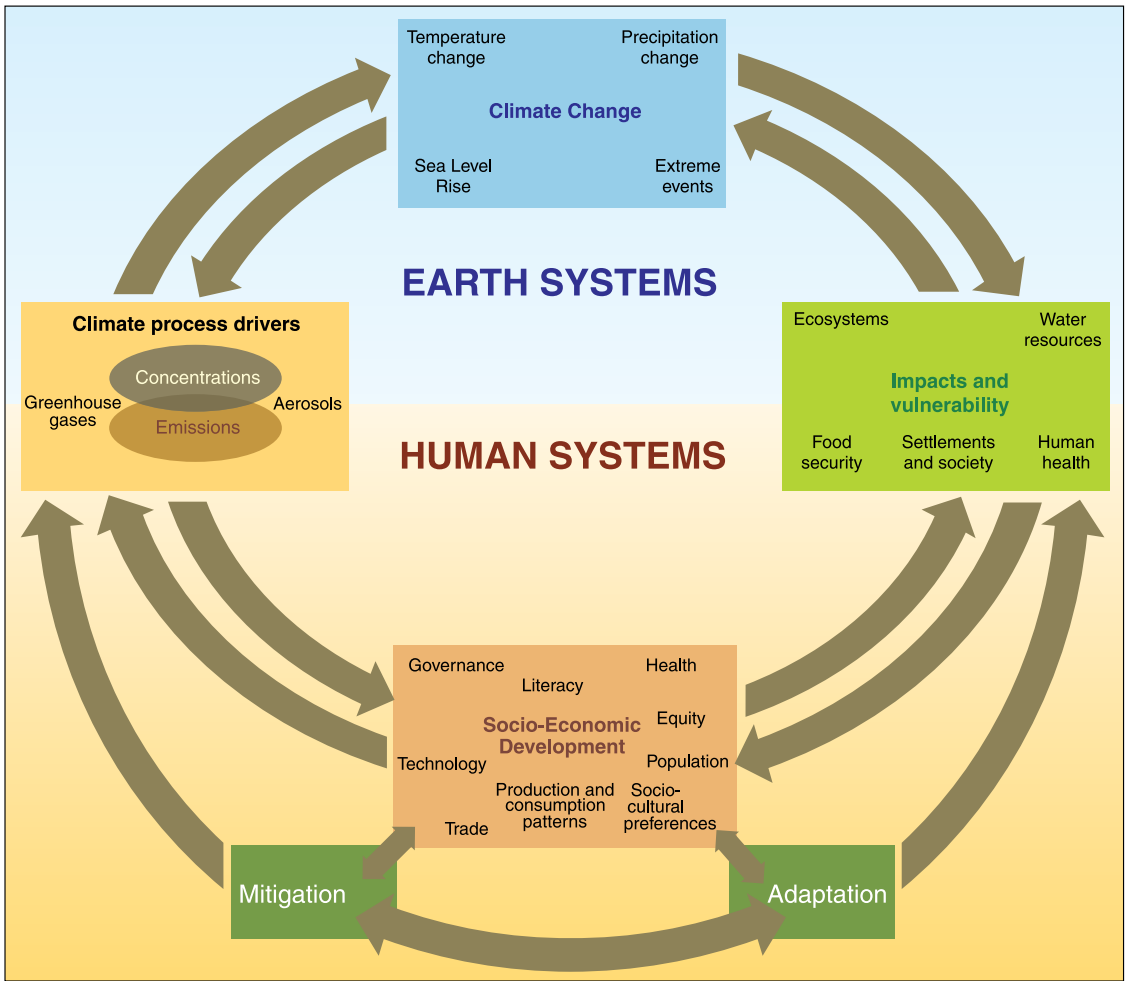
1.8 Climate change

Introduction

The international community now widely recognizes that climate change is the Earth's major environmental problem and that it is inextricably linked to human activities. In 2014, the Intergovernmental Panel on Climate Change reported that anthropogenic greenhouse gas (GHG) emissions were the highest in history and that its impacts on human and natural systems have been widespread. It also warns that continued GHG emissions will increase the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. These risks can only be limited by substantially reducing emissions in a sustained way and acting to adapt to climatic changes (IPCC, 2014a).

Figure 19 illustrates how climate change acts as a driver of environmental change as emissions cause temperatures, ocean levels and extreme events to increase and precipitation patterns to change, which in turn have impacts on ecosystems and human well-being. Mitigation and adaptation responses

Figure 19: Climate change flow chart

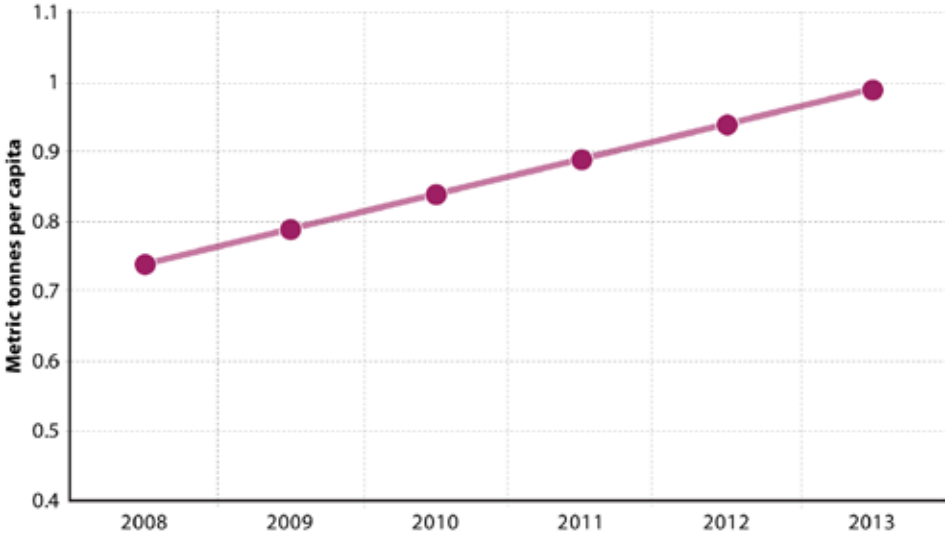


Source: (IPCC, 2007)

undertaken by society can influence the system; the former reduces GHG emissions and the latter enables human societies to reduce their vulnerability to climate change impacts.

Rwanda is highly vulnerable to the impacts of temperature and rainfall changes due to climate change since it relies heavily on rain-fed agriculture for subsistence livelihoods and tea and coffee cash crops. As well, half of its electricity generation, which is a significant driver of economic growth, depends on hydropower (RoR, 2011). It increasingly feels the impacts of global climate change, especially in the form of flooding and droughts, which cost lives and resources and adversely affect agricultural output (RoR, 2012).

Figure 20: Trend in per capita CO_2 emissions in Rwanda, 2008-2013



Source: (NISR, 2014a)

According to the Notre Dame Global Adaptation (ND-GAIN) Index, Rwanda is the world's thirteenth most vulnerable country and the ninetieth least ready country to combat climate change effects out of 192 countries on the index. The assessment deems it to be on the road to responding effectively to climate change, but notes that the adaptation needs and urgency to act are greater (ND-Gain, 2013).

Greenhouse gas emissions

Every four years, Rwanda submits a national communications report to the United Nations Framework Convention on Climate Change (UNFCCC). The emissions data that follow were obtained from its Second National Communication (2nd NC) to the UNFCCC in 2010.

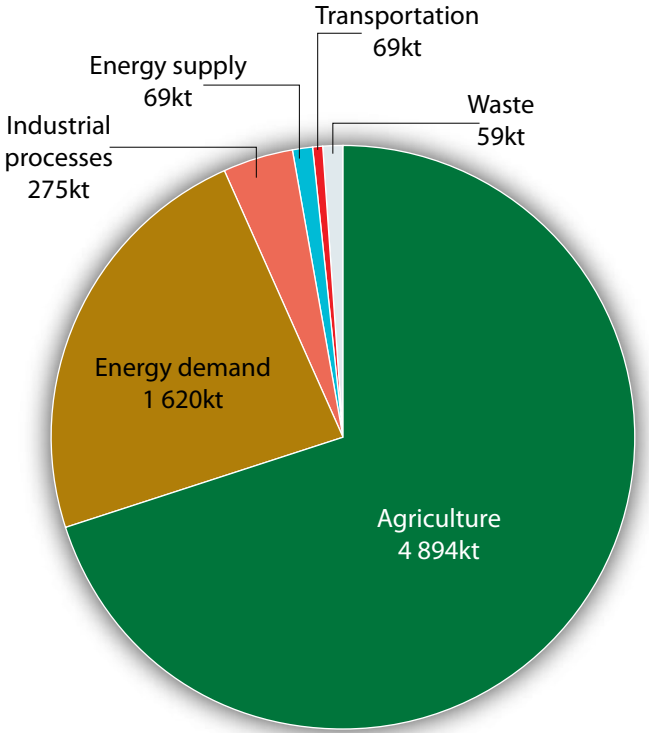
Data from 2005 show that Rwanda has one of the world's lowest per capita GHG emissions, estimated at 0.4 tonnes of carbon dioxide equivalent per person (tCO_2 e/person), compared to a global average of 6.7 tCO_2 e/person, including land use change (RoR, 2011). Figure 20 shows the trend in per capita emissions from 2008 to 2013.

Emissions by sector

The baseline GHG emissions from 2005 used in the 2nd NC report show aggregate emissions or total CO_2 equivalent as 5,010 Gg. Four key sources contributed 91 per cent of aggregate emissions: N_2O from agricultural soils (57 per cent), CH_4 from enteric fermentation in domestic livestock (19 per cent), CH_4 from residential energy from fuel combustion (8 per cent) and CO_2 from road vehicles (5 per cent). Carbon dioxide emissions are mostly from transport and industrial processes. There are uncertainties in the GHG inventory however, due to inadequate representation, and lack of basic data and application of emissions factors for different conditions (RoR, 2011).

A report by the International Institute for Sustainable Development (IISD) (Stiebert, 2013) calculated data for sector emissions using historical GHG emissions based on and calibrated against Rwanda's 2nd NC inventory; it separates emissions into those with the land-use change and forestry (LULUCF) sector and those without LULUCF. Figure 21 and Table 7 illustrate

Figure 21: Total emissions by sector in 2010
(in kilotonnes of carbon dioxide equivalent [KtCO_2e], excluding LULUCF)



Source: (Stiebert, 2013)

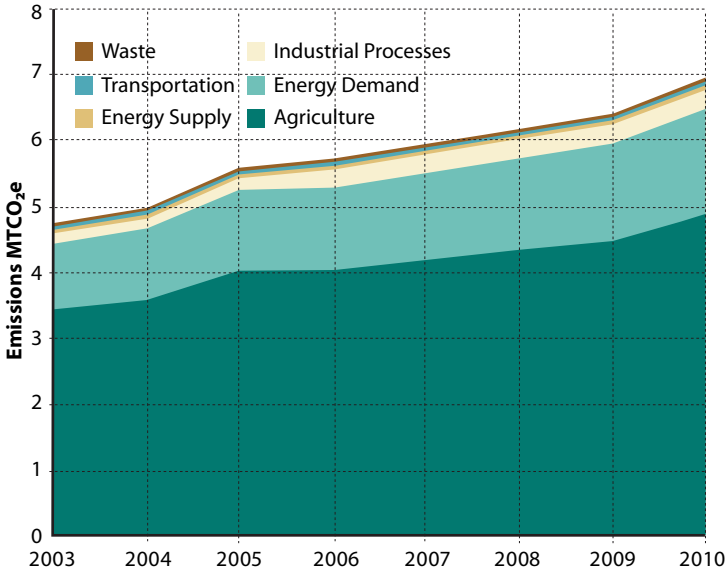
Table 7: Trend in net emissions: 2003, 2007 and 2010 (in kilotonnes CO_2E [$KtCO_2e$])

Sector	2003	2007	2010
Agriculture	3,477	4,179	4,894
Energy demand	969	1,342	4,620
Industrial processes	154	270	275
Energy supply	52	65	69
Transportation	35	44	52
Waste	48	59	59
LULUCF	-14,238	-7,168	1,866
Total (Without LULUCF)	4,734	5,950	6,969
Total (With LULUCF)	9,504	1,218	5,103

Note: Negative values denote net removals

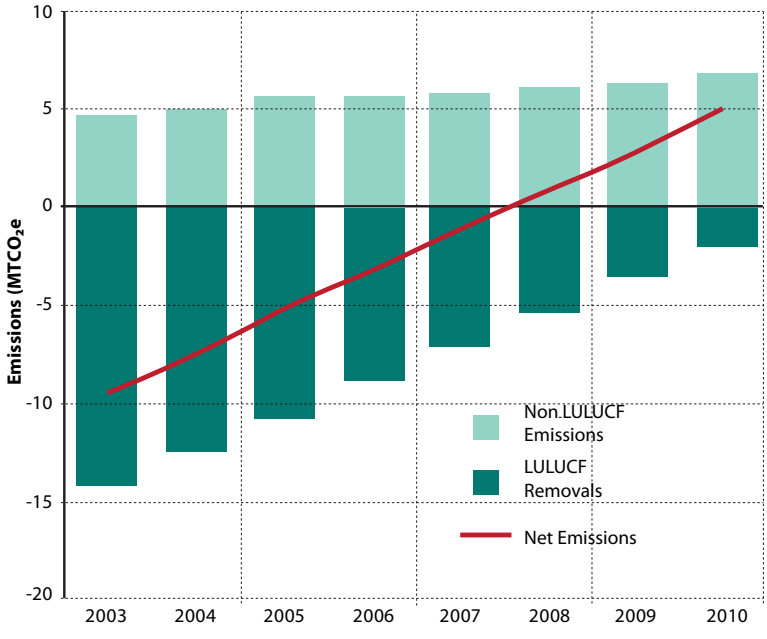
Source: (Stiebert, 2013)

Figure 22: Total emissions by sector 2000-2010 ($MtCO_2e$ excluding LULUCF)



Source: (Stiebert, 2013)

Figure 23: Total emissions by sector in 2000–2010 ($MtCO_2e$)



Source: (Stiebert, 2013)

Reforestation in the hillsides of Ibiro Eugene Apindi Ochieng

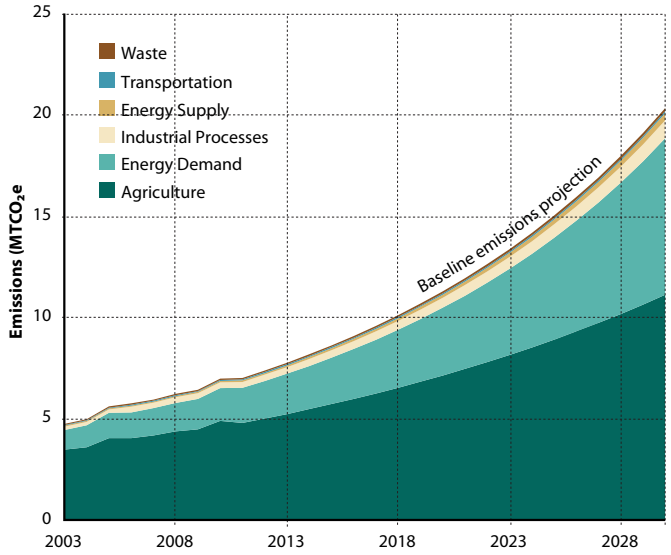
the specific sources that contributed to the total estimated emissions in 2010. Agriculture contributes most, emitting about 65 per cent of non-LULUCF emissions, mainly because of carbon released from cultivating soils. Next is the energy demand sector, dominated by methane (CH_4) and nitrous oxide (N_2O) emissions from biomass combustion, which accounted for 23 per cent of non-LULUCF emissions. Industrial processes accounted for about 4 per cent of non-LULUCF emissions and energy supply for about 1 per cent (Stiebert, 2013).

Emissions from land use, land-use change and forestry (LULUCF)

It is important to recognize the contribution of standing vegetation and undisturbed soil in mitigating climate change. Atmospheric CO_2 can accumulate as carbon in vegetation and soils in terrestrial ecosystems, so conserving and planting trees and other vegetation acts to reduce the rate of CO_2 build-up in the atmosphere (UNFCCC, 2014). According to the IISD assessment of Rwanda's emissions in the LULUCF sector, from 2000 to 2010, carbon removals from the atmosphere by storage or sequestration in biomass were larger than the country's emissions, resulting in a net sink every year. IISD notes that "this historical trend is very significant, as it suggests that Rwanda as a whole is moving from being a considerable sink (-9,504 kt in 2000) to a small contributor to global emissions in 2010 (5,103 kt in 2010)". It also notes that there is a high degree of uncertainty since the trend is based on limited forestry data (Stiebert, 2013).

Figure 22 is the trend in total emissions over time for non-LULUCF sectors and Figure 23 shows both emissions and removals, including LULUCF and the resulting trend in net emissions (Stiebert, 2013).

Figure 24: Emissions baseline projections (excluding LULUCF)



Source: (Stiebert, 2013)

Projections

Economic forecasts and projections of population growth were used to project the baseline emissions into the future. Results of the baseline projection are shown in Figure 24 excluding LULUCF (Stiebert, 2013). It shows the significant contribution of agriculture and energy demand in the potential growth of Rwanda's GHG emissions, suggesting the imperative to continue on the path towards low carbon agricultural growth according to the GGCR strategy, including practices such as agroforestry and low-till farming to increase carbon sequestration in biomass.

Trend in annual average temperature

The International Panel on Climate Change (IPCC) reports that there has been increased warming over Africa's land regions in the last 50 to 100 years, as is consistent with human-induced climate change (IPCC, 2014b). In Rwanda, the average temperature increased by 1.4°C since 1970, higher than the global average, and by the 2050s, it is likely to rise by up to 2.5°C from the 1970 average (RoR, 2011).

A study by Safari (*Trend Analysis of the Mean Annual Temperature in Rwanda during the Last Fifty Two Years, 2012*), based on 1958 to 2010 data from the Rwanda National Meteorological Service, also detected statistically significant abrupt changes and trends and concluded that climate change has indeed occurred in Rwanda. It noted the major change in the annual mean temperature around 1977, followed by a significant warming trend (Safari, 2012).

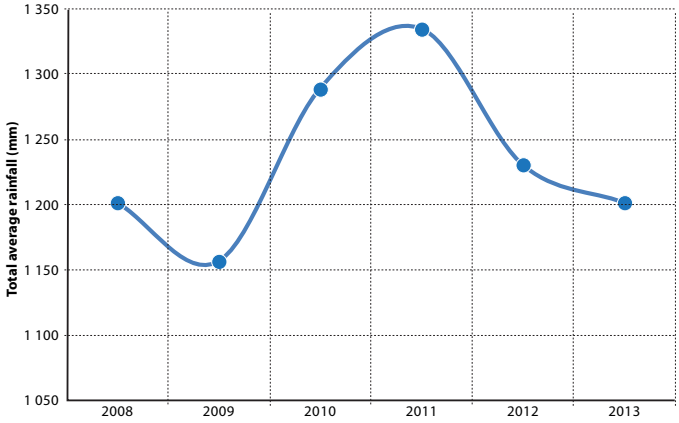
Projections

The IPCC reports that extensive areas of Africa are likely to see a mean annual temperature rise exceeding 2°C by the last two decades of this century, relative to the mean annual temperature rise during the late 20th century. It is also likely that land temperatures over the continent will rise faster than the global land average, particularly in more arid regions (IPCC, 2014b).

Trend in total average rainfall

In contrast to the trends in average temperature in Rwanda, no significant trend has been observed in precipitation patterns during the early 20th century (1931-1990) and inter-annual rainfall variability has been high. In the early 1960s, however, there was a step-change to slightly higher annual rainfall totals, consistent with a trend seen across much of East Africa (RoR, 2011) (Figure 25).

Figure 25: Total average rainfall in Rwanda, 2008-2013



Source: (NISR, 2014a)

Projections

The IPCC reports uncertainty about projected changes in rainfall over sub-Saharan Africa in the mid- and late 21st century (IPCC, 2014b). The GGCR strategy suggests that Rwanda and Burundi could experience increased rainfall intensity during both rainy seasons; by the 2050s, Rwanda's average annual rainfall may increase by up to 20 per cent from 1970 levels (RoR, 2011).

The impacts of climate change

The IPCC reports that "African ecosystems are already being affected by climate change, and future impacts are expected to be substantial". For example, as highland regions in Africa become warmer, crop pests could expand their ranges into areas that were once too cold for them. Under such circumstances, the coffee berry borer (*Hypothenemus hampei*) might

Flooding of Lake Karago, Nyabihu District REMA

become a serious threat to highland coffee in eastern Africa, including Rwanda (IPCC, 2014b). On the other hand, warmer temperatures in Rwanda's higher altitudes could also create conditions favourable for expanding tea and coffee crops upslope (RoR, 2011).

Another crop pest that could expand its altitudinal range with higher temperatures is the highly destructive burrowing nematode, *Radopholus similis*, in banana-producing areas of eastern Africa, although the risk has not been studied in detail (IPCC, 2014b). It is also possible that higher temperatures may increase malaria parasites (Ngoga, Mutabazi, & Thomas, 2012).

The IPCC also reports that Africa will suffer from increased pressure on already stressed water availability due to climate change, with important impacts on economic development (IPCC, 2014b). For example, increased floods, landslides and droughts are likely to increase damage to infrastructure and property. Research in Rwanda has estimated that in addition to already variable climatic conditions, climate change could result in additional net economic costs equivalent to a loss of almost one per cent of GDP each year by 2030 (RoR, 2013).

Finally, as shown further on in Chapter 8, the IPCC warns that climate change will interact with other drivers and pressures to increase the vulnerability of agricultural systems, particularly in semi-arid areas (IPCC, 2014b). Increasing temperatures and changes in rainfall patterns are very likely to reduce cereal crop productivity (IPCC, 2014b) and could exacerbate crop pests, weeds and disease, all of which would impact food security and export earnings (RoR, 2011).

Box 10: The Vulnerability Index

"Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity" (REMA, 2015b). "The vulnerability index was calculated from 14 component indicators which were combined to provide three sub-component indices of vulnerability (exposure, sensitivity, and adaptive capacity):

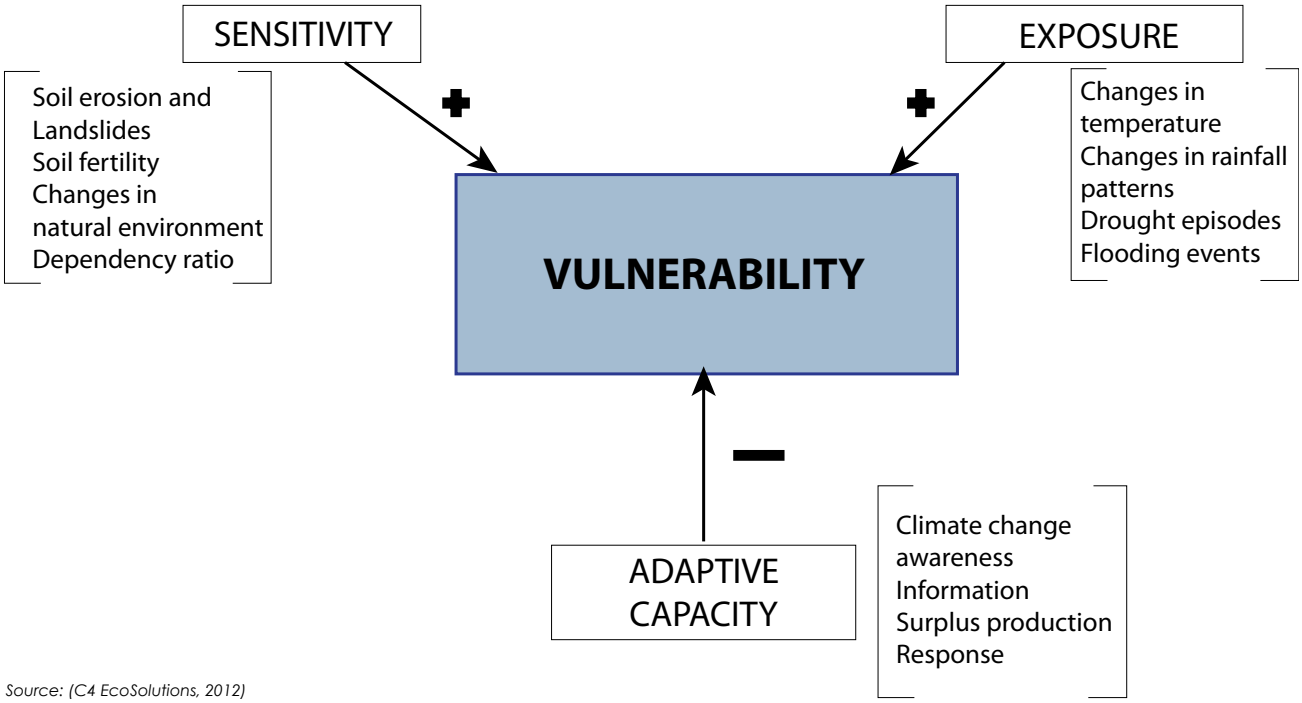
1. Exposure: nature and degree to which a system is exposed to significant climatic variations;
2. Sensitivity: responsiveness of a system to climatic influences (shaped by both socioeconomic and environmental conditions);
3. Adaptive capacity: ability of communities to cope, re-organize and minimize loss from climate change impacts at different levels. The key determinant of adaptive capacity is access to resources and capital (natural, financial, social, human and physical)" (C4 EcoSolutions, 2012).

Vulnerability to climate change impacts

Increasing population pressure and subsequent settlement and farming in marginal or vulnerable areas, means that more people are exposed to extreme climate events, such as droughts, landslides and floods (GeoSAS, 2012). The impacts of climate change will thus worsen this vulnerability.

Recently, Rwanda began developing a set of indicators to measure vulnerability to climate change impacts, populating the indicators with data from national statistics. Combining the vulnerability indicators and baseline data creates a climate change vulnerability index that can be used to monitor future climate change adaptation initiatives. According to the IPCC, vulnerability is "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" (REMA, 2015b). Box 10 explains this definition more fully and introduces Rwanda's Vulnerability Index.

Figure 26: Vulnerability framework - components and indicators



Source: (C4 EcoSolutions, 2012)

The EDPRS II counts reducing vulnerability to climate change as one of Rwanda's foremost priorities and the environment and climate change are cross cutting issues. The new climate change vulnerability index will allow Rwanda to plan climate change adaptation actions more effectively, enable it to evaluate progress in reducing climate change vulnerability and help it to build adaptive capacity (REMA, 2015b).

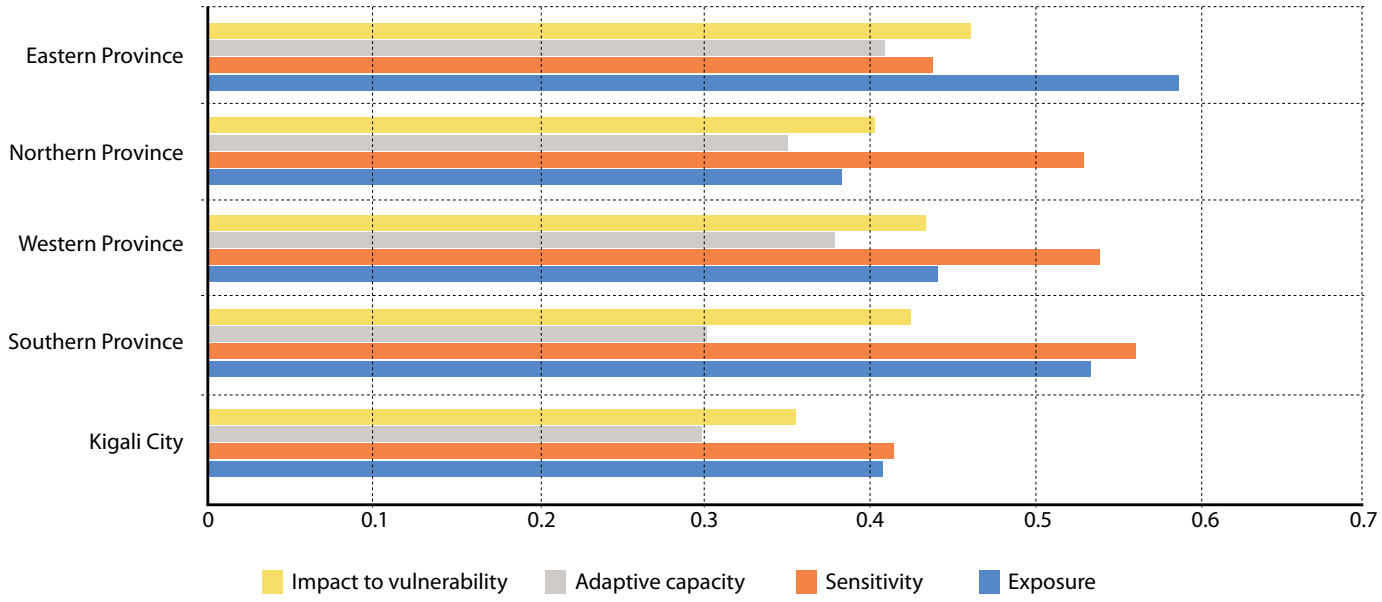
Figure 26 illustrates how the vulnerability index is the product of sensitivity and exposure minus adaptive capacity and provides the indicators used to construct each of the three sub-indices.

Figure 27 is the aggregated index, showing that overall, Kigali is the least vulnerable province.

Responses

Rwanda has taken on the challenge of mitigating its emissions and strengthening its adaptive capacity. It recognizes that as a Least Developed Country (LDC), it is not required to reduce its GHG emissions, since such actions could hamper development. However, along with other like-minded countries, it supports action in international climate negotiations and it is a member of the Climate Vulnerable Forum (V11)

Figure 27: Exposure, sensitivity, adaptive capacity and impact to vulnerability by province



Source: Baseline Climate Change Vulnerability Index for Rwanda (May, 2015)

and the Cartagena Dialogue group. Because of its heavy reliance on rain-fed agriculture and thus its high vulnerability to a changing climate, its main focus has been on adaptation. More recently, however, its focus has shifted to climate resilience and low carbon development, which addresses both adaptation and mitigation. Vision 2020 affirms that "Rwanda will continue 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" (RoR, 2012). Thus, while addressing climate change, Rwanda simultaneously focuses on sustainable economic growth and poverty reduction. In this regard, it is guided by the GGCR strategy, which celebrates Rwanda's opportunity to leapfrog old technologies and destructive development pathways, and looks forward to building a green economy that is resilient to oil-price spikes and a changing climate (RoR, 2011).

The GGCR mainstreams climate resilience and low carbon development into key sectors of the economy through its strategic framework, programmes of action, enabling pillars and implementation roadmap (RoR, 2011). All the strategy's 14 Programmes of Action, presented in Figure 5 focus on sustainable, low carbon, climate resilient, and otherwise "green" development. Programme 14 focuses specifically on Climate Data and Projections (Box 11).

Box 11: Programme 14 of the GGCR strategy

"Robust observed climate data and climate projections for Rwanda are crucial to understanding the current and future impacts of climate change and developing scenarios to assess the potential adaptation strategies for Rwanda. The Rwanda Meteorological Service is executing its five-year Strategic Plan to upgrade its network of meteorological stations. In addition, Rwanda will

1. Arrange additional observations to provide all climate information necessary for future monitoring, climate trend detection, management of climate variability, early warning and disaster management;
2. Establish a team to produce and interpret climate change projections for Rwanda, with a focus on disseminating climate model data in a user-friendly format for use by all stakeholders;
3. Develop the capacity in climate science necessary to underpin this work by incorporating climate science into secondary school and university curricula; and
4. Enhance the use of climate data in disease prevention and mitigation programmes for human health and agricultural crop productivity."

Source: (RoR, 2011)

Akanyaru watershed protection project

Nyiragongo volcano, DRC

1.9 Natural hazards

The United Nations Office for Disaster Risk Reduction (UNISDR) defines natural hazards as "natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage". It also explains that "there is no such thing as a "natural" disaster, only natural hazards" (ISDR, 2009). In other words, natural hazards do not always cause disasters; they result from the exposure of a vulnerable and ill prepared population or community to a hazardous event (MIDIMAR, 2012a). Natural hazards turn into disasters when they have a severe impact on society and the environment. Increasingly, natural hazards are exacerbated by human activity that degrades the environment, heightening the intensity, severity and frequency of some natural hazards such as landslides and floods, and increasing their impacts on humans and their settlements that live in their path, as well as on the environment. In Rwanda, poor farming practices, deforestation and environmental degradation are some of the human-related triggers or intervening facts that influence the severity of many natural hazards (REMA, 2009).

Natural hazards in Rwanda can be categorized as: geological; hydro-meteorological; and biological and technological (UNDP, 2013). Rwanda is subject to hydro-meteorological hazards such as droughts, floods and various types of storms (i.e., windstorms, rainstorms and thunderstorms). Geological hazards in Rwanda include earthquakes and landslides, while biological and technological hazards include traffic accidents, diseases and epidemics. Figure 28 shows the areas in Rwanda most prone to the major types of natural hazards.

In 2015, Rwanda published *The National Risk Atlas of Rwanda*, a comprehensive assessment of existing risks

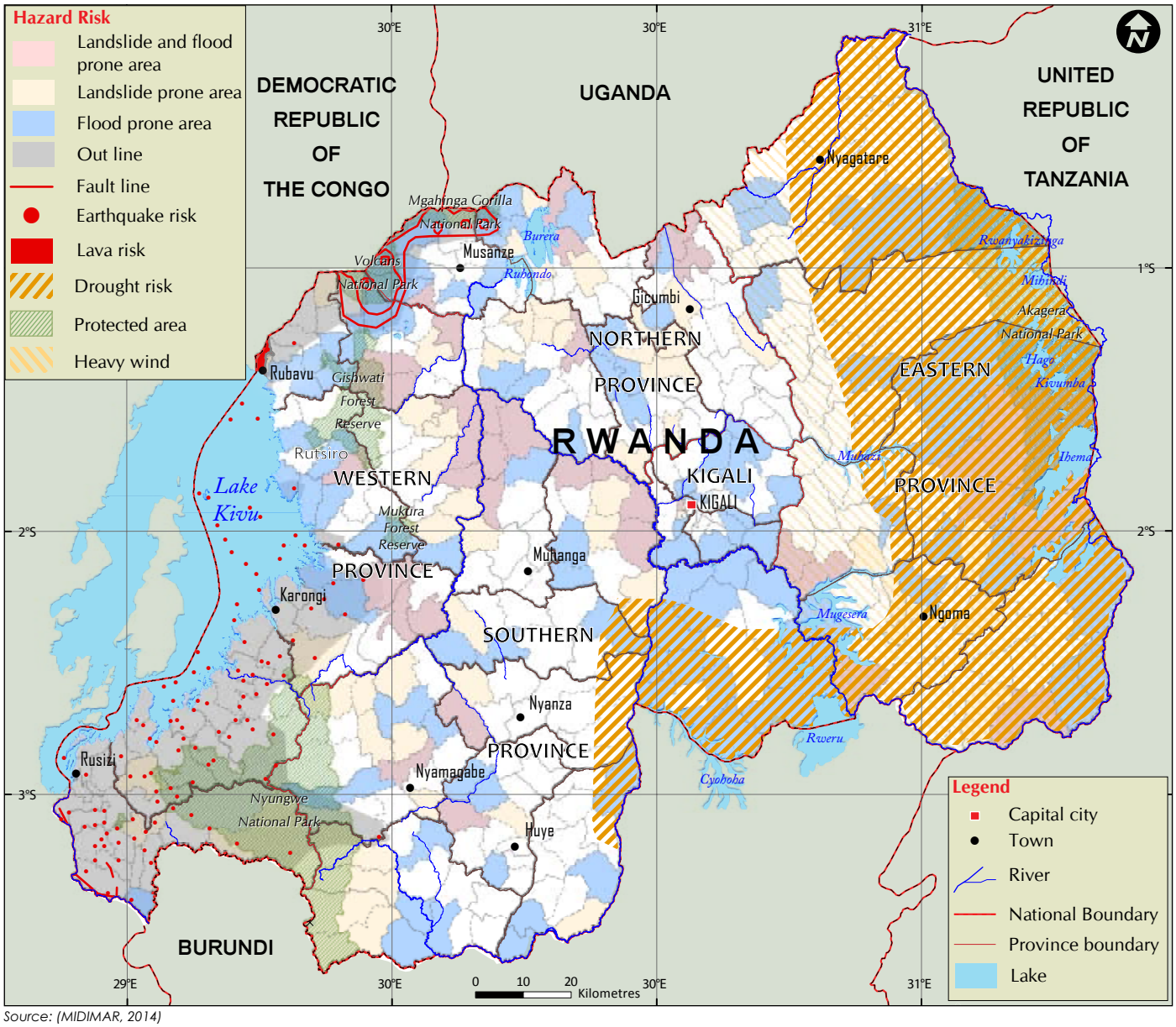
at the national and local level, led by the Ministry of Disaster Management and Refugee Affairs (MIDIMAR). It reports that over the last decade, the frequency and severity of natural disasters, particularly floods and droughts, have significantly increased, raising the toll of human casualties as well as economic and environmental losses (MIDIMAR, 2015) (Table 8). These hazards have caused mortalities, displaced populations, damaged infrastructure (roads, bridges, houses, schools and other properties), destroyed crops and caused serious environmental degradation. Hydro-meteorological hazards such as floods and droughts have affected the most people in Rwanda over the past two decades (UNDP, 2013). Over the 33-year period from 1974 to 2007, drought affected about 4 million Rwandans and 2 million were affected by floods (Zimmerman & Byizigiro, 2012).

Table 8: Disasters in Rwanda, 1994 to 2013

Disaster	Date	Total affected
Drought	1996	82,000
Drought	1999	894,545
Mass movement of population (due to volcanic eruption)	2002	300,000
Flood	2002	20,222
Drought	2003	1,000,000
Flood	2003	7,106
Flood	2007	4,000
Flood	2008	11,346
Mass movement	2010	5,937
Flood	2011	3,608
Flood	2012	11,160

Source: (UNDP, 2013)

Figure 28: Hazard prone areas



Source: (MIDIMAR, 2014)

Geological hazards

Volcanic eruptions

With its geographical location in the East African Rift Valley near the Nyiragongo volcanoes, which are still active, Rwanda is vulnerable to seismic disturbances. This volcanic activity is a hazard for the inhabitants of Goma in the Democratic Republic of the Congo and the population in and around Rubavu in Rwanda. The 2009 SEOR reported on the 2005 and 2002 volcanic eruptions; none have occurred since then (REMA, 2009).

Earthquakes

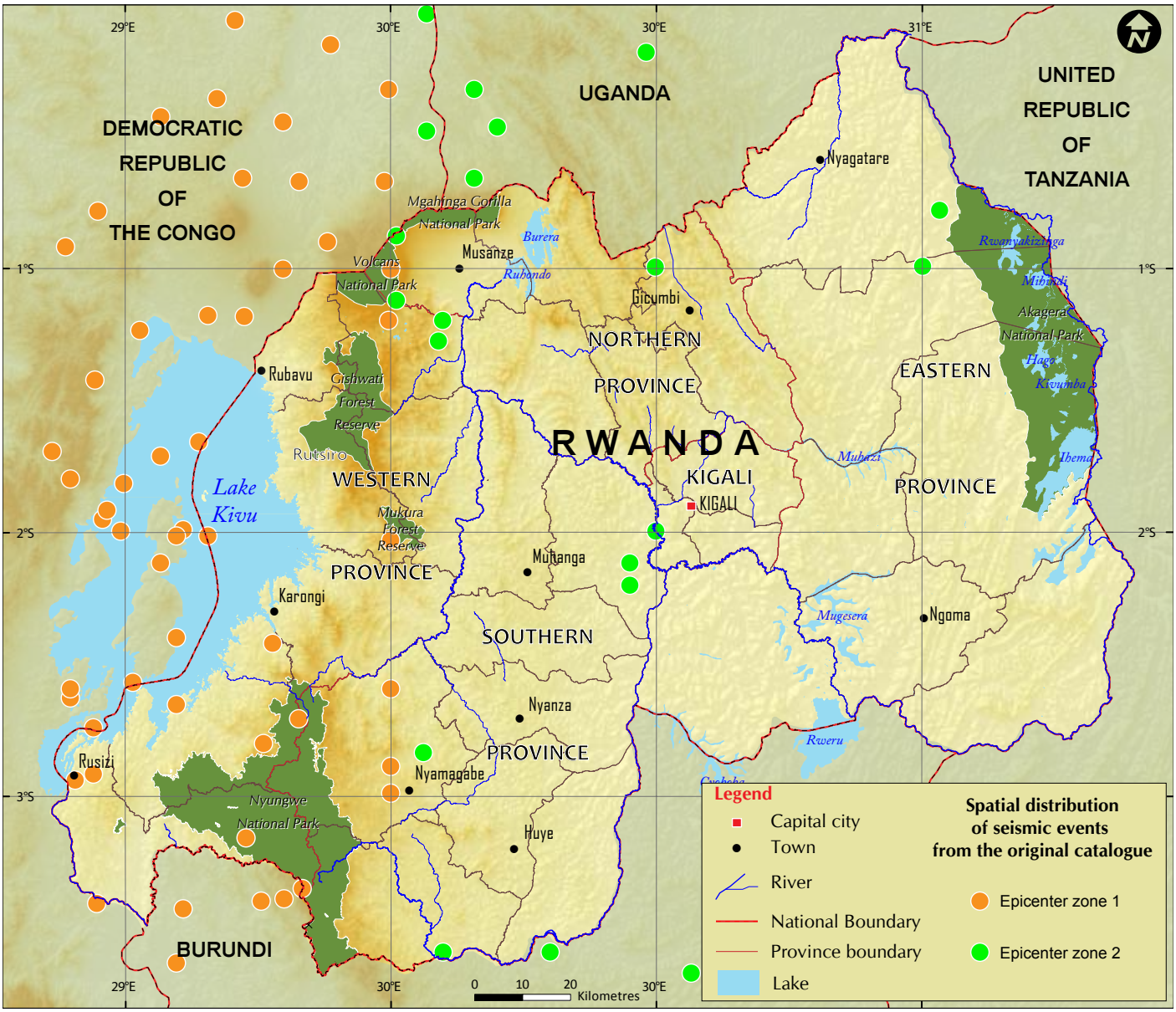
Rwanda and its surrounding areas straddle Africa's Kibaran and Western Rift zones. To Rwanda's west is the least prominent East Lake Kivu border fault, which is part of the Eastern African Rift System (EARS). The western rift system is the main source of seismic activity in Rwanda and the Western Province is the most hard hit by earthquakes. Between 2002 to 2008, there were five earthquake events, which caused the deaths of 85 people, many injuries and the total or partial destruction of various houses, schools and hospitals. The most impacted districts are Rubavu, Rusizi and Nyamasheke (MIDIMAR, 2015). Figure 29 shows where seismic events have taken place in and around Rwanda.

Hydro-meteorological hazards

Storms

Local storms can be major hazards causing severe damage. Generally, wind speeds in Rwanda are around 1-3 Knots, but sometimes they can reach up to 20-25 Knots, damaging roofs, banana plantations and other facilities such as schools that are mainly made of inferior materials as well as downing electrical wires and cutting out electricity (MIDIMAR, 2015). According

Figure 29: Spatial distribution of seismic events in and around Rwanda



Source : (MIDIMAR, 2015)

Table 9: Storm events and damages/loss, 2011-2013

2011

District	Death	Injured	Houses destroyed & damaged	Crop Lands affected (ha)
Ngororero			45	53
Rwamagana			223	455
Kamonyi				50
Kayonza			21	31
Bugesera			37	130
Ngoma			5	500
Gatsibo		6	113	52
Rubavu			66	
Rulindo			202	1,793
Nyagatare			0	
Ruhango			79	545
Karongi	3		55	2,301
Nyaruguru	2		40	
Gicumbi	4		64	
Total	**9**	**6**	**950**	**5,909**

2012

District	Death	Injured	Houses destroyed & damaged	Crop Lands affected (ha)
Bugesera			141	15
Ngororero			278	
Kayonza			85	15
Rwamagana			129	
Nyagatare			72	
Kirehe	1		65	
Gatsibo			35	
Gicumbi			32	159
Nyamagabe	4		70	29
Nyamasheke			48	
Rubavu	1		121	
Huye	1		133	20
Ngoma			28	
Rusizi			113	
Gasabo		1	131	21
Karongi			78	
Nyanza			45	2
Burera			3	
Ruhango			25	
Kamonyi			155	
Nyarugenge			9	
Kicukiro			8	
Total	**7**	**1**	**1,804**	**261**

2013

District	Death	Injured	Houses destroyed & damaged	Crop Lands affected (ha)
Nyanza			35	
Nyamagabe			14	
Gisagara			10	10
Rubavu	4		179	38
Bugesera		6	148	
Burera	7	14	30	920
Gakenke			40	20
Gasabo	1		313	
Gatsibo			65	4
Gicumbi			29	
Kamonyi			126	
Karongi			6	
Kayonza			76	102
Kicukiro			72	
Kirehe			376	27
Muhanga			37	
Musanze	2		150	
Ngoma			53	5
Ngororero			18	
Nyabihu	4	1	23	
Nyagatare	6	16	95	18
Nyamasheke			127	
Nyarugenge	3		366	
Nyaruguru			7	4
Ruhango		4	60	13
Rulindo		5	299	
Rusizi	1		199	235
Rutsiro			20	40
Rwamagana		1	177	5
Gakenke			40	20
Total	**28**	**47**	**3,190**	**1,460**

Source: MIDIMAR, 2014 (Annual Report); (MIDIMAR, 2015)

to MIDIMAR assessment reports (2013b), windstorms and associated heavy rain have destroyed many houses and schools in mostly low-lying areas of Eastern and Southern Districts, including Rwamagana, Kayonza, Kirehe, Gatsibo, Bugesera, Nyagatare, Ngoma and Gisagara, among others, as well as some higher land in the Northern and Western Districts (MIDIMAR, 2013b).

In 2011, the Rwanda Red Cross reported that Rwamagana District in the Eastern Province experienced severe weather. In March 2012, heavy rainfall associated with storms also severely affected many districts in the Eastern Province, including Rwamagana, Kayonza, Gatsibo, Ngoma, and Kirehe. It damaged buildings and hectares of crops such as banana plantations. In most of cases, heavy rains caused rivers to flood, aggravating the impacts. In

general, severe weather in Rwanda affected some 3,600 people (MIDIMAR, 2015). Table 9 lists the storm events that occurred between 2011 and 2013 and the resulting destruction.

Research to identify the causes and impacts of windstorms in four districts of the Eastern Province (Rwamagana, Kayonza, Gatsibo and Nyagatare) concluded that the flat topography, with little or no wind breaks such as trees, contributed to the vulnerability to wind damage, as did the poor construction materials with which buildings were made (MIDIMAR, 2013b).

Drought

All droughts are the result of a lack of precipitation. In contrast to aridity, which is a permanent feature of some regional climates, drought is a temporal aberration from what is perceived as "normal". The United Nations Convention to Combat Desertification (UNCCD), defines drought as "the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems" (MIDIMAR, 2015).

Crop failure due to drought IFDC Photography /Flickr /CC BY-NC-SA 2.0

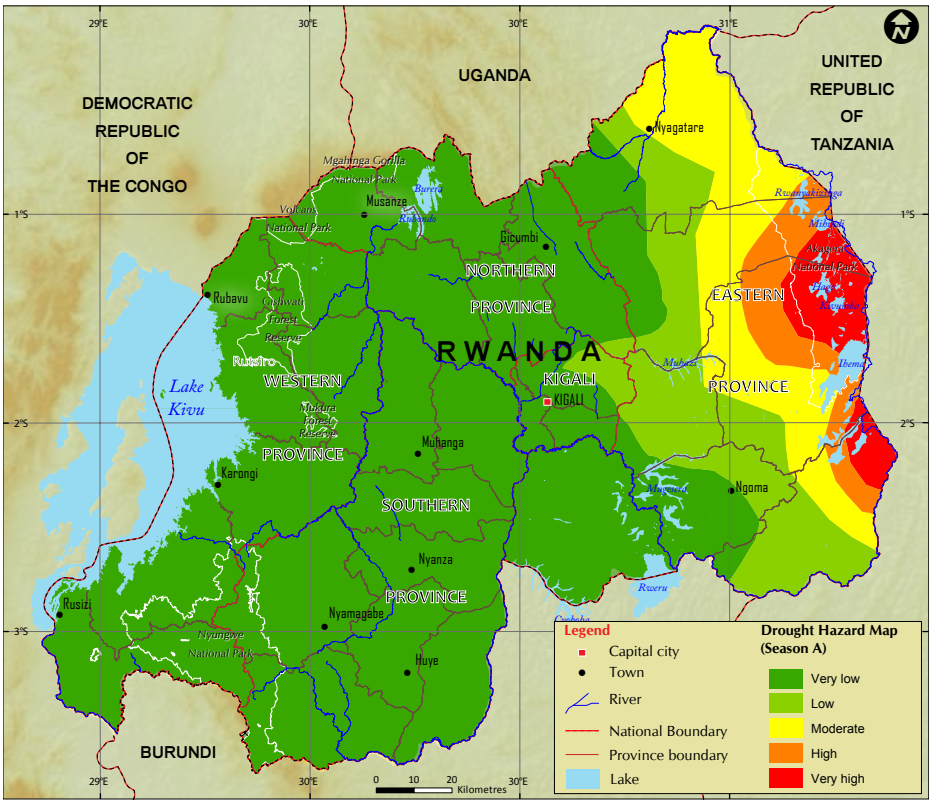
A prolonged dry season or a delay in the onset of the rainy season are the main triggers for droughts in Rwanda. Rainfall distribution across the country is not homogeneous and Rwanda is subject to two

Table 10: History of drought events in Rwanda, 1910-2014

Event date	Affected zone	Secondary hazards	Chained events	Death	Affected Pop	Source info	Comments
1910	Kibungo/Zaza (EP)					Scaetta, 1932	
1976-1977	National	Famine/ Crop failure	Famine/Crop failure	0	1,700,000	CRED	
Oct-84	National	Famine/ Food shortage	Famine/Food shortage	0	420,000	CRED; Reliefweb	
Dec-89	Gikongoro, Gitarama and Butare (SP)	Famine/ Crop failure	Famine/Crop failure	237	60,000	CRED	
1996	Gikongoro	Famine/ Food shortage	Famine/Food shortage	0	82,000	CRED	
Nov/99-2000	Umutara, Kibungo (EP), Kigali (Central), Gitarama, Butare and Gikongoro (SP)	Famine/ Food shortage	Famine/Food shortage	0	894,545	CRED; Glidenumber; Reliefweb	
15/05-15/09/2000	Kibungo, Umutara, (EP) Butare, Gitarama (SP) and Kigali (Central)				267,000	Glidenumber; FAO; Profil environmental Rwanda, June 2006	267,000 people in need of food aid; several hippopotamuses killed
Mar 2003	Kigali Rural (Gashora and Bugesera), Kibungo, Umutara (EP), Butare, Gikongoro and Gitarama (SP)			0	1,000,000	CRED	
12-15/2/2005	National	Famine/ Crop failure	Famine/Crop failure			CATNAT; OCHA; Reliefweb	6.5 million people affected in eastern africa; also in Burundi
Mar-Sept 2006	Kibungo, Umutara, Bugesera (EP), Butare, Gikongoro and Gitarama (SP)	Famine/ Food shortage	Famine/Food shortage	0	1,011,200	IFRC	202,239 households affected
June 2014	Bugesera and Kayonza Districts (EP)					MIDIMAR	

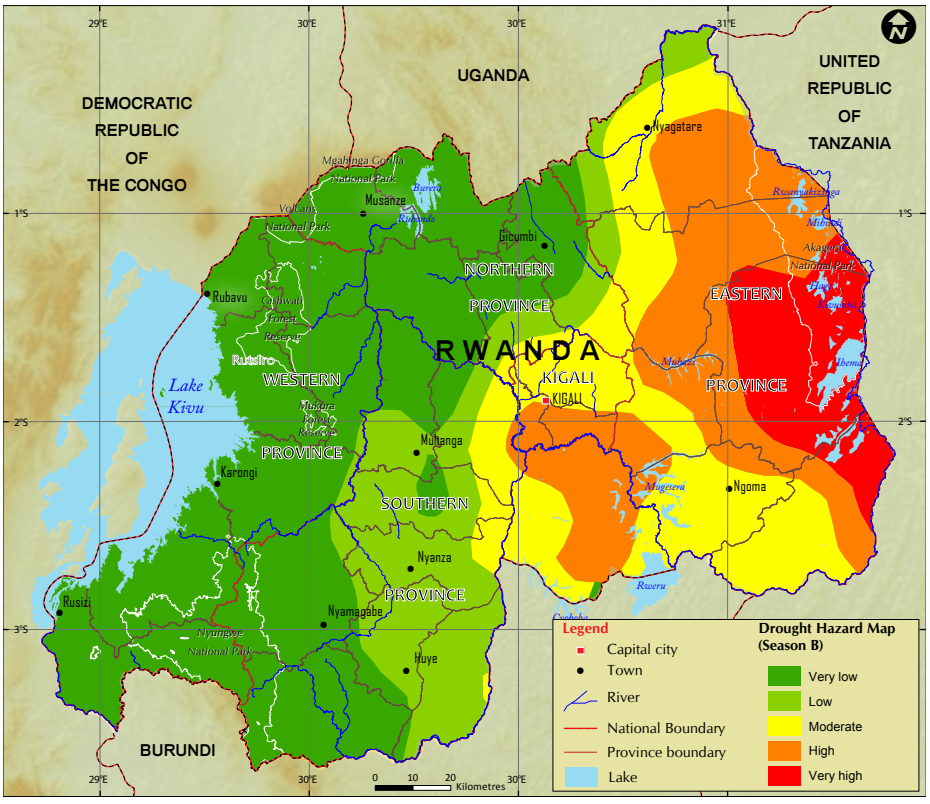
Source: Royal Museum of Central Africa combined with MIDIMAR data (from 2010). (MIDIMAR, 2015)

Figure 30: Drought hazard map (Season A: September-February), 2014



Source: (MIDIMAR, 2015)

Figure 31: Drought hazard map (Season B: March-July), 2014



Source: (MIDIMAR, 2015)

rainy seasons. Between 1998 and 2000 and annually from 2002 to 2005, there have been recurring drought incidences that have resulted in crop failure and serious food insecurity, malnutrition and famine in affected areas. Water shortages also hampered livestock production and the quality and quantity of pasture also declined (UNDP, 2013).

The districts of Bugesera, Nyagatare, Gatsibo, Kayonza, Ngoma and Kirehe in the Eastern Province and the eastern parts of Nyanza and Gisagara districts in the Southern Province are most prone to drought. These districts suffer from a high frequency of rainfall deficit, late rainfall onsets, early rainfall cessations, and a significant number of dry spells (MIDIMAR, 2015).

Drought conditions can contribute to the susceptibility to forest fires. There were major fire outbreaks in Nyungwe National Park in 2005 and Virunga National Park in 2009. The latter spread to the top of mount Muhabura in the Volcanoes National Park, consuming 150 ha of the park. Recurrent droughts are likely to have a significant impact on long-term vegetation cover as well as on soil conditions (UNDP, 2013). Table 10 lists the most severe drought events in Rwanda since the early 1900s and Figures 30 and 31 are maps of drought susceptibility in the country's two crop seasons: Season A (September to Febraury) and Season B (March to July).

With the continued change in climate and climate variability, droughts could occur more frequently and last longer, especially in the Eastern Province causing communities to suffer from the effects of destroyed crops, animals and livelihoods (MIDIMAR, 2015).

Floods

Floods are the world's most common natural hazards affecting 80 per cent of the global population. It is estimated that more than one third of the world's land area is flood-prone. Floods alone killed 100,000 persons and affected over 1.4 billion people during the 20th century worldwide (Jonkman, 2005).

Flood and erosion control Eugene Apindi Ochieng

The most frequent flood types in Rwanda are riverine floods and flash floods. Riverine floods occur when high precipitation levels, melting snow or barriers to water flow cause rivers to overflow their banks. Flash floods occur after local, intense rainfall events, when water levels rise extremely quickly. Due to its dense river network and large wetlands, riverine floods are the main threats in Rwanda. Major flood events resulted in infrastructure damage, fatalities and injuries, landslides, loss and damage to agricultural crops, soil erosion and environmental degradation (Table 11).

Landslides

Landslides in Rwanda are typically associated with heavy rainfall on fragile slopes. As described in Chapter 1, the western side of Rwanda has a very hilly topography, with steep slopes that are prone to landslides, especially when the vegetation has been removed, there are no erosion preventions and in the presence of heavy rainfall. They turn into disasters when they result in lost lives and damage to property because of settlements on risky slopes and poor housing construction (MIDIMAR, 2012a).

Table 11: Historical flood events, 1974-2013

Date	Province	District	Death	Affected	Damages	Source info
Jun-74	National	National	0	1.9m		CRED
6-9 May 1988	Ruhengeri, Kibuye, Gisenyi, Gitarama and Gikongoro		48	21,678	1,225 houses & 19 bridges destroyed, 7 roads cut off	CRED; Reliefweb; Byers A. C., 1992
21-Nov-2000	Gisenyi	Karambo and Nyundo	0	1,000	>200 houses destroyed; crops & roads damaged	IRIN
22-Sep-2001	Gikongoro	Nshili, Nyaruguru and Mushubi	10			CRED; Glidenumber
30 Oct - 2 Nov 2001	Gisenyi, Kibuye, Ruhengeri, Byumba, and Gikongoro		2	3,000		CRED; Glidenumber; IRIN
26 Apr- 28 May 2002	Kibuye, Cyangugu, Byumba and Kigali	Rusenyi	69	20,000		CRED; Reliefweb; Earth observatory; IRIN
30-Oct-2003	Umutara and Byumba		0	7,016	>100 houses, 60 schools & crops destroyed	CRED
16-Aug-2005	Kigali	Kigali	2	3		CATNAT; Reliefweb
16-Aug-2005	Ruhengeri and Byumba		25	25,000	5,000 houses & 3,000 plantations flooded	CATNAT; OCHA; Reuters
12-20 Sep 2007	Western	Rubavu and Nyabihu	20	4,000	678 partially & 342 houses completely destroyed	CRED; Reliefweb; Moeyersons et al. 2007
3-16 Feb 2007	Western	Rubavu and Nyabihu	10	500		CRED; Reliefweb
12-Sep-2007	Western and Northern	Nyabihu and Gicumbi	15	2,810	37 houses destroyed, 562 families homeless	Moeyersons et al. 2008; allAfrica.com
Oct-2008	Western and Southern		0	500	2,000 Ha crops damaged	Reliefweb
2-Oct-2008	Western and Northern				numerous houses and crops destroyed	Glidenumber; IRIN
6-Oct-2008	Western and Northern		0	2,500	>500 homes submerged; 2,000 ha crops destroyed, as well as bridges, roads, pylons & schools	IRIN; Reliefweb
Sep-2009	Western	Rubavu			houses and crops destroyed	Personal Communication Paul Nshimyimana
23-24 Feb 2010	City of Kigali	Kigali	3		Industrial sites submerged (around Rwandexco factory), damage to constructions and crops	Vincent Manirakiza, Kigali Institute of Education
2011	Western	NYABIHU	1		19 houses and 87 ha of land affected	MIDIMAR
	Northern	BURERA	1			MIDIMAR
	Eastern	NYAGATARE			65 ha of land affected	MIDIMAR
2012	Northern	Bugesera	2			MIDIMAR
		Burera	1			MIDIMAR
		Gicumbi	2			MIDIMAR
		Musanze	1			
	Western	Rubavu	7		252 houses and 58 ha of land affected	MIDIMAR
		Rusizi	3		341 houses and 125 ha of land affected	MIDIMAR
	City of Kigali	Gasabo			6 people injured	MIDIMAR
		Kicukiro	3			MIDIMAR
	Southern	Nyamagabe	1			MIDIMAR
2013	Western	Karongi	5		2 houses affected	MIDIMAR
		Nyabihu	2		35 houses and 4 ha of land affected	MIDIMAR
		Rubavu	3		65 houses affected	MIDIMAR
	Southern	Nyaruguru	2			MIDIMAR
		Ruhango			48 houses and 12 ha of land affected	MIDIMAR
	City of Kigali	Gasabo			49 houses affected	MIDIMAR
		Kicukiro			8 houses affected	MIDIMAR
		Nyarugenge	3		20 houses affected	MIDIMAR
	Northern	Musanze			39 houses and 395 ha of land affected	MIDIMAR

Source: (MIDIMAR, 2015)

Table 12: Historical list of landslides, 1963-2013

Date	Province/ District	Death	Affected people	Damages	Source info	Comments
1963	Ruhengeri	-	-	-	Byers A. C., 1992	Multiple landslides
1987	Gitarama	-	-	fields destroyed	Byers A. C., 1992	-
May-88	Ruhengeri	-	15	3 houses destroyed	Byers A. C., 1992	debris avalanche at Nyagitaba
Nov-06	Kigali	24	2,000	-	CRED; Afrol	-
2010		21	5,937	-	em-dat	-
2011	Nyabihu	17		3 Houses destroyed or damaged	MIDIMAR	2 people injured
	Burera	7			MIDIMAR	1 people injured
	Rutsiro	1		14 Houses destroyed or damaged	MIDIMAR	
2012	Ngororero	2		19 Houses destroyed or damaged and 54 ha of Crop lands affected	MIDIMAR	
	Nyabihu	5		147 Houses destroyed or damaged and 305 ha of Crop lands affected	MIDIMAR	
	Gasabo	2		6 Houses destroyed or damaged	MIDIMAR	
	Nyamagabe			2 Houses destroyed or damaged	MIDIMAR	
	Rulindo			1 house damaged and 40 ha crop lands affected	MIDIMAR	
	Nyamasheke	3		1 house damaged	MIDIMAR	
	Nyarugenge	-		1 house damaged	MIDIMAR	
	Burera	2		-	MIDIMAR	1 people injured
2013	Gasabo	2		47 Houses destroyed or damaged	MIDIMAR	3 people injured
	Nyarugenge	4		87 Houses destroyed or damaged	MIDIMAR	4 people injured
	Kicukiro	-		22 Houses destroyed or damaged	MIDIMAR	
	Rutsiro	3		18 Houses destroyed or damaged	MIDIMAR	1 people injured
	Rulindo	12		79 Houses destroyed or damaged and 257 ha crop lands affected	MIDIMAR	7 people injured
	Gakenke	2		41 Houses destroyed or damaged	MIDIMAR	
	Gicumbi	3		52 Houses destroyed or damaged	MIDIMAR	
	Nyamagabe	-		8 Houses destroyed or damaged	MIDIMAR	
	Burera	2		19 Houses destroyed or damaged	MIDIMAR	
	Ngororero	-		4 Houses destroyed or damaged	MIDIMAR	
	Rubavu	2			MIDIMAR	3 people injured
	Karongi	5		2 houses damaged	MIDIMAR	

Source: Royal Museum for Central Africa, (MIDIMAR, 2015)

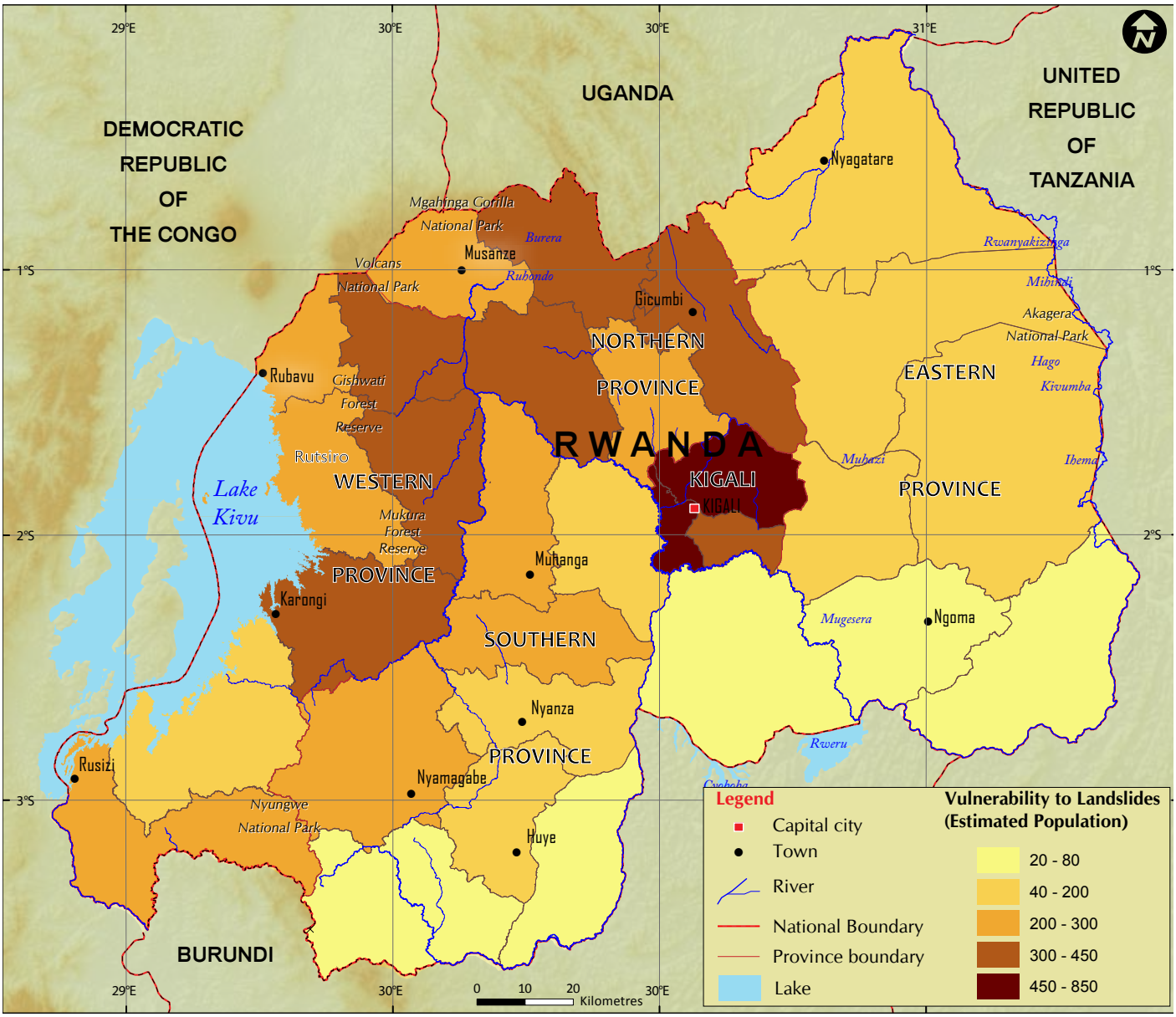
A 2012 study of flood events in Nyabihu, Musanze and Burera Districts found the triggers to be high erosion levels and sedimentation; water runoff; clogged or destroyed drainage channels; inadequate rainwater infiltration resulting in rapidly rising water tables; fragile soil due to intense farming; and high rainfall events (Zimmerman & Byizigiro, 2012).

Table 12 lists the major landslides since the 1960s.

Figure 32 shows show that populations in some districts are more highly prone to floods and landslides than others. The reasons vary according to the triggering factors present. The most affected Districts are Burera, Rubavu, Gicumbi, Nyabihu, Ngororero, Musanze, Rutsiro, Nyamagabe, Muhanga, Kamonyi and Bugesera. The natural risks for landslides in these areas are exacerbated by the population's high level of vulnerability and exposure (MIDIMAR, 2012a). The socioeconomic conditions that contribute to a population's vulnerability include a wide range of reasons, the most important of which is high poverty levels (Zimmerman & Byizigiro, 2012).

Persistent, above-normal heavy rains have resulted in numerous recent localized landslides. In 2010, three cells of rural communities in the Rubavu District suffered heavy losses from landslides. Of the 5,920 people affected, 1,184 families lost their homes. Landslides

Figure 32: Map of the population vulnerable to landslides at moderate to very high susceptibility



Source: (MIDIMAR, 2015)

killed at least 17 people between April and June of 2012 and and hundreds of houses were destroyed in Northwestern Rwanda (MIDIMAR, 2012b).

Responses

The Ministry of Disaster Management and Refugee Affairs (MIDIMAR) has put in place various tools to tackle natural hazards and their impacts, among them the National Disaster Management Plan, a revision of the National Disaster Preparedness and Contingency Plan 2009, Guidelines on Gender in Disaster Management, and the National Disaster Risk Reduction Policy. The National Disaster Management Policy 2012 revises the National Disaster Management Policy 2009 and provides guiding principles and architecture for Disaster Management in Rwanda through a legal and institutional framework and coordinated, decentralized and participatory partnership between the Government and other stakeholders (MIDIMAR, 2013a). The National Disaster Management Policy has a coordination platform called the National Platform for Disaster Risk Reduction (NPDRR), which comprises line Ministry focal points for Disaster Management and all organizations that play a significant role in disaster management (MIDIMAR, 2013a).

MIDIMAR also developed a 5-Year Strategic Plan for 2012 to 2017, with clear objectives aligned with the five priorities of the Hyogo Framework for Action (HFA) (MIDIMAR, 2013a), an international ten-year plan (2005-2015) to make the world safe from natural hazards. Rwanda views environmental sustainability as the single most important element of the post-HFA since most natural disasters are strongly linked to environmental mis-management (MIDIMAR, 2013a).

MIDIMAR is also a partner with One UN Rwanda to implement various Disaster Risk Reduction (DRR) projects that focus on capacity building, disaster

communication and early warning as well as on providing technical assistance. One UN (a new UN strategy, called "Delivering as One" or "One UN") supports Rwanda's economic transformation agenda based on the pillars of pro-poor economic growth, social inclusion and pro-poor environmental sustainability (One UN, 2014). The World Bank and the European Union have also partnered with the Ministry in carrying out a large-scale DRR project known as "Evidence-based Comprehensive National and District Disaster Risk Analysis in Rwanda" (MIDIMAR, 2013a).

The Government is also developing local disaster management bodies with the aim of building local government capacity to accommodate grassroots DRR initiatives. Currently, it is establishing First Respondent Teams in all sectors and deploying District Disaster Management Officers in all districts (MIDIMAR, 2013a).

Within the GGCR, DRR and Disaster Management touches all priority areas and is mainstreamed in all priority sectors. The most important are: agriculture, infrastructure, education, environment and natural resources, private sector development, energy, urbanization, information communication technology, health, youth and social protection. Measures include investment in rapid response disaster management equipment, early warning systems, and awareness campaigns directed to residents of vulnerable areas (RoR, 2013).

Finally, the Government partnered with UNDP on the project "Building National and Local Capacities for Disaster Risk Management in Rwanda", an initiative that aims to support the GoR in building its capacity to address disaster and climate threats. One component of that project is a disaster risk profile created by the Risk Atlas Project. Led by the Ministry of Disaster Management and Refugee Affairs (MIDIMAR), the Risk Atlas Project has conducted a comprehensive assessment of existing risks at the national and local level (UNDP, 2015). Data and maps from the Atlas feature in this chapter.

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Chapter 2: Forests

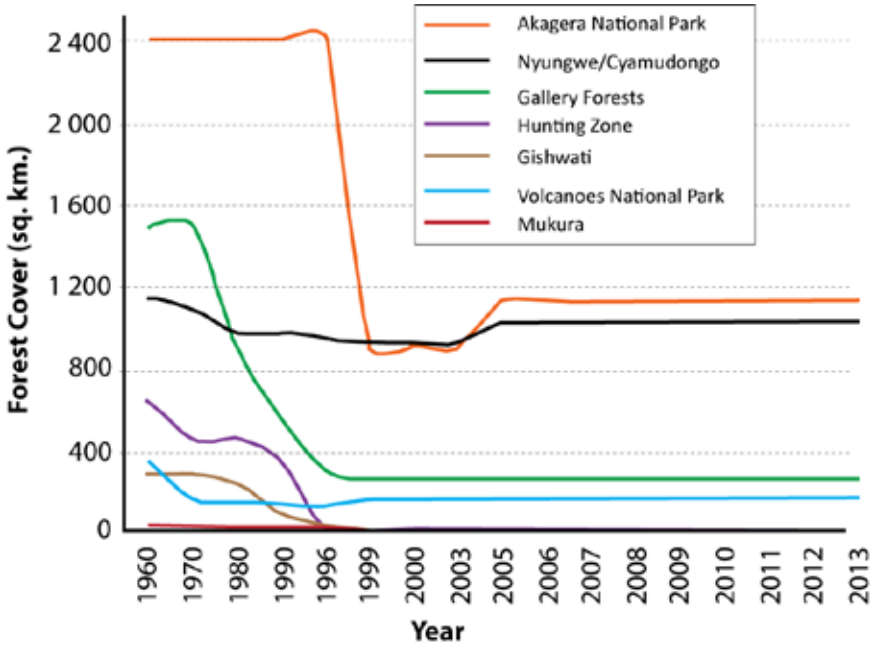
2.1 Status and trends

Forest cover

Rwanda is turning around a legacy of deforestation in keeping with its 2020 goal to increase forest cover to 30 per cent of the land area (MINIRENA/RNRA, 2015). Historically, natural forest is thought to have covered about 70 per cent of the national territory. By some estimates, forest cover declined to about 30 per cent of Rwanda's total land area by 1930, and

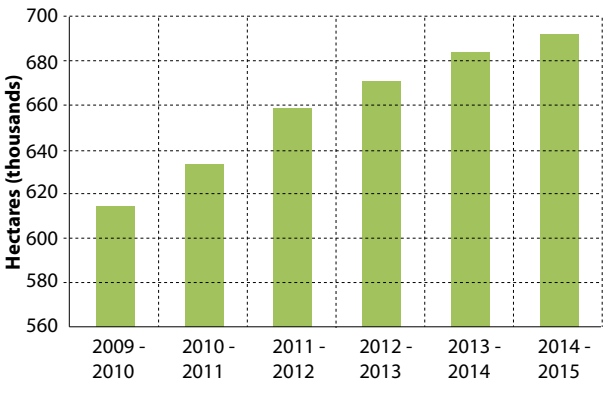
Reforestation on the edge of Gishwati. Eugene Apindi Ochieng

Figure 1: Trend in the area of natural forest cover, 1960-2010



Source:(REMA 2011a)

Figure 2: Trend in total area covered by all forests, 2009-2015



Source: (MINIRENA/RNRA, 2015)

by 2000, it had been reduced to only 8.9 per cent (Habiyaremye, Jowen, de la Paix Mupenzi, & Balogun, 2011). Overall, forest department statistics show that between 1960 and 2007, natural forest area declined by about 64 per cent (REMA, 2009), mostly due to deforestation for agriculture and to settle returning refugees (Havugimana, 2009). The precipitous decline in natural forest starting in the 1960s and '70s is clearly evident in Figure 1.

Thanks to Vision 2020 and an aggressive tree-planting programme, the trend began to reverse. In 2007, forests covered 21 per cent, or 553,100 hectares (ha), of Rwanda's total land area (RNRA, 2010). Today, about 696,402 ha or 29.2 per cent of the land is now occupied by forest of some sort — both natural and planted.

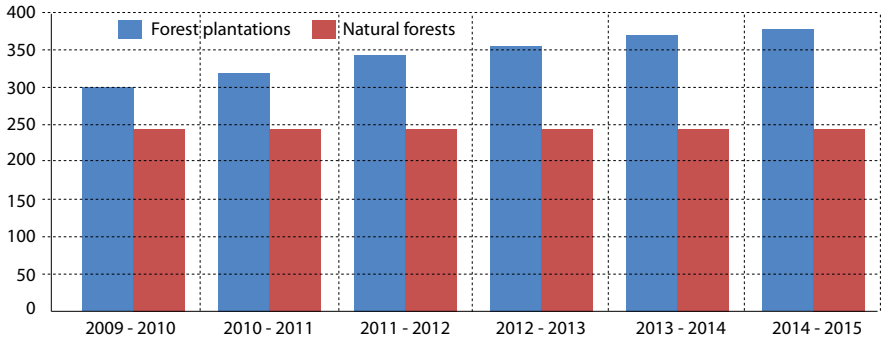
In 2011, the United Nations gave Rwanda the gold award for its forest promotion policies, noting that "despite continuing population and land pressures, Rwanda is one of only three countries in Central and Western Africa to achieve a major reversal in the trend of declining forest cover" (UN, 2011).

Figures 2 and 3 show the recent changes in area covered by forests, the latter illustrating that the rise in forest area is due to increased area under plantations. Figure 4 is a forest cover map of Rwanda for 2014.

The total forest coverage in 2015 was 696,402 ha, of which 258,066 ha was natural forest (40 per cent) and 438,336 ha (60 per cent) was plantations. Natural and human made forests covered 10.8 per cent and 18.4 per cent of the country, respectively (MINIRENA/RNRA, 2015).

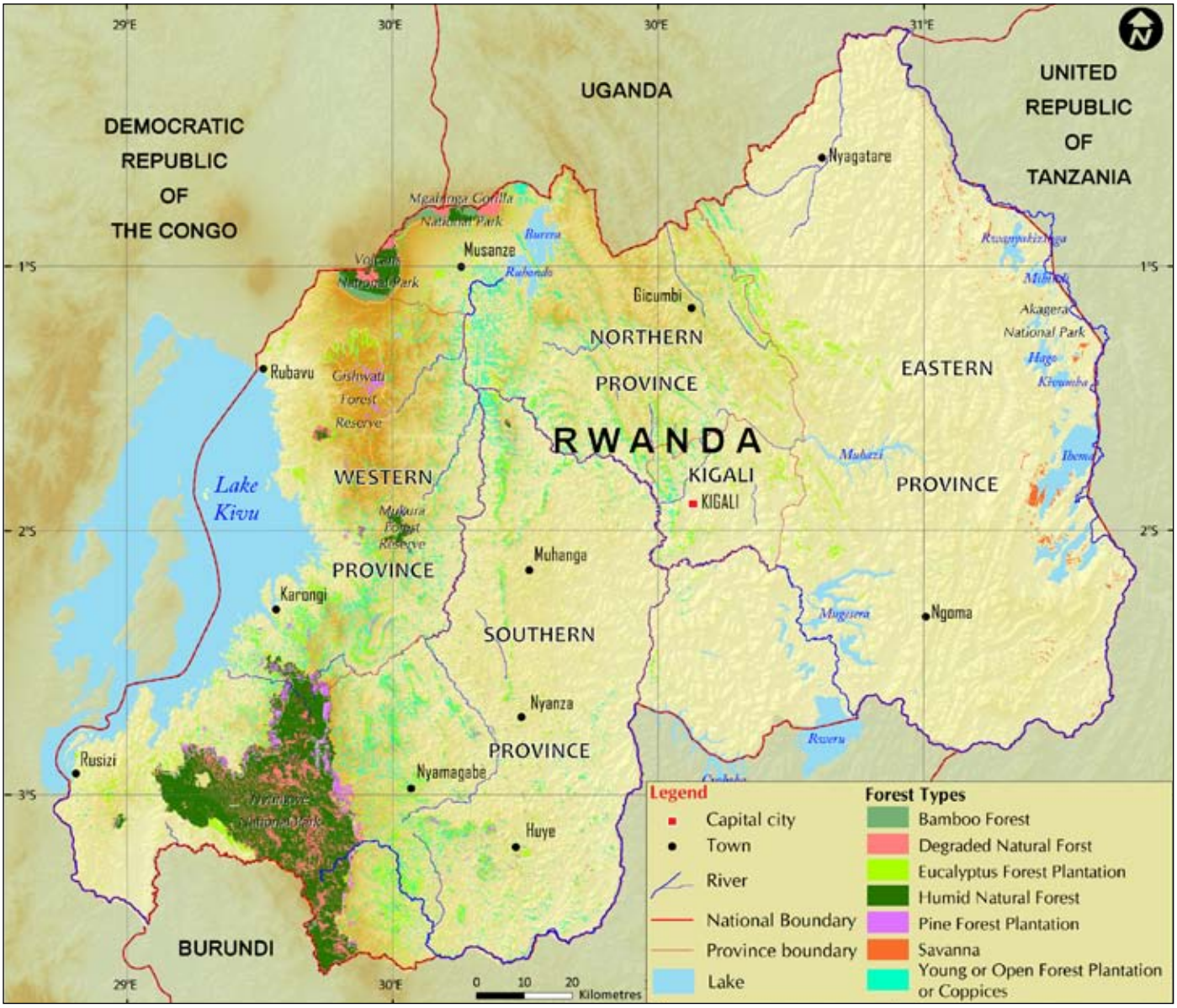
Geographically, the climate, water resources and soils in the western half of Rwanda are more supportive of vegetation than the arid east, which is almost devoid of forest. Figure 4 emphasizes the distribution of greenery in the

Figure 3: Trend in natural and human made forest area, 2009-2015



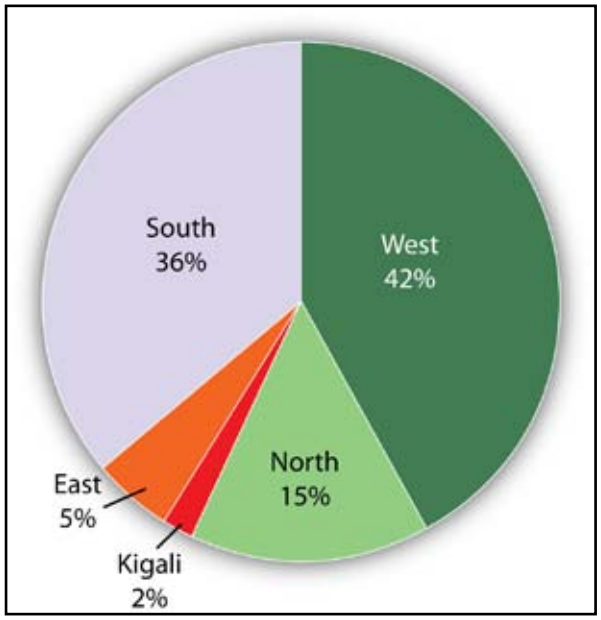
Source: (MINIRENA/RNRA, 2015)

Figure 4: Forest cover map of Rwanda, 2014



Source: Data provided by REMA, 2015

Figure 5: Forest cover by Province



Source: (World Bank, 2012)

Box 1: Forest types in Rwanda

- Afro-montane rainforests: the natural forests of the Congo Nile Ridge comprised of the Nyungwe National Park, Gishwati and Mukura Forest Reserves; and the natural forests of the Volcanoes national park;
- Forest patches in savannah landscapes: the natural forests in the savannah and gallery-forest of the Akagera National Park and remnants of gallery-forests and savannahs of Bugesera, Gisaka and Umutara;
- Tree plantations: plantations dominated by exotic species (*Eucalyptus sp, Pinus sp, Grevillea robusta*);
- Other trees and shrubs outside natural forests and tree plantations, including tree stands scattered on farmlands (agroforestry) and serving to prevent erosion.

Source: (UNEP, 2011)

landscape and Figure 5 shows that an estimated 42 per cent of the country's forests grow in the west and 36 per cent in the south.

Forest ecosystems

The Government of Rwanda defines forests as "ecosystems dominated by trees (defined as perennial woody plants taller than 5 metres at maturity), where the tree crown cover (or equivalent stocking level) exceeds 10 per cent of the ground surface and the area is larger than 0.5 ha" (RoR, 2010). The country's forests are comprised of an association of forested belts in its national Parks (Akagera, Nyungwe and Volcanoes National Parks); forest reserves (Gishwati and Mukura); and natural forests (Busaga, Buhanga and the gallery forests in the Eastern Province) and other remnant forested areas; forest plantations that primarily consist of exotic tree species; woodlots; and agroforestry plantations (REMA, 2011a).

Thus, Rwanda's definition of today's forests includes areas now planted through agroforestry initiatives as well. The Government of Rwanda (GoR) defines agroforestry as "a collective name for land-use systems and technologies, where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence" (RoR, 2010).

Because Rwanda's topography, climate and soils are so varied, its forested landscapes are characterized by a wide variety of forest and woodland ecosystems. Box 1 describes the four major categories: Afro-montane rainforests, forest patches in savannahs, tree plantations and "other" trees and shrubs (UNEP, 2011).

Natural forests

Today, natural forests are located almost entirely in protected areas as National Parks or Reserves (Table 1). These natural forests and protected areas cover 10.8 per cent of the country's land base and are effectively sheltered since extraction has been prohibited since 2000 (RoR, 2012). See Figure 3 in

Reforestation on the edge of Gishwati

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Table 1: Natural forest types and area in parks and reserves

National park/Natural reserve	Forest type	Area (Ha)
Nyungwe National Park (including Cyamudongo)	Humid natural forest	70,363
	Natural forest (secondarisée)	33,500
Volcanoes National Park	Humid natural forest	7,211
	Natural forest (secondarisée)	4,628
	Bamboo	4,380
Akagera National Park	Savanna	1,277
Gishwati Natural Reserve	Humid natural forest	316
	Natural forest (secondarisée)	712
Mukura Natural Reserve	Humid natural forest	1,726
	Natural forest (secondarisée)	187
Busaga Natural Reserve Humid	Natural forest	82
	Natural forest (secondarisée)	70
Other		2,565
TOTAL		**127,016**

Source: (NISR, 2008)

Chapter 3 for a map of the location of Rwanda's National Parks and Forest Reserves.

Forest plantations

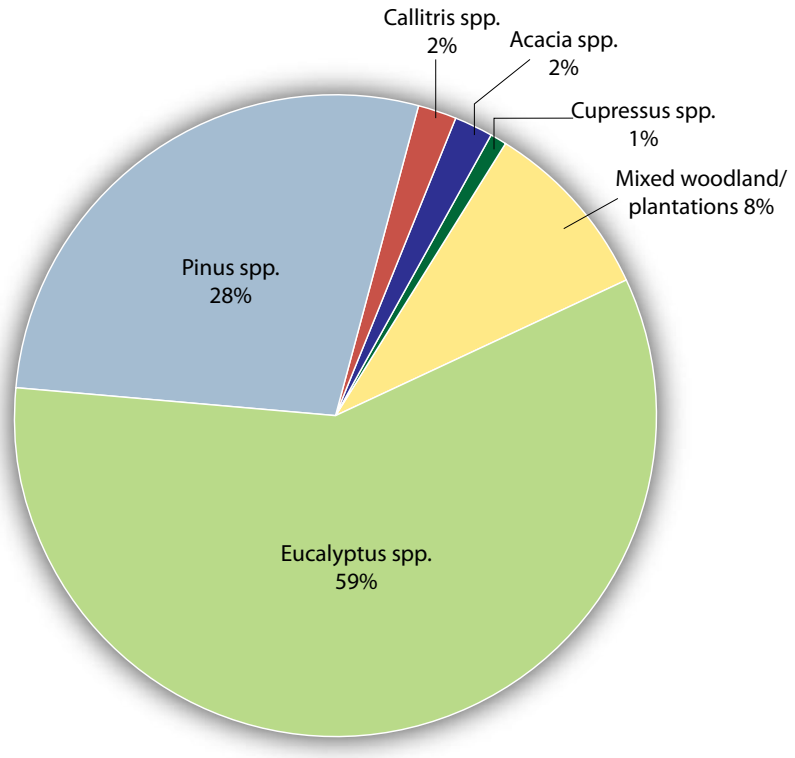
Private forest plantations and woodlots provide most of the country's forest products, except for a limited amount of imports (AFF, 2011). These products consist mostly of eucalyptus with some *Grevillea robusta* and pine (EC, 2014). Many of the country's larger plantations were created before independence, providing fuel wood and helping to stem pressures on natural forests. They are spread throughout the country but are more abundant in humid areas (REMA, 2009). Rwanda increased its area of plantations from about 359,527 to 438,336 ha between 2009 and 2015.

Almost fifty nine per cent of the total area under plantations and most private plantations consist of Eucalyptus trees (Figure 6). At least 10 Eucalyptus species are growing in Rwanda. They have been favoured because of their fast growth, coppicing ability, caloric value and adaptability to a wide range of soils and climate (Ndayambaje & Mohren, 2011). Pines (mainly *Pinus patula*), which account for about 28 per cent of species in plantations, have been widely planted in buffer zones around natural forests in the Congo-Nile highlands (UNEP, 2011). Poverty, high population densities and associated land shortages constrain the expansion of plantations since forests are seen to compete with food crop production; thus agroforestry is currently considered the only feasible option for producing wood for fuel needs and ecosystem goods and services (AFF, 2011).

Agroforestry

Outside of natural protected forests and plantations, other trees and shrubs make up the rest of the country's general tree cover. This category is significant and includes agroforestry areas that are mainly planted on farmlands, as well as trees and shrubs in marginal and other open spaces (UNEP, 2011).

Figure 6: Forest plantations by species



Source: Adapted from (World Bank, 2012)

Box 2: Greening the farming of trees and shrubs for ecosystem health and better livelihoods

Farmer Managed Natural Regeneration (FMNR) is a global project led by World Vision and Australia's Food Security and Climate Change team. It is a low-cost land restoration technique used to combat poverty and hunger amongst poor subsistence farmers by increasing food and timber production and resilience to climate extremes. One of the practices involves allowing trees and shrubs to regrow from the stumps of felled trees. Integrating these trees into crops and pastures helps to restore soil structure and fertility since many of the species can fix nitrogen from the atmosphere. They also protect soils from erosion, and by shading the soil, inhibit soil moisture from evaporating, allowing springs to return and rehabilitating the water table; they also increase biodiversity and sequester carbon. In addition to increasing crop yields, the trees provide building timber and firewood; fodder and shade for livestock; wild foods for food security, nutrition and medication; and increased incomes and living standards for farming families and their communities (FMNR, 2015). In fact, these ecosystem goods and services were once provided by indigenous tree species that were lost to land-use conversion for agriculture. As a result of FMNR successes, its techniques are increasingly being adopted as farmers appreciate the impacts of losing their indigenous trees and the value of replacing them.

Although the programme is still young, farmers are benefiting from the return of fruiting and valuable and rare species; increased fodder, honey and fuel wood; the value of pruned branches and leaves for compost and the improved soil structure that results; and restored habitat for wildlife (Rinaudo, 2014). Women no longer have to walk long distances to fetch firewood and now have time to rest and to cultivate kitchen gardens and improve their family's nutrition (FMNR, 2015).

Agroforestry is of increasing importance in Rwanda as a practice that can help to green both agriculture and the economy. As explained in the *Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development* (GGCR):

> "Rwanda does not have the land available to expand its forests and plantations, yet the majority of the population depends on wood for cooking and will continue to do so until electricity is available and affordable for all. Agroforestry will provide wood for fuel and social protection while avoiding deforestation. Different tree species will be used in agroforestry to provide construction materials as well as livestock fodder and food (fruit and nuts), which improve food security. Agroforestry has multiple additional benefits, namely reduced soil erosion and increased resilience to heavy rains through improved slope stability; water management and nutrient recycling which improve agricultural production; and carbon sequestration" (RoR, 2011, p. v).

In view of the land shortage in Rwanda for extensive forest plantations, Rwanda's strategic plan for the forest sector calls for the vigorous adoption of farm forestry using multi-purpose species that also increase soil fertility by fixing nitrogen (RNRA, 2010). The GGCR strategy intends the agroforestry sector to be guided by latest best practices and research, such as Farmer Managed Natural Regeneration (FMNR) (RoR, 2011) (Box 2).

The value of Rwanda's forests

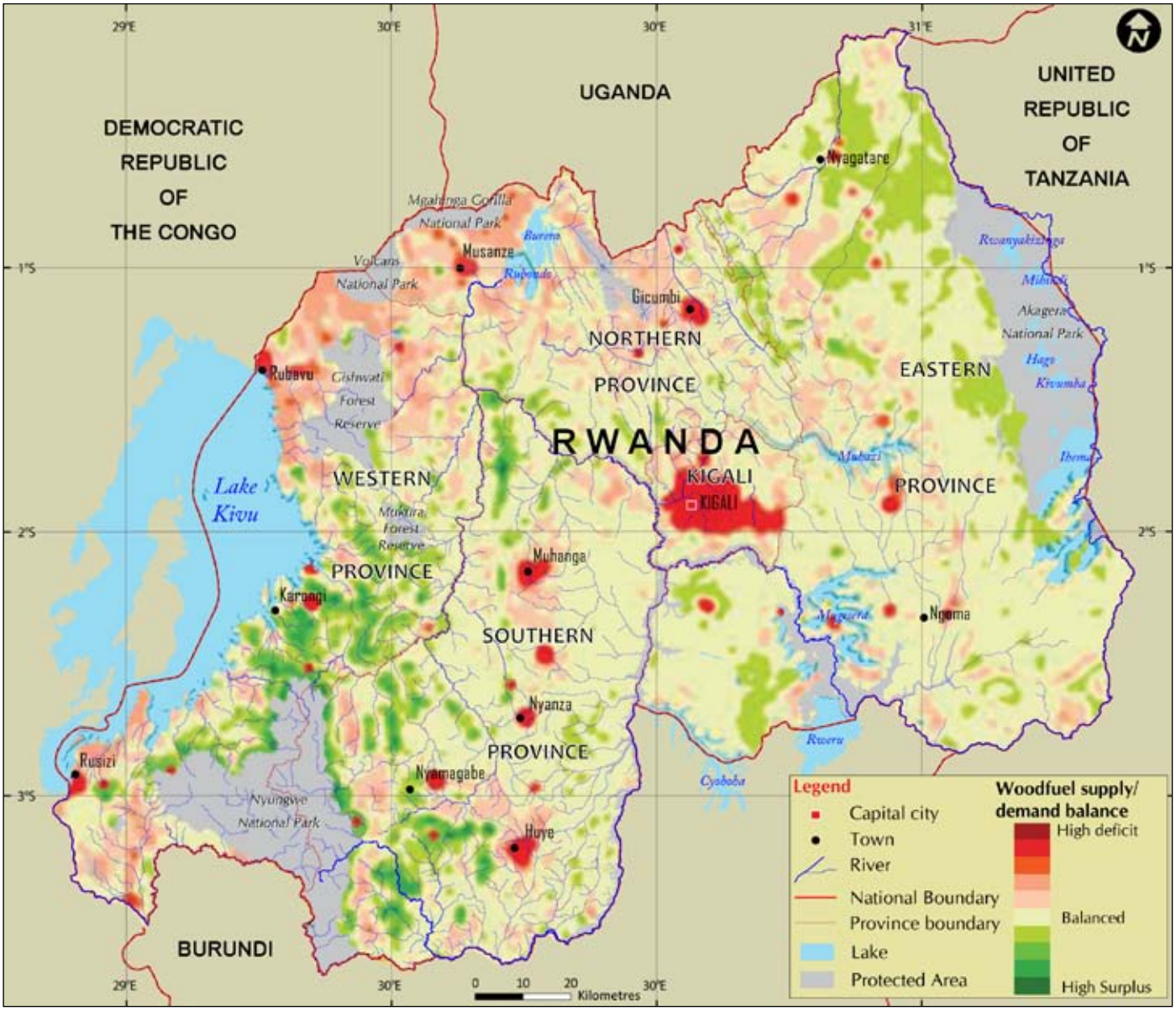
Fuelwood and charcoal

Rwanda's forests supply fuelwood and charcoal that are still critically important in Rwanda's transition to a low carbon economy. Fuelwood is a key issue that links forestry, deforestation and forest degradation; energy provision; agriculture; poverty alleviation and food security; and regional economic development.

Planted forests supply almost all of Rwanda's fuelwood. Total wood-fuel consumption for Rwandan households is estimated at 2.7 million t/yr and charcoal (converted into wood equivalents) accounts for around 40 to 50 per cent of total wood-fuel use. The City of Kigali alone consumes 120,000 tonnes of charcoal a year, equivalent to 1.2 million m^3 or 850,000 tonnes of wood (World Bank, 2012).

In 2011, the wood-fuel sector directly employed about 20,000 people who in turn supported some 300,000 people. These jobs include 7,000 loggers who fell, size and stack the wood and about 8,000 charcoalers, most of them in rural areas of the Southern and Western Provinces. In addition, some 200-300

Figure 7: Available woody biomass



Source: (Drigo & Nzabanita, 2011)

people transport the wood and there are about 2,000 charcoal vendors, mostly in urban areas (Ndegwa, Breuer, & Hamhaber, 2011).

The Wood fuel Integrated Supply/Demand Overview Mapping (WISDOM), a specialized system to examine the spatial distribution of wood fuel supply and issues of sustainability, was used to assess Rwanda's biomass needs and supply constraints. Conducted in 2011, the research used 2009 data with the following findings:

- The total annual productivity of woody biomass accessible and potentially available for energy use for the entire country is 1.1 Mt. The annual amount could rise to 1.7 Mt with better forest and agroforestry management;
- Total residential, commercial and public sector consumption with current carbonization and stove efficiency is estimated at 2.9 Mt. With realistic improvements in the efficiency of charcoal making and the dissemination of improved stoves, the demand could lower to 2.47 Mt;
- The national supply/demand balance is an annual deficit of 1.8 Mt. Improved management and conversion efficiencies could raise the balance to a deficit of 0.75 Mt;
- Over 1.5 million people (or 20 per cent of the rural population) live in areas with a serious wood fuel deficit and high poverty, which make them extremely vulnerable (Drigo & Nzabanita, 2011).

New studies are needed to update the figures and analysis. Figure 7 is a map of wood fuel deficit, balance or surplus across the country; the majority of the country has sufficient wood fuel but areas coloured in red suffer from a high deficit.

Charcoal is an extremely important source of fuel in Rwanda, accounting for about 23 per cent of primary energy sources (MININFRA, 2014); it will continue to play a major role in energy provision during the country's transition to a low carbon economy since a clear alternative fuel that provides the same service for a similar price is not yet available. Effectively all of Rwanda's charcoal is derived from private and community plantations, removing this pressure from the country's natural forests (World Bank, 2012).

Timber

The country's forests also have the potential to produce timber for construction and furniture. Rwanda does not have a wood processing industry and all processed wood products are imported. Since timber felling is banned in indigenous forests and state plantations, wood-based industries depend on private forests and individual farms to source logs and supplement hardwood imports from the Democratic Republic of the Congo (DRC). Small and medium-scale industries in formal and informal sectors engage in secondary wood processing in the form of furniture so the data about this industry are often not reflected in official statistics. In 2010, an estimated 40,950 people were employed in Rwanda's wood-based production industry, which contributed 0.9 per cent to GDP (MINIRENA, n.d.).

Non-timber forests products

Finally, but not the least in importance, forests provide non-timber forest products to local communities with access to them; these include medicinal plants for both humans and livestock, fodder, honey, fruits, seeds, essential oils, handicraft material, mushrooms, ornamental plants, game and fish, among others (REMA, 2011b).

2.2 Pressures and impacts

The major drivers of deforestation and forest disturbance in Rwanda are high population densities, land fragmentation, limited jobs in non-agricultural sectors and high poverty levels (Mukankomeje, 2011), as well as climate change that might affect forest pests, for example. Pressures include the collection of firewood and other forest products, illegal logging, charcoal production, bush fires, mining and the invasive liana, among others (UNEP, 2011).

Charcoal

Traditional small-scale charcoal production has significant environmental impacts, since the charcoal fuel cycle is highly inefficient and among the most greenhouse gas intensive in the world. Furthermore, its emissions cause respiratory infections that can lead to cancer (World Bank, 2012). Box 3 describes Rwanda's Biomass Energy Strategy (BEST), which is helping to green the charcoal value chain.

Box 3: Greening the charcoal value chain

In 2008-9, the Ministry of Infrastructure (MININFRA) developed the Biomass Energy Strategy (BEST). It focuses on 4 key areas: 1) increased and sustainable wood fuel supplies and professionalizing the charcoal value chain; 2) increased efficiency in the use of wood and charcoal; 3) promoting alternative cooking fuels (Liquified petroleum gas (LPG), peat, biogas); and 4) increased government capacity to deal with biomass. Much has already been done to facilitate the LPG and biogas markets, promote more efficient cookstoves in both urban and rural areas and support better technologies and organization in the charcoal chain. A recent study looked at the potential for GHG emissions to be certified along a sustainable, "green" charcoal chain. Such a scheme could allow farmers and others growing trees as well as charcoal producers to potentially add value to their products and improve their livelihoods. It proposes a number of "greening" interventions related to sustainable wood production, including the exploitation and transformation of wood-fuels; the transport and commercialization of charcoal; the use of wood-fuels; and improved framework conditions, including innovative funding mechanisms.

Source: (World Bank, 2012)

Eucalyptus

There is some debate over the environmental impacts of eucalyptus in Rwanda. Some environmentalists and politicians have criticized the use of eucalyptus in woodlots and suggested it should not be used in the country's reforestation efforts. They argue it out-competes other species for soil nutrients and water, especially since in water scarce conditions, it continues to use water longer than other species. Research on fuelwood demand and supply in Rwanda and the role of agroforestry cites studies indicating that these effects depend on the species, site characteristics and management practices and suggest they can be avoided by planting fewer trees per unit area or by thinning (Ndayambaje & Mohren, 2011).

Farm terrances Eugene Apindi Ochieng

Other threats to Rwanda's forests

Threats from forest insects, disease and fire (except in Nyungwe National Park) are minor in Rwanda's forests. The *liana Sericostachys scandens*, which is native to Afromontane forests, appears to be a threat in some forest ecosystems. This plant seems to be multiplying in the Nyungwe National Park, where it often covers trees, clearings and road edges. Its potential to kill trees and impede regeneration is a threat to this forest, which is globally significant for its biodiversity (Scholte, et al., 2010).

In addition to the loss of forest cover, biodiversity and ecosystem services in general, the impacts of human pressures in forested areas include localized flooding, erosion and landslides, decreased soil fertility and water quality, and heavy river siltation, all of which exacerbate local poverty (GPFLR, 2013a). Another impact has been the gradual conversion of natural tree varieties to pine plantations and pasture, as has occurred in the Gishwati forest, for example (Nyandwi & Mukashema, 2011).

Table 2: Vision 2020 targets for forests

Indicator	Status in 2012	Vision 2020 target (revised)
Percentage of land protected to maintain biodiversity	10.13	10.3
Forest land (percentage of land area)	22.4	30
Percentage of households using wood as a source of energy	86.3	50

Source: (RoR, 2012)

2.3 Response

Vision 2020, EDPRS and the National Forest Policy

Rwanda's Five Year Strategic Plan for the Environment and Natural Resources Sector (MINIRENA, 2013), in line with Vision 2020 and the EDPRS II, sets the goal to increase forest cover across the country and sustainably manage ecosystems and forestry resources. The EDPRS 2013-2018 cites forestry as a main concern because of its significant contribution to GDP. Targets include increasing forestry jobs from 0.3 per cent to 0.5 per cent by 2018 and reducing biomass energy use through the use of improved stoves and kilns to produce 75 per cent of the country's charcoal by 2018. Vision 2020's forestry related targets are shown in Table 2 (MINIRENA, 2013).

To reverse deforestation and achieve its Vision 2020 goals and those of the EDPRS, the government has embarked on an ambitious afforestation programme. The National Forestry Policy facilitates the achievement of these forest cover targets (RNRA, 2011). The 2004 policy was updated in 2010 to address the following issues:

- Increasing competition for land between forestry and other developmental activities;
- Poor management of man-made forest that compromises a sustained yield;
- Low private investment in the creation of forest resources, in value addition to forest products and in diversification of forest products;
- Existence of over mature and degraded forests; and
- High dependence on importation of industrially processed forest products (RNRA, 2010).

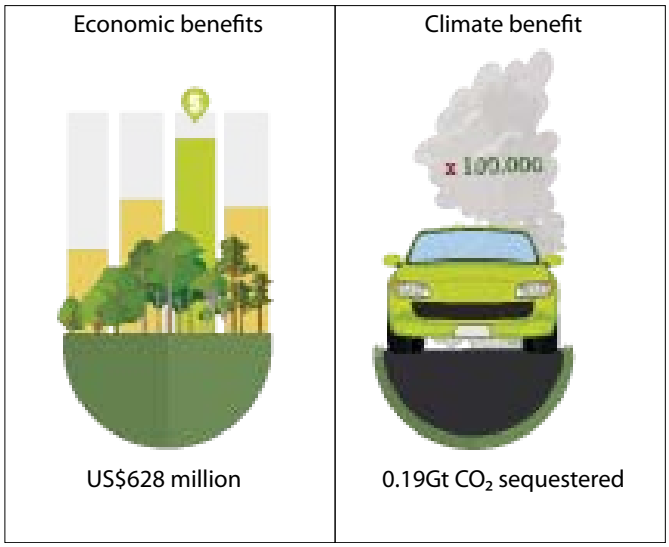
The overall goal of the National Forest Policy is to make the forestry sector "one of the bedrocks of the economy and to create a national ecological balance for sustainable benefits to all segments of the society" (RNRA, 2011). In 2011, the Policy won the World Future Council's Future Policy Award as the world's most inspiring and innovative forest policy (Bizimana, 2012). It is guided by the following 14 principles that also inform the Strategic Plan for the Forest Sector (RNRA, 2010):

1. Sustainable Forest Management (SFM);
2. Commercialization of forestry operations;
3. Species diversification;
4. Agroforestry technologies;
5. Special management of ecologically and physically fragile areas to conserve biodiversity and protect areas prone to soil erosion and landslides;
6. Forestry research;
7. Stakeholder involvement and partnerships;
8. Forest management planning;
9. Private sector involvement;
10. Decentralized governance;
11. Management of forests to serve the common good irrespective of ownership because of the multiple roles of forests. (Therefore, any action taken in any forest will be regulated to safeguard the public interest);
12. Livelihoods enhancement;
13. Gender and equity; and
14. Internalization of current and future international forestry conventions, agreements and protocols into all strategies and interventions in the forest sector (RNRA, 2011).

Forest restoration: The Bonn Challenge

At the international level, Rwanda is one of almost a dozen countries and institutions that have pledged to restore land in response to the Bonn Challenge, a global aspiration to restore 150 million hectares of the world's deforested and degraded lands by 2020. In 2011, the government of Rwanda pledged to bring 2 million hectares under restoration by 2020, which represents the proportionally highest national commitment to the Bonn Challenge to date. The Challenge is founded on the principles of Forest Landscape Restoration, a long-term process of regaining ecological integrity and enhancing human well-being in degraded and deforested lands (GPFLR, 2013b). It has both economic and climate benefits, corresponding to Rwanda's national goals for a green and low carbon economy. Figure 8 shows that its commitments to the Bonn Challenge could sequester 0.19 Gt of CO_2 equivalents and have the potential to bring financial benefits of US$628 million.

Figure 8: Potential green growth benefits to Rwanda of Forest Landscape Restoration



Source: (Bonn Challenge, 2011)

The Bonn Challenge recognizes the importance of agroforestry in Rwanda. Given its high population density and the significance of agriculture to the economy, agroforestry represents the most important and wide-reaching restoration opportunity. In addition, it supports Rwanda's efforts to foster regeneration in natural forests, such as in the Gishwati Forest Reserve, and in establishing protective forests along steep slopes, wetlands and rivers (Bonn Challenge, 2011).

Carbon sequestration

Rwanda's carbon storage in forest biomass helps to mitigate climate change. By planting trees through afforestation, reforestation and agroforestry, Rwanda can continue to offset its GHG emissions by sequestering carbon. Reforestation refers to planting forests on land that was relatively recently covered by trees, while afforestation refers to replanting on land that has been without forest for much longer (Watson, Noble, Bolin, Ravindranath, & Dokken, 2000). Box 4 highlights the potential for Rwanda to take advantage of the carbon captured in natural and replanted forests as a way to mitigate the emission of greenhouse gases and climate change and in exchange, earn financial compensation.

Conclusion

Since about 2007, Rwanda has been successful in sustainably managing its forest ecosystems and resources to optimize their economic and ecological functions. For example, planted forests supply almost all of Rwanda's fuelwood, but there is hardly any room to expand plantations. Thus, Rwanda is actively promoting agroforestry to provide wood for fuel during the transition to available and affordable electricity for all. The numerous ecological benefits of agroforesty, from controlling erosion, providing fodder and improving soil fertility, also contribute to social well-being and green economic growth.

Rwanda is rare among the world's countries to have not only stemmed forest loss but also significantly increased the area under forest cover. By 2015, Rwanda had nearly attained Vision 2020's goal to increase forest cover to 30 per cent of its land area by intensive planting and protecting the natural forests that remain. Thus, it increased both forest productivity and biodiversity and is maintaining critical natural forest ecosystems. As well, forestry and nature

Box 4: Paying for ecosystem services to help green the economy

Deforestation and forest degradation are responsible for 20 per cent of global greenhouse gas emissions. The causes are agricultural expansion, conversion to pastureland, infrastructure development, destructive logging and fires, among others (UN-REDD, 2015). In recognition of the potential for forests to store carbon and mitigate climate change, the international community is providing financial incentives for countries to keep their forests intact (UNFCCC, 2014). The Clean Development Mechanism (CDM) under the Kyoto Protocol, for example, allows developed countries to fund afforestation and reforestation projects in developing countries to sequester carbon in their stead and so meet some of their reduction requirements (Andrew & Masozera, 2010). If eligible, such projects can earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2, which can be put towards meeting their Kyoto targets (UNFCCC, 2014). Voluntary carbon marketing (VCM) mechanisms offer the same reduction credits but operate outside the Kyoto context (World Bank, 2012).

Rwanda's promotion of agroforestry and its on-going efforts to restore degraded forests mean that it has a significant potential to generate revenues from forest carbon activities such as the CDM. Rough estimates suggest that replanting 325,000 ha of forest land could potentially contribute more than 100 million tonnes of CO_2 emission reductions every year (UNEP RISØ, 2013).

Another opportunity is through REDD+. Launched in 2008, the UN-REDD Programme is the United Nations collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries. Its aim is to create a financial value for the carbon stored in forests. Going beyond deforestation and forest degradation, REDD+ includes the role of conservation, sustainable forest management and enhancing forest carbon stocks (UN-REDD, 2015). REDD+ provides a framework for compensating carbon-sequestration services of existing forests (World Bank, 2012).

Rwanda has plans for forest carbon projects (Afforestation and Reforestation, or A/R) within the voluntary market in the Gishwati forest, Eastern Province, Volcanoes National Park and Nyungwe National Park. It has also signed an agreement with the Congo Basin Forest Fund for 4.9 m Euros to support sustainable Woodland Management and Natural Forest Restoration under REDD+, which makes Rwanda eligible for carbon market benefits (UNEP RISØ, 2013).

The CDM and REDD are examples of Payment for Ecosystem Services (PES) programmes. PES can also be used as incentives for resource users to pay hosts to protect biodiversity, provide clean water and enhance other valuable ecosystem services on their behalf. A study in the Nyungwe National Park provided financial incentives to communities to reduce activities that were detrimental to biodiversity (such as hunting with snares, cutting trees and mining) and to rather engage in sustainable alternative activities outside the park, such as private tree and bamboo planting. The results found that the scheme effectively increased biodiversity conservation, and importantly, "it changed the motives for protecting the park and improved local perceptions both of the park and its authority" (Martin, Gross-Camp, Kebede, & McGuire, 2014).

conservation have increasingly contributed to GDP and people's livelihoods through the use of non-timber forest products, the benefits of forest ecosystem services and adding value to wood products.

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Golden Monkey

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Chapter 3: Biodiversity and Protected Areas

3.1 Status and trends

Biodiversity (biological diversity) is "the variability of life expressed at the ecosystem, species and genetic levels. It is the combination of life forms and their interactions with each other and with the rest of the environment that has made the earth a uniquely habitable place for humans" (CBD, 2000). The loss of biodiversity makes ecosystems less resilient, threatening their services. When

landscapes or aquatic environments become more homogeneous (less diverse), they usually become more vulnerable to sudden external impacts, such as disease and climatic changes (CBD, 2010).

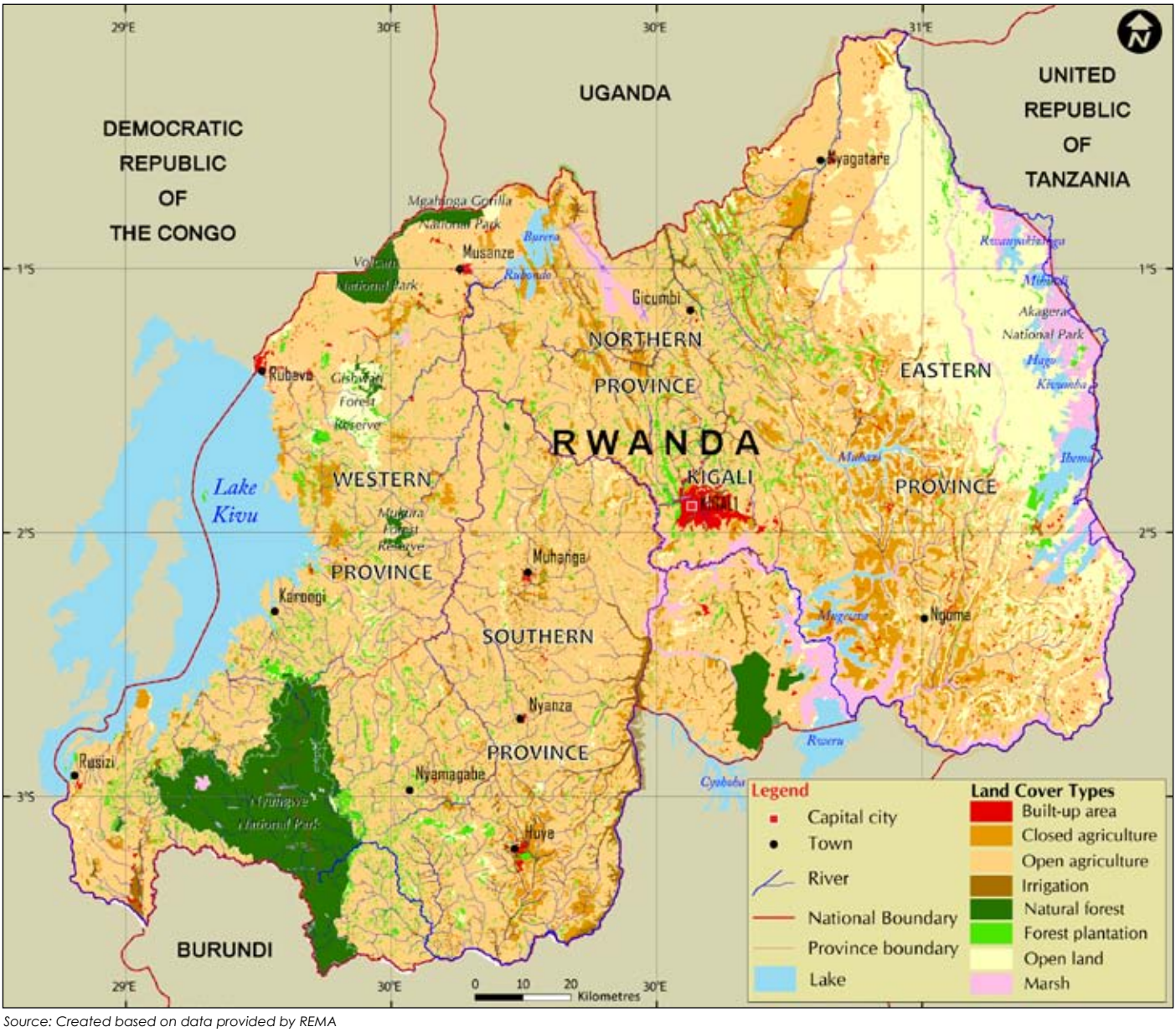
Rwanda's ecosystem diversity

Rwanda's ecosystems lie within and are characteristic of a larger ecological and geographical region or ecoregion of East Africa called the Albertine Rift. Due in part to its location within the biodiversity-rich Albertine Rift and because of its varied landscapes and climates, Rwanda is one of Africa's most important biodiversity areas (REMA, 2010a). Its landscape is made up of a variety of ecosystems, including humid Afromontane forests, planted forests and remnant forests such as riparian gallery forests; savannahs; a large network of water bodies (lakes, rivers and wetlands); and large cropland and grazing areas (REMA, 2009) (Figure 1). Other significant ecosystems include volcanic hot springs and old lava flows, mainly in the northern and western parts of the country (REMA, 2015). Each ecosystem in turn harbours globally outstanding species diversity (GEF, 2003).

Rwanda's natural forest ecosystems mostly lie within the Akagera, Nyungwe and Volcanoes National Parks, and the Gishwati, Iwawa Island and Mukura Forest Reserves. Wetlands cover a significant proportion of the country and are often referred to as marshes. Rwanda's wetlands are some of its most threatened ecosystems (REMA, 2011a). They are discussed at length in the next chapter on water resources.

Large parts of Rwanda were once covered with natural montane-grassland ecosystems, which today are occupied mostly by terraced agriculture. This has led to serious soil erosion in some areas. In the flatter

Figure 1: Rwanda's ecosystem diversity, illustrated by land cover



Source: Created based on data provided by REMA

eastern part of the country, poorer soils support open savannah and broad-leafed woodland areas with acacia and grass species typical of Africa's classic savannahs and open woodlands (RoR, 2014c).

A huge proportion of Rwanda's land is under agricultural systems defined as "ecosystems used in agriculture under similar conditions, with similar components, interactions and conditions. Included in agro-systems are mono-cropping, mixed farming and associated crops, including agro-pastoral systems, agroforestry, aquaculture, grassland, grazing land and fallow land" (MINITERE, 2003). Chapters 8 and 9 describe and assess Rwanda's agricultural systems and their biodiversity.

In 2015, REMA conducted the *Study to Establish a National List of Threatened Terrestrial Ecosystems and Species in Need of Protection in Rwanda*. It concluded that there are 17 threatened ecosystems, classified in different categories as defined by the IUCN (a Ministerial Order that will formalize the final classification is pending). Three ecosystems are classified as Collapsed (Ndoha Natural Forest; Sanza Natural Forest; and Mashyuza Natural Forest); ten are Critically Endangered (Volcanoes National Park; Busaga Natural Forest; Dutake Natural Forest; Gishwati Natural Forest; Karama Natural Forest; Karehe-Gatuntu Natural Forest Complex; Ibanda-Makera Natural Forest; Nyagasenyi Natural Forest; Rujambara Natural Forest; and Mukura Natural Forest); and four are Endangered (Kibirizi and Muyira Natural Forest; Akagera National Park; Nyungwe National Park; and Muvumba Gallery Forest) (REMA, 2015).

Table 1: Number of threatened species in Rwanda and their endangered status

Species	Number threatened	Threatened status
Plants	42	• Critically endangered: 7 • Endangered: 28 • Vulnerable: 7
Birds	17	• Critically endangered: 9 • Endangered: 4 • Vulnerable: 4 • Data insufficient to assess: 46
Mammals	42	• Critically endangered: 6 • Endangered: 32 • Vulnerable: 4
Reptiles and amphibians	4	• Critically endangered: 2 • Endangered: 2

Source: (REMA, 2015)

Moreover, a list of protected tree species with their distribution has been established. The list specifies trees that are in danger of disappearing; trees endemic to the Albertine rift and are rare trees endemic to Rwanda; trees of medicinal value; important trees for the timber industry that take more than 20 years to reach harvesting maturity; trees with cultural significance; and trees that are protected internationally are on the list (RoR, 2015a).

The Alliance for Zero Extinction (AZE), which was launched globally in 2005, engages non-governmental organizations to prevent species extinctions by identifying and safeguarding the places where species evaluated to be Endangered or Critically Endangered under IUCN criteria are restricted to single remaining sites. It has identified Nyungwe National Park as the only site in the world where the Hill's Horseshoe Bat (*Rhinolophus hilli*) still exists (AZE, 2013).

Rwanda's species diversity

Because of its varied ecosystems, Rwanda has a very rich diversity of flora and fauna, with some 2,150 known plant species, 151 mammal species, 87 species of amphibians and reptiles and 670 bird species (REMA, 2011b). Rwanda accounts for 40 per cent of Africa's mammalian species (REMA, 2009) and about 30 per cent of the global population of mountain gorillas is situated in the Rwandan part of the Albertine Rift (REMA, 2010a).

Rwanda's forests also provide habitat for a large chimpanzee troop, estimated at as many as 500 individuals and for other monkey species including the vervet monkey, olive baboon, L'Hoest's monkey, the silver monkey, grey-cheeked mangabey and red-tailed monkey. It is also home to the rarer golden monkey and the Angolan colobus (REMA, 2011c).

The 2015 study to establish lists of Rwanda's threatened ecosystems and species considered five taxonomic groups of species: plants, birds, mammals, reptiles and amphibians and assessed their status based on IUCN criteria; Table 1 is a summary of the results.

3.2 Pressures and impacts

Biodiversity is lost or compromised with the disappearance, conversion, fragmentation, pollution or degradation of an area's natural flora, fauna, land and water resources. The main pressures are activities such as mining, poaching, poisoning and illegal wildlife hunting, encroachment on protected areas, introduction of alien and invasive species, damming, water extraction, wetland draining and commercial fishing, among others (RoR, 2014a); (REMA, 2011b).

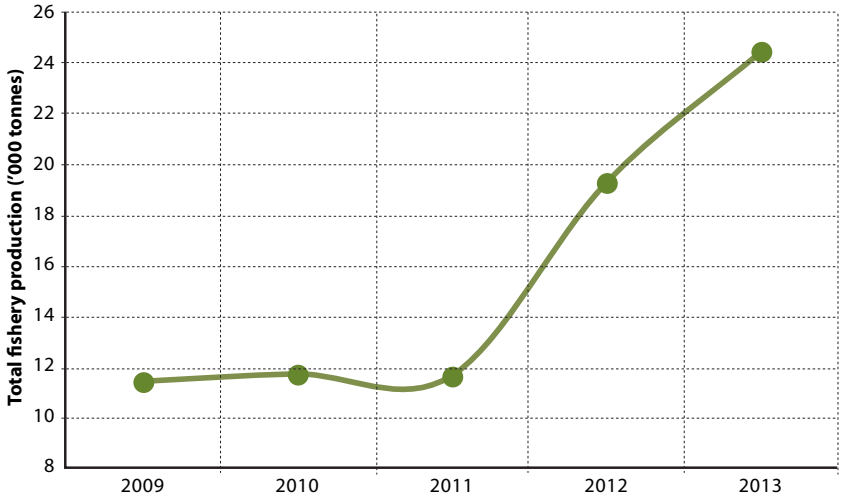
Recent examples of some of these human pressures on biodiversity in Rwanda include the following: the conversion of natural areas in the Karama savannah natural forest into farmland, grazing areas and other economic activities (REMA, 2011c); mining in the Mukura Forest Reserve that has led to degradation; and the invasion and increase of non-native predator species, which has caused the decline or extirpation of indigenous fish species in the Nyabarongo-Akagera rivers system (RoR, 2014a) (See also Table 3).

Fisheries

Although artisanal fishing has been practiced in Rwanda since colonial times, fishing has never been a major economic activity. Since the 1970s, donors have supported a number of projects to support capture fisheries but fishing has been unsustainable. Overfishing has been a concern due to the increasing value of fish, the increase in fishing capacity and poor fishing practices (Rutaisire, 2011). Table 2 shows fish harvests from the main fishing areas and Figure 2 gives the trend in total fish harvests from 2009 to 2013, highlighting the significant increase in production since 2011.

An increase in fish harvests, however, is not an indicator of the health of fish stocks. In many cases, it points to over-fishing. The 2011 Master Plan for Fisheries and Fish Farming in Rwanda suggests that there has been "increased fishing pressure, heightened illegal, unregulated and unreported fishing, and increased unmonitored fish movements; all driven by increased fish demand and inadequate fisheries and aquaculture management framework." The results have been the depletion of natural fish stocks (Rutaisire, 2011).

Figure 2: Total annual fish harvests, 2009-2013



Source: (NISR, 2014)

Other threats to biodiversity

Natural and human-exacerbated hazards, including drought, floods, landslides, earthquakes and volcanic eruptions also destroy the diversity of living things in their wake. Biopiracy of genetic materials, soil micro-organisms, animals, genes and indigenous knowledge identified, developed and used by local communities is another threat (REMA, 2011a), although Rwanda is now addressing this through its ratification of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) to the Convention on Biological Diversity. In addition, climate change is exacerbating existing pressures (REMA, 2011c). It is directly causing physiological impacts on individual species, changing abiotic factors and opportunities for reproduction, survival and the addition of new individuals to a population, and altering interactions among species (REMA, 2011a). It is also the most likely cause of the drying out of small lakes on mountain summits of the Volcanoes National Park and it might cause the altitudinal upward migration of species distribution (RoR, 2014a).

There are also potential threats to biodiversity from neighbouring countries in trans-boundary situations where Rwanda's natural resources and ecosystems cross political borders and outside pressures can spill over into Rwanda (REMA, 2010b).

Table 2: Trend in fish harvests in Rwanda's main fishing areas (in thousands of tonnes), 2008-2013

Zone	2008	2009	2010	2011	2012	2013
Musanze	244	220	482	166	717	-
Rwamagana	3 316	1 377	658	1 058	1 438	-
Kivu	8 121	9 484	10 601	10 438	15 333	-
Other zones	0	0	0	-	1 857	-
Total	**11 682**	**11 445**	**11 741**	**11 662**	**19 344**	**24 550**

Source: (NISR, 2014)

3.3 Response

In response to biodiversity loss, Rwanda adopted a Biodiversity Policy in 2011 and a Biodiversity Law in 2013. The Policy aims to "conserve Rwanda's biological diversity, to sustain the integrity, health and productivity of its ecosystems and ecological processes, whilst providing lasting development benefits to the nation through the ecologically sustainable, socially equitable, and economically efficient use of biological resources" (REMA, 2015). In 1996, Rwanda ratified the Convention on Biological Diversity (CBD). Rwanda's institutional framework for implementing the Convention has been strengthened through the establishment of the Rwanda Natural Resources Authority (RNRA), Rwanda National Climate and Environment Fund (FONERWA), CBD Steering Committee and the Centre of Excellence in Biodiversity and Natural Resources Management to coordinate and monitor all biodiversity conservation and management activities (CBD, n.d.).

Rwanda submits regular reports to the Secretariat of the Convention on Biological Diversity to provide the latest information on the state of the county's biodiversity assets. The GoR also renewed efforts at conservation and species protection with the revised National Biodiversity Strategy and Action Plan (NBSAP) in 2014. The NBSAP's objectives are to improve environmental stability for natural ecosystems and their biodiversity; restore degraded ecosystems and maintain equilibrium among biological communities; establish an appropriate framework for access to genetic resources and equitable sharing of benefits arising from biodiversity use and ecosystems services; improve policy, legal and institutional frameworks for better management; and conserve national biodiversity (RoR, 2014b). To achieve these objectives, it laid out 19 specific and time-bound national targets (RoR, 2015b).

Protected Areas

Setting aside areas to protect nature is one of the most successful responses to biodiversity loss. It is also a key source of development, poverty alleviation and employment, especially in tourism, which contributes to greening the Rwandan economy (MINICOM, 2013). The CBD deems protected areas to be "the critical tool to conserve biodiversity in the face of the global crisis of species extinction and the loss of the world's natural capacity to support all life and human existence". It also notes the importance of protected resources in providing ecosystem goods and services that serve human well-being (CBD, 2008).

Edge of Gishwati

Eugene Apindi Ochieng

Categories and distribution of protected areas

At the global level, the World Database on Protected Areas (WDPA), the most comprehensive global dataset on terrestrial and marine protected areas, recognizes two areas in Rwanda under international or regional conventions or agreements: the Ramsar Wetlands of International Importance and the UNESCO Man and the Biosphere Reserve (MAB). The Rugezi-Bulera-Ruhondo wetland is a RAMSAR site, one of a global network of wetlands whose ecosystem components, processes and services should be maintained to help conserve the world's biological diversity and sustain human life. The Volcans Biosphere Reserve, located about 15 km northwest of the town of Ruhengeri in the Virunga Massif in northwest Rwanda, is a designated MAB, one of 631 biosphere reserves in 119 countries in a global network of "sites of excellence." It is part of the Volcanoes National Park and is contiguous to the Virunga National Park in the DRC and Gorilla Game Reserve in Uganda (IUCN; WCMC, 2015).

The goal of Rwanda's protected areas is "to promote the conservation of natural resources and wildlife habitat and the sustainable use of biological resources" (MINICOM, 2013). Rwanda legally classifies protected areas as state land in the public domain, reserved for environmental protection (Bizoza & Ndangiza, 2013). One of the NBSAP's targets for 2020 is to protect at least 10.3 per cent of national territory holding particular biodiversity and ecosystem services, up from 10.13 per cent in 2012 (RoR, 2015b).

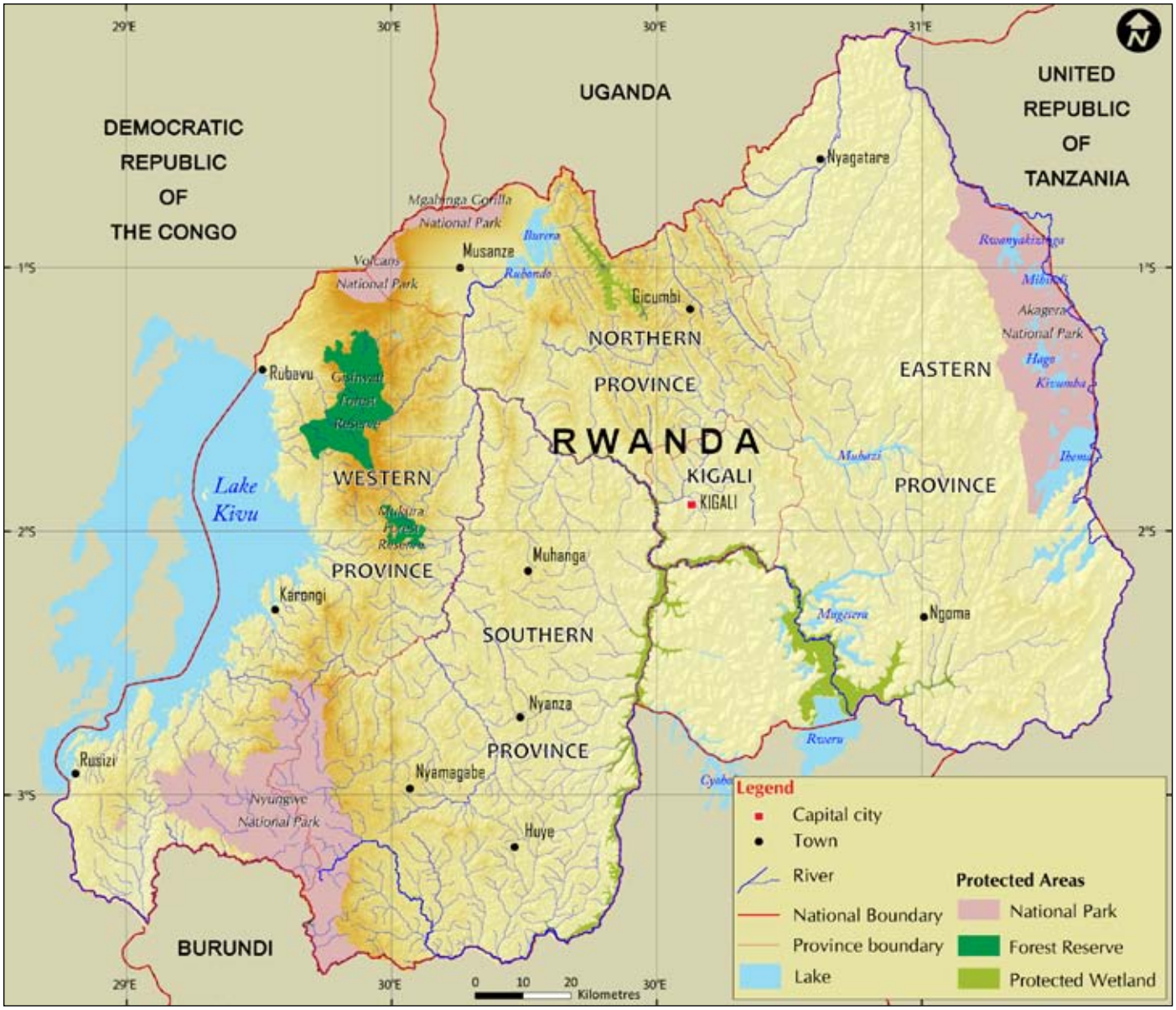
There are four types of protected areas in Rwanda:

1) National Parks: Akagera, Nyungwe and Volcanoes;
2) Forest Reserves: Gishwati, Iwawa Island (in Lake Kivu) and Mukura;
3) Forests of cultural importance: Buhanga forest;
4) Wetlands of global importance: Rugezi-Bulera-Ruhondo wetland complex.

Rwanda's National Parks and Reserves harbour almost all of the country's natural forests; extractive uses are prohibited, effectively protecting these ecosystems

Volcanoes National Park

Figure 3: Location and extent of Rwanda's protected areas, 2010



Source: (REMA, 2015)

and their goods and services from destruction and loss (REMA, 2015). Figure 3 shows the location and extent of Rwanda's National Parks and Forest Reserves.

Conservation of protected areas

There are many other remnant natural forest areas that are not yet gazetted as protected areas but within which human activities are prohibited. The results of a 2011 survey of terrestrial ecosystems were reviewed for the 2015 *Study to Establish a National List of Threatened Terrestrial Ecosystems and Species in Need of Protection in Rwanda* (REMA, 2015), which resulted in a list of 17 natural forests (Table 3). It also provided a preliminary classification of them under IUCN categories; as mentioned earlier, a Ministerial Order is pending to formalize the final classification.

The 2015 Ministerial Order Determining the Management of Protected State Forests Not Governed by Special Laws produced a long list of small, terrestrial natural ecosystems within which activities and tree cutting are also prohibited. It stipulated that they should be protected by demarcating a boundary around them, by planting a belt of trees of a different species, for example (RoR, 2015a). Many of these remnant forests resulted from the fragmentation of former larger ecosystems.

Table 3 provides a summary of the status of Rwanda's major forest protected areas and other natural forests and ongoing efforts to protect these ecosystems and their species diversity.

Table 3: Conservation of protected areas and other natural forests

Name	Area (ha)	Progress and threats
Akagera National Park	112,193	The main threats are human activities. Historically, more than 60 per cent of the park area was converted into farmland and biodiversity losses have been estimated at 50-80 per cent of large mammals and 13 per cent of birds, although generally, the Park has maintained an important diversity of birds. Large wild herbivores declined between 1990 and 2011, except zebras, warthogs and duikers, whose numbers increased. Law enforcement has improved significantly since 2012 and there is now a 2011-2015 Business and a Tourism Plan. The commercial fisheries have been handed back to the Park. Exotic plants are being removed; water hyacinth has been eradicated from a valley dam as well as 2 ha of prickly pear from the Rurama peninsula. The number of patrols increased by 40 per cent by 2013, bringing down the incidence of poaching. In June 2015, 7 lions (5 females and 2 males) were introduced into the Park. Sources: (Kanyamibwa, 2013); (Plumptrea, 2007); (African Parks, n.d.); (Gatali, 2013).
Nyungwe National Park	101,659	Located in one of the country's most densely populated areas with high levels of poverty, NNP faces heavy pressures from poaching, illegal mining, habitat loss by fire, tree harvesting for firewood and house construction and livestock grazing. There has been massive logging of the Nyungwe buffer zone forest for charcoal and timber production. Management has improved through: (i) development of its management plan, (ii) monitoring and implementing preventive measures, (iii) improving scientific knowledge on biodiversity, awareness raising in communities surrounding the parks on biodiversity conservation and supporting alternative livelihoods to avoid encroachment. Significant progress has been made in preventing forest fires through community awareness raising and controlling them once they occur. Degraded areas are being rehabilitated. Sources: (REMA, 2015); (RoR, 2014a); (Bucyensenge, 2014).
Volcanoes National Park (Includes Buhanga Natural Forest (also known as Gihondohondo Forest) – 18 ha)	16,021	An extremely high human population density surrounds VNP. Land scarcity in the region and the high potential for agricultural productivity on the volcanic soils has compelled farmers to cultivate on fragile slopes on the edge of the park. The rate of poaching and other illegal activities increased from 2003 to 2013. A management plan has been developed, however, including monitoring threats, implementing preventive measures and improving scientific knowledge of biodiversity and the importance of conservation through awareness raising in communities surrounding the parks as well as supporting alternative livelihoods to avoid encroachment. According to the 2010 census, there were 480 gorillas in the Virunga Massif Buhanga that has been protected since 2005 and there are plans to develop ecotourism in the forest. Its understory is highly encroached on and dominated by secondary species. Sources: (UNEP/WCMC, 2011); (RoR, 2014a)
Gishwati Natural Forest	1,488.89	Gishwati Natural Forest has faced many threats that undermined most of its ecosystem. Recent management and conservation programmes have halted forest degradation and substantially contributed to reducing flooding, landslides, soil infertility, poor water quality and heavy river siltation. Since 2012, the Forest of Hope Association (FHA) has been engaging local communities in forest conservation. Sources: (REMA, 2015); (RoR, 2014a); (IUCN, 2007).
Mukura Natural Forest	1,601.15	Forest degradation due to forest encroachment and hunting has had negative impacts on animal species richness and relative abundance in the Mukura Natural Forest. By 2012, the number of mammals species had been reduced from 14 to 4 and the ecosystems was reduced to a series of small disjointed forest relics. Conservation has improved through rehabilitation and land reallocation and related legislation. Sources: (REMA, 2015); (RoR, 2014a).
Karama Natural Forest (Also known as Isar Karam)	1,064.85	This forest has been under high human pressure and degraded due to agriculture expansion, fuelwood cutting, charcoal production, poles and timber production. Illegal exploitation of Osyris lanceolata also undermines the integrity of Karama. Sources: (REMA, 2015); (RoR, 2014a); (REMA, 2011c).

Name	Area (ha)	Progress and threats
Karehe-Gatuntu Natural Forest Complex	19.14	The main threat is tree felling and introduced eucalyptus species. The lack of a management authority is also a challenge (REMA, 2015).
Kibirizi and Muyira Natural Forest	352	This forest is not currently protected. The conservation value of these forests is for their endemic plant species. Historically, these two forests were connected; now, a valley dam, roads and human settlements separate them. Threats include hunting, logging, cultivation, bee-keeping, charcoal and free grazing. In the past 10 years, people inhabited the near surroundings of the forests. This has caused huge losses in biodiversity richness and severe ecosystem degradation. Until now, there is no demarcation between the forest and farm lands. The forests are also threatened by invasive species of Lantana camara, which cover large areas around and inside the forest (REMA, 2015); (CARPE; RECOP, 2011).
Ndoha Natural Forest	26	The forest is degraded, mainly because of agricultural encroachment. There are no restrictions to forest access (REMA, 2015).
Sanza Natural Forest (also known as Nyabitukura)	23.9	This forest is not currently protected. It is highly degraded and dominated by secondary species. Mining is the most important threat. The second-greatest threat is the felling of trees for bean supports, firewood, handicrafts, etc., followed by free grazing by farmers in the surrounding areas. Sources: (CARPE; RECOP, 2011); (RoR, 2014a); (UNEP/WCMC, 2011).
Dutake Natural Forest	10.76	The major threat is tree felling for construction and fire wood, in particular at the summit of the hill, as well as Coltan extraction. Law enforcement is very low as the forest is under village authority, whose capacity to control all illegal activities is inadequate. Source: (REMA, 2015).
Busaga Natural Forest	158.85	There is a district plan to protect the forest and implement a forest management plan. The forest is important for cultural reasons but illegal hunting and logging persist and wildlife has been decimated. Although surrounded by a buffer zone and protected by the authority, agricultural encroachment and clay exploitation constitute a big threat. Sources: (Muhanga District, 2013); (Godfrey & Kinyua, 2010); (UNEP/WCMC, 2011); (Mukashema, 2015); (REMA, 2015).
Ibanda - Makera Natural Forest	168.88	This forest contains many endemic and rare species, many of which are used in traditional medicine. It is under high human pressure and large areas of bush, thicket and woodland have been degraded due to agricultural expansion, firewood collection, charcoal production and poles and timbers production. There is no delimitation between the forest and agricultural fields Sources: (REMA, 2015); (RoR, 2014a).
Mashyuza Natural Forest	6.2	Mining for cement materials is the most serious and permanent threat to the survival of biodiversity in these ecosystems. Drilling has destroyed much of the natural forest. It also disrupts the hydrological cycle and compromises water quality in streams. There are rare species that exist nowhere else in Rwanda. This forest was home to the world's smallest waterlilly, which has now completely disappeared. Eucalyptus, which was planted following deforestation of the natural forest, has invaded a large area. Sources: (REMA, 2015); (RoR, 2014a); (Aleph, 2014).
Nyagasenyi Natural Forest (Also known as Bishop Kayinamura forest)	18.66	This forest protects water sources for the Rwagitugusa swamp. Ecosystem services include water filtration and retention before it is drained into the swamp. Agricultural and tree-cutting incursions are degrading this remnant forest. People have free access to the forest and very few tree stands remain. Consequently, invasive species dominated by Tithonia diversifolia and Acanthus pubescens now cover a large part of the remaining forest. Sources: (REMA, 2015); (RoR, 2014a).

Name	Area (ha)	Progress and threats
Mashoza Natural Forest (Also known as Rujambara Natural Forest, Rugomero or Parike)	17.78	This forest is an isolated ecosystem within areas of extensive agriculture, making it a refuge for many plant and animal species. Prunus africana is under CITES protection as a very much sought- after species due to its pharmacological properties, especially in treating prostate cancer. Mashoza is highly degraded due to anthropogenic activities. The surrounding wetland exploited for rice cultivation progressively encroaches on the forest and there are no boundaries between fields of various crops and the forest. Additionally, the local population is accustomed to cutting trees for firewood and building materials. Sources: (REMA, 2015); (RoR, 2014a).
Muvumba Natural Forest	715.3	The forest shelters a relict gallery forest constituted mainly of Acacia kirkii, which is endemic to Rwanda and cannot be found elsewhere in the Great Lakes Region. Rwandan forest law provides for a mandatory 10 m-wide virgin strip to protect river banks. Although this is an extraordinary effort to conserve river wetlands, in the case of Muvumba River it is not enough, as the Acacia trees are threatened with extinction. Farming, settlement, firewood collection and agriculture threaten the forests as well as a recent large-scale rice farming project in the Muvumba valley. Sources: (REMA, 2015); (RoR, 2014a); (Nsengimana, 2010).

Ecotourism helps conserve biodiversity and green the economy

Tourism in Rwanda is mostly nature-based and concentrated in National Parks and other protected areas. Ecotourism refers to "responsible travel to natural areas that conserves the environment and improves the well-being of local people" (TIES, 1990). Gorilla-watching in Volcanoes National Park is the most well-known tourism activity in Rwanda (Box 1), but other protected areas, especially Nyungwe and Akagera National Parks, are growing in importance (World Bank, 2014).

Tourists hiking to view gorillas in Volcanoes National Park.

Biodiversity makes a substantial direct contribution to the Rwandan economy through tourism; in 2011, it was Rwanda's largest foreign exchange earner (at US$251 million) (World Bank, 2014); tourism revenues have continued to rise, to US$281.8 million in 2012 and US$293.6 m in 2013 (RoR, 2015b). In 2012, the Volcanoes National Park alone attracted 23,800 visitors (RoR, 2014a).

While helping to significantly reduce the threats to Rwanda's iconic wildlife and ecosystems, ecotourism also provides livelihoods to local people who might otherwise engage in poaching and harvesting fuelwood and other ecosystem goods. For example, instead of felling trees in the Nyungwe National Park (NNP), the traditional way to harvest honey from natural beehives, local people have been trained in income-generating beekeeping and have formed cooperatives, which generated 18,000,000 RWF in 2012 (RoR, 2014a). Local communities around NNP and Volcanoes National Park (VNP) also benefit from revenue-sharing schemes that ensure local communities benefit directly from tourism (Birdlife International, 2011). The EICV 3 national household survey conducted in 2010/11 estimated that 23,000 people were directly employed in tourism in Rwanda, with many other services, such as restaurants, transportation services and the retail trade, benefitting indirectly (MINICOM, 2013).

hjalliq / Flickr / CC BY 2.0

Box 1: Gorilla tourism, biodiversity and greening the economy

Since 1999, Rwanda, the DRC and Uganda have been cooperating in a very successful trilateral transboundary regional agreement across the Virunga Mountains in which some revenues from gorilla tourism are shared between the countries. According to the December 2010 mountain gorilla census, the Virunga mountain gorilla population in the DRC, Rwanda and Uganda was 480 animals, a 25 per cent increase since the last count in 2003 (UNEP/WCMC, 2011). In 2015, over 60 members of the region's conservation agencies were being trained to conduct the next survey (IGCP, 2015).

Responsible wildlife tourism is an important tool for both conserving biodiversity and the environment and growing the economy. UNEP notes that "in addition to conserving gorillas and their rainforest habitat, generating jobs and combating poverty, gorilla tourism has sparked a multi-million-dollar boom, contributing substantially to the Green Economy in Rwanda and Uganda" (UNEP, 2011).

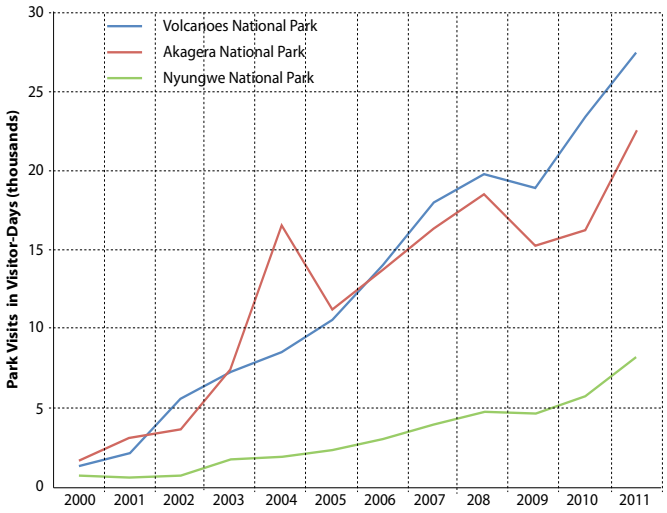
Ongoing efforts to attract tourists and encourage them to stay in and around the VNP include new trails to Mount Visoke's summit and crater lake, to Dian Fossey's grave and to Lake Ngezi. Groups of primates continue to be habituated to human presence to attract visitors. In VNP, this includes three groups of golden monkeys (*Cercopithecus mitis kandtii*) and a beautiful blue monkey subspecies (*Cercopithecus mitis doggetti*) found only in the Virungas. Some private tour operators also offer community-based tourism activities, such as stays with a local family, village walks, banana beer production or volunteering opportunities (Birdlife International, 2011).

Tracking chimpanzees is the most sought-after tourism experience in the Nyungwe National Park; from 2009 to 2012, visits more than doubled from 859 to 1,954. Participation in hiking, watching monkeys and birds and generally experiencing the rainforest also increased in recent years, with a total of 8,200 visitors in 2011 and 7,700 in 2012. The NNP's amenities have recently been improved with more and better trails, a canopy walk and a new interpretive and reception centre (Webber, 2013).

Visits to Akagera National Park continue to grow, with an average annual increase of 12 per cent.

Nyungwe National Park Ibis Tour and Travel, 2013

Figure 4: Visitor permits to Nyungwe, Volcanoes and Akagera National Parks, 2000-2011



Source: (USAID, 2012)

Rwandans account for half of all park visitors. In 2013, entry fees, accommodation and activities generated over US$800,000, representing a yearly increase of 65 per cent (African Parks, n.d.).

Figure 4 shows that tourist visits to Volcanoes and Akagera National Parks grew rapidly between 2000 and 2013, with an average 50 per cent annual growth from 2000 to 2005 alone; visits to Nyungwe also grew significantly, with an average 25 per cent annual growth during that period (USAID, 2013).

Tourism in protected areas can also have detrimental impacts when the footprints of mass tourism or unsustainable activities destroy the very attributes that attract visitors. Creating protected areas can also cause local residents to be displaced. As well, farmers in buffer zones can suffer the impacts of crop raiding by wildlife and restricted access to natural resources they used to rely on for their livelihoods. Conservation organizations and governments worldwide, including in Rwanda, increasingly engage in integrated conservation and development projects (ICDP) that recognize and support the interconnected nature of livelihoods and biodiversity conservation and seek to ensure local communities benefit from tourism in adjacent protected areas through revenue sharing schemes (Tolgert, 2014).

With the Government's commitment to developing a private sector-led economy, it has instituted the Rwanda Protected Areas Concessions Management Policy, to improve the private sector's competence and expertise in providing tourism services in protected areas. In turn, this will increase revenues as well as the level of effective protected area management (MINICOM, 2013). The next section provides short profiles of Rwanda's main protected areas.

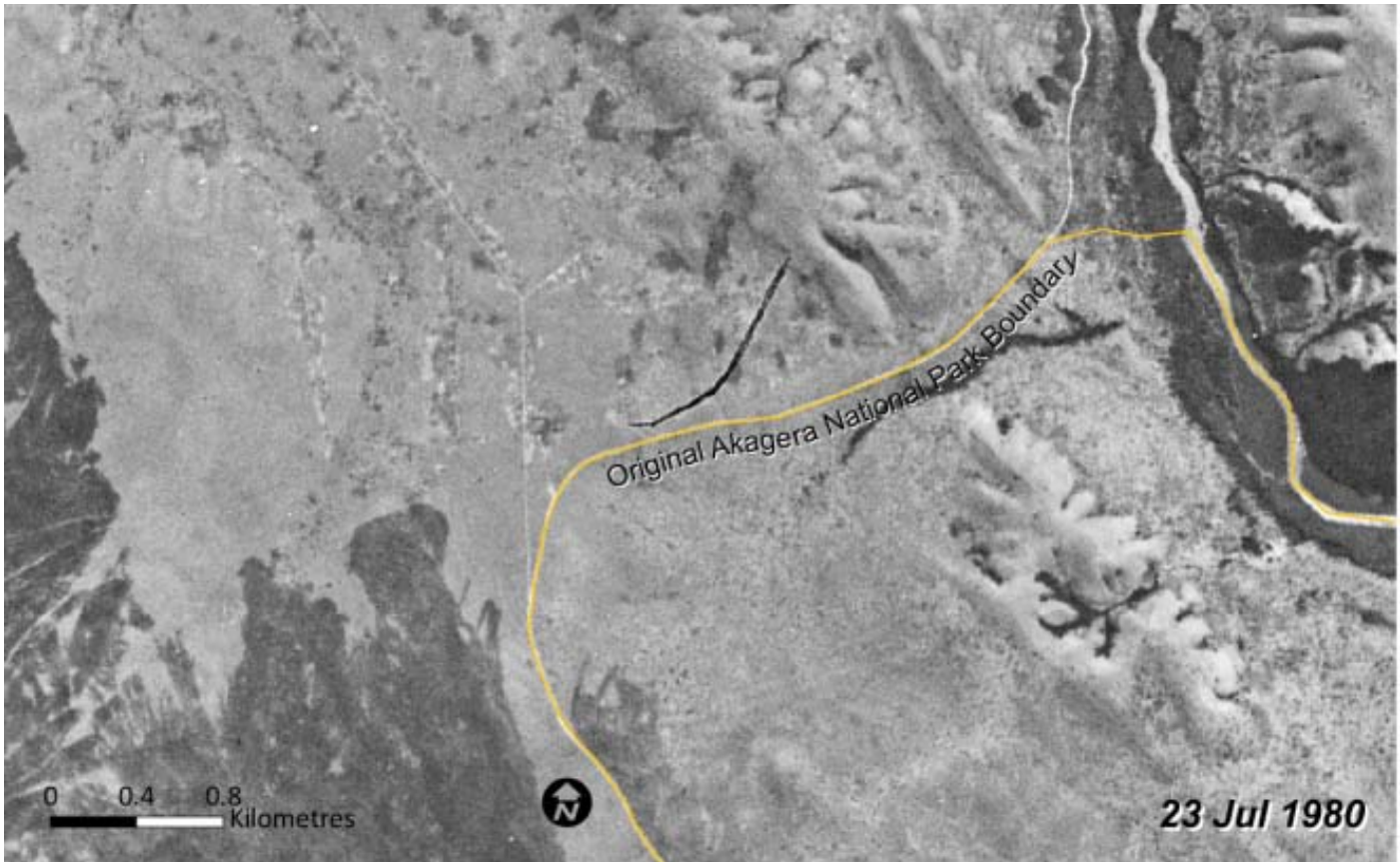
National Parks

Akagera National Park (ANP)

Located in the northeastern corner of Rwanda against the Tanzanian border, the Akagera National Park (ANP) currently covers 112,193 ha (RoR, 2014a). It was founded in 1934 to protect animals and vegetation in three ecoregions: savannah, mountain and swamp. The park is named for the Akagera River, which flows along its eastern boundary feeding into several lakes, the largest of which is Lake Ihema. The complex system of lakes and linking papyrus swamps makes up over one-third of the park and represents the largest protected wetland in central Africa (CHM, 2007). It provides habitat for a rich diversity of fauna, including nearly 600 species of birds and over 50 species of large mammals (GEF, 2003); (Gatali, 2013).When it was founded, the park covered an estimated 245,000 ha. In 1997, two-thirds of the surface area of the ANP was de-gazetted to accommodate Rwandans returning from exile (Bizoza & Ndangiza, 2013) (Figure 5). Subsequent deforestation led to a decline of more than 90 per cent of faunal species. It also affected the ecosystem's climate regulating services, since monthly temperatures increased by 0.5° and average monthly rainfall declined by 10 mm between 1970 and 2010 (Habiyaremye, Jowen, de la Paix Mupenzi, & Balogun, 2011).

As shown in Table 3, the conservation status of the ANP has recently improved. Some of the features of this change include high levels of local community involvement around the park to restore the Akagera lakes; the erection of an electrical fence in the park's southwest; improved environmental education and awareness; and the provision of boreholes, solar surface water pumps and small dams to communities outside the park (RoR, 2014a).

Figure 5: Akagera National Park



Source: Google Earth

Akagera National Park used to extend all the way to northeastern Rwanda (close to Uganda) before it was moved southwards to its current location. These two images, from 1980 and 2014, illustrate the changes that have taken place in a small part of the Park after its boundary was moved. In 1980, the area under park protection was unscarred by human activity, unlike areas outside the park's border that show some level of human presence. By 2014, however, the same area within the old park boundary has been settled and active farming is visible in the image.

Nyungwe National Park. *Rwanda Government / Flickr / CC BY-ND 2.0*

Nyungwe National Park (NNP)

Nyungwe National Park (NNP) in southwest Rwanda, which is contiguous with Kibira National Park in Burundi, was established as a forest reserve in 1933 (EC, 2007). It includes the Cyamudongo and Gisakura Natural Forests and was promoted to a National Park in 2005 (USAID, 2013). The altitude gradient goes from 1,600 m to 2,990 m and it is the largest block of high-altitude montane forest in East and Central Africa, and one of the most ancient, dating back to before the last Ice Age (UNDP, 2006); (WCS, n.d.).

The NNP is extremely important for its role as a water tower. Its forests are crucial to providing water to the hydrological network of the Akagera-Nile system; 40 per cent of dry season flow to the Nyabarongo River system and 70 per cent of all Kigali's water comes from the park's forested ecosystems (UNDP, 2006); (Mirsky, 2014). It includes an important wetland, Kamiranzovu, which contributes to high biodiversity levels, maintains the water cycle and reduces water loss by evaporation (RoR, 2014a).

The NNP is extremely rich in flora and fauna species and is characterized by high levels of endemism. It is home to 13 primates, including L'Hoest's monkeys, colobus, mangabeys, the very rare owl-faced monkey and one of Africa's greatest concentrations of chimpanzees (USAID, 2012), representing 20 per cent of all African primates. It is habitat for 280 bird species (including 25 endemic species — more endemic bird species than any other protected area in the Albertine Rift (GEF, 2003)), 43 species of reptiles and 85 mammal species. There is also an extremely rich plant life with more than 240 orchid species (USAID, 2013).

A recent study on the impact of human and environmental stress on plant diversity in the NNP found that some plant species are threatened by human activities such as forest fires from illegal honey collection; illegal logging; poaching; bamboo and tree cutting; ecotourism activities; and local people collecting firewood and medicinal plants. In addition, invasive species are a problem. For example, *Sericostachys scandens*, a native but invasive liana, is a serious pressure since it kills trees and bamboo (Akayezu, 2011). Forest fires and mining have degraded the NNP's habitat in recent years, although community awareness raising and controlling fires have helped to reduce their occurrence (RoR, 2014a).

A number of new livelihood opportunities appear to have helped reduce illegal incursions and resource collection. These include the introduction of water harvesting facilities, apiculture techniques in the buffer zone and the distribution of livestock such as goats through the Rwanda Development Board's Revenue Sharing Programme. As indicated in Table 3, management in NNP has improved and protection is more stringent (Bizoza & Ndangiza, 2013).

Because they share common biodiversity features and to preserve an isolated group of 40 chimpanzees (*Pan troglodytes*) and a population of the Mona monkey (*Cercopithecus mona*) living in Cyamudongo remnant forest, an ecological corridor has been proposed to link NNP and Cyamudongo (RoR, 2015b).

Volcanoes National Park (VNP)

Volcanoes National Park (VNP) is considered to be one of the most important protected areas for biodiversity conservation in the Albertine Rift (Munanura, 2013). It lies in northwestern Rwanda and borders Virunga National Park in the DRC and Mgahinga Gorilla National Park in Uganda (REMA, 2011c). Settlements and agricultural land completely surround the park on both sides of the border. Within it are located five of the eight volcanoes of the Virunga Mountains (Karisimbi, Bisoke, Muhabura, Gahinga and Sabyinyo), which rise from 2,300 m to 4,005 m above sea level. VNP's varied ecosystems include montane forests and afro-alpine systems. A belt of bamboo forest stretches from near the base to about 3,000 m above sea level. A Hagenia forest belt with herbaceous patches covers the next 300 m followed by sub-afro-alpine vegetation for the next 600 m, after which the topmost reaches feature afro-alpine vegetation (REMA, 2011c).

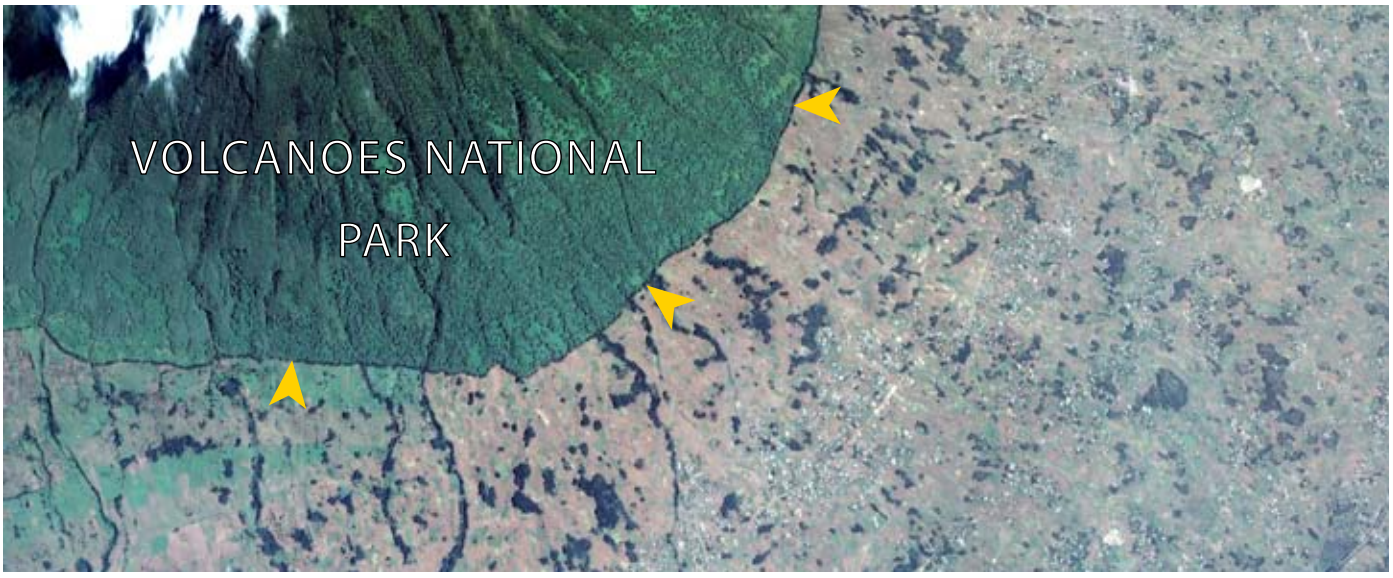
The mountain gorilla (*Gorilla gorilla beringei*) is Rwanda's most iconic animal. Rwanda and Uganda are the only two countries where mountain gorillas can be visited safely (DRC is considered unsafe) (Birdlife International, 2011). Gorilla tourism is the main basis for tourism and is emerging as one of the fastest growing sectors of the Rwandan economy (REMA, 2010a) (Box 1, above). The VNP hosts a number of other mammals, including the golden monkey (*Cercopithecus mitis kandti*), black-fronted duiker (*Cephalophus niger*), buffalo (*Syncerus caffer*), spotted hyena (*Crocuta crocuta*) and bushbuck (*Tragelaphus scriptus*). Although the elephant has also been spotted, it is now very rare. In addition, there are 178 recorded bird species. At least 13 of these species and 16 subspecies

Gorilla in Volcanoes National Park. mrflip / Flickr / CC BY-SA 2.0

are endemic to the Virunga and Rwenzori Mountains (REMA, 2011c).

With its densely populated surroundings, the VNP is almost the only reservoir of forest biodiversity in the area. Although the park is strictly protected, local communities are allowed to collect specific non-timber forest products, such as wild honey and mushrooms, and to gather water. Because of its protected status, increased conservation programmes and initiatives and livelihood opportunities in diversified employment outside the park, there has been a recent decline in the illegal use of the park by local people to poach wild animals, harvest bamboo, fuelwood and medicinal plants and to graze animals (Pavageau, Butterfield, & Taini, 2013). As well, the increased devolution of authority to local levels has strengthened adaptive capacity in the region. On the other hand, the population continues to expand making poverty reduction difficult and communities are still vulnerable (COBAM, 2014).

Border between Volcanoes National Park and the surrounding farmlands and settlements



Data Source: CNES/Astrium via Google Earth. 7th January 2014.

Hotspot to Hopespot: the future Gishwati-Mukura National Park

The ecosystem and its goods and services

The Gishwati and Mukura Forest Reserves are in northwestern Rwanda (Figure 6). The Gishwati Reserve, which was founded in 1933, covers parts of four Districts: Rutsiro and Rubavu in the west towards Lake Kivu and Ngororero and Nyabihu in the east, while Mukura (founded in 1951) is located within the Rutsiro and Ngororero Districts (Musabyimana, 2014).

Geographically, the Gishwati region is a part of the Congo-Nile Divide and the Albertine Rift, with characteristic steep slopes, cool temperatures and high rainfall (GPFLR, 2013). The Gishwati watershed drains through the Sebeya River and its main tributary, the Pfunda River. The relief in the Mukura Forest Reserve is also very hilly (Musabyimana, 2014), with elevations between 2,300 and 2,700 m (RoR, 2014a).

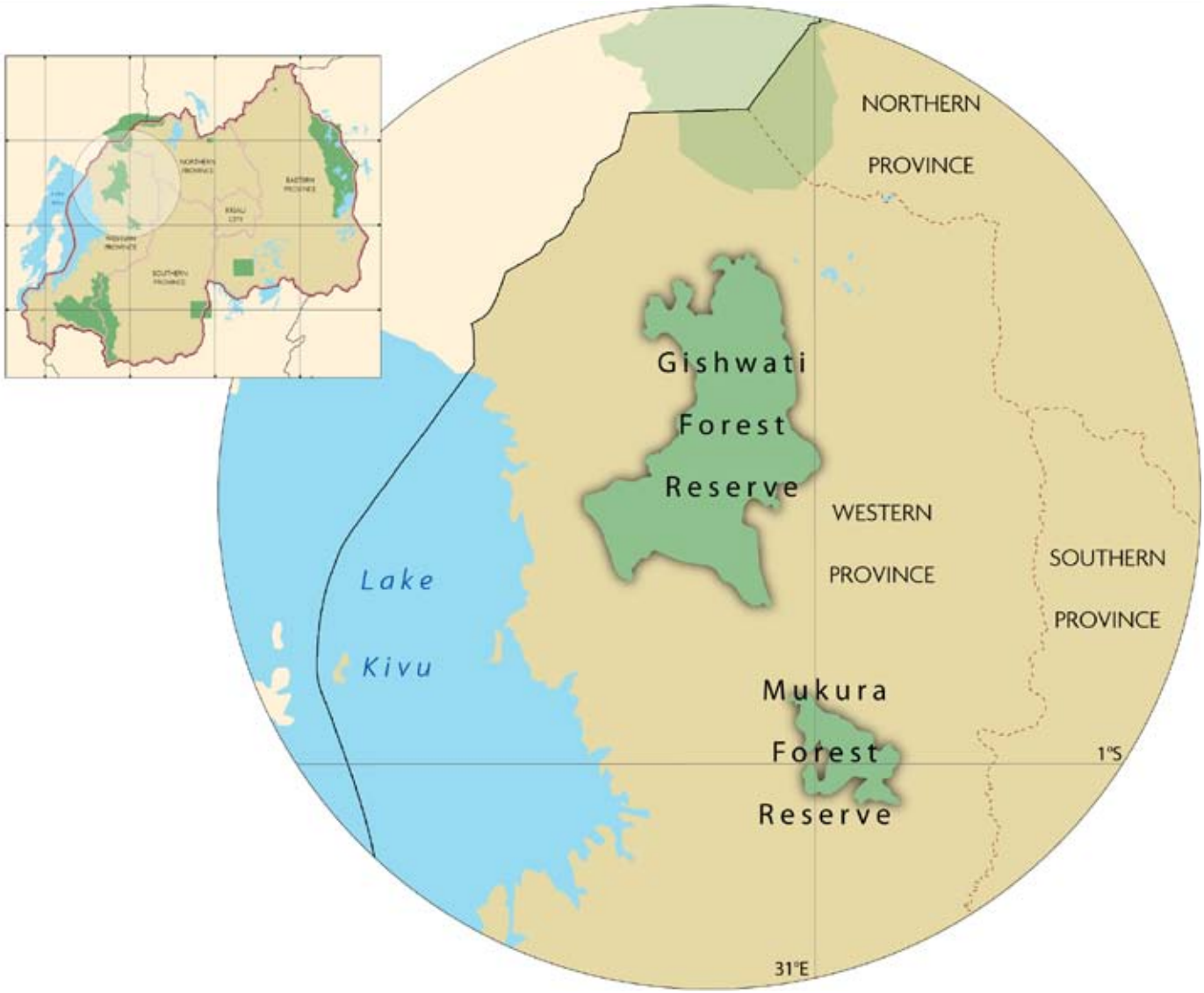
The Gishwati forest performs significant ecosystem services, including absorbing and slowly releasing rainwater, preventing erosion and often-disastrous landslides, stabilizing the microclimate and storing carbon (FHA, n.d.). These services benefit local farmers as well as many people further afield. The recent Total Economic Valuation of Mukura Forest conducted by ARCOS estimated the monetary value of this forest at a total of US$1,692,132 (RoR, 2015b).

Flora and fauna

Gishwati

Once there were 16 large trees species in the Gishwati forest. With deforestation and degradation, biodiversity has diminished, although the remaining natural forest still contains several plants endemic to the Albertine Rift, such as *Vittaria reekmansii*, an epiphytic fern that grows in the mountain rainforest up to 2,700 m; *Rytigynia bugoyensis* and *Chassalia subochreata*, which are shrubs or small trees; endemic epiphytic

Figure 6: Location of the Gishwati and Mukura Forest Reserves



orchids such as *Rhipidoglossum bilobatum*; a prostrate creeping herb called *Octomeron montanum*; and *Impatiens mildbraedii*, a perennial herb (RoR, 2014a).

There are also endemic bird species. Of 101 bird species recorded in the forest reserve, 14 are endemic to the Albertine Rift, of which 2 are listed as vulnerable on the 2009 IUCN Red List: the martial eagle (*Polemaetus bellicosus*) and grey crowned crane (*Balearica regulorum*) (USAID, 2014). Rwanda's Fifth National Report to the Convention on Biological Diversity also lists the Black Billed Turaco (*Tauraco schuetti*), the Great blue Turaco (*Corythaeola cristata*) and Ross's Turaco (*Musophaga rossae*) as living in the forest. Gishwati is also home to five migrant bird species: Barn Swallow, Eurasian Hobby (palearctic), European bee-eater (palearctic), Red-capped Robinchat and Red-chested Cuckoo (RoR, 2014a). Other bird species include Woodhoopoes (*Phoeniculidae*), White-headed Woodhoopoe (*Phoeniculus bollei*), Old World Warblers (*Sylviidae*), and Mountain Yellow Warbler (*Chloropeta similis*) (Musabyimana, 2014).

Monkey species that live in the forest reserve include l'Hoest monkey (*Cercopithecus l'hoesti*), the Blue monkey (*Cercopithecus mitis doggetti*), the Golden monkey (*Cercopithecus mitis kandti*) and the Eastern chimpanzee (*Pan troglodytes schwenfurthii*). The latter two are Endangered on the IUCN Red List of Endangered Species. In 2012, it was estimated that the entire chimpanzee population was between 19 and 29 individuals (RoR, 2014a). A population of 20 amounts to a 54 per cent increase in population size from the 13 chimps that were recorded in 2008 (Musabyimana, 2014).

Other mammals include the red river hog (*Potamochoerus porcus*), the black front duiker (*Cephalophus nigrifrons*), the southern tree hyrax (*Dendrohyrax arboreus*), the serval (*Felis serval*) and *Felis aurata*. Among amphibians are the brown forest frog and multiple species of toads and reptile species including the great lakes bush viper and multiple chameleon species (Musabyimana, 2014).

Mukura

The Mukura Forest has a total of 243 known plant species (RoR, 2014a). There are no primates in the Mukura Forest and deforestation has led to a dramatic decline in the number of mammal species (RoR, 2014a). The remaining forest hosts the fire-footed rope squirrel (*Funisciurus pyrropus*), the Ruwenzori sun squirrel (*Heliosciurus ruwenzorii*), the greater cane rat (*Thryonomys swinderianus*), the black-backed jackal (*Canis mesomelas*) and the crab-eating Mongoose (*Herpestes urva*) (World Bank, 2014).

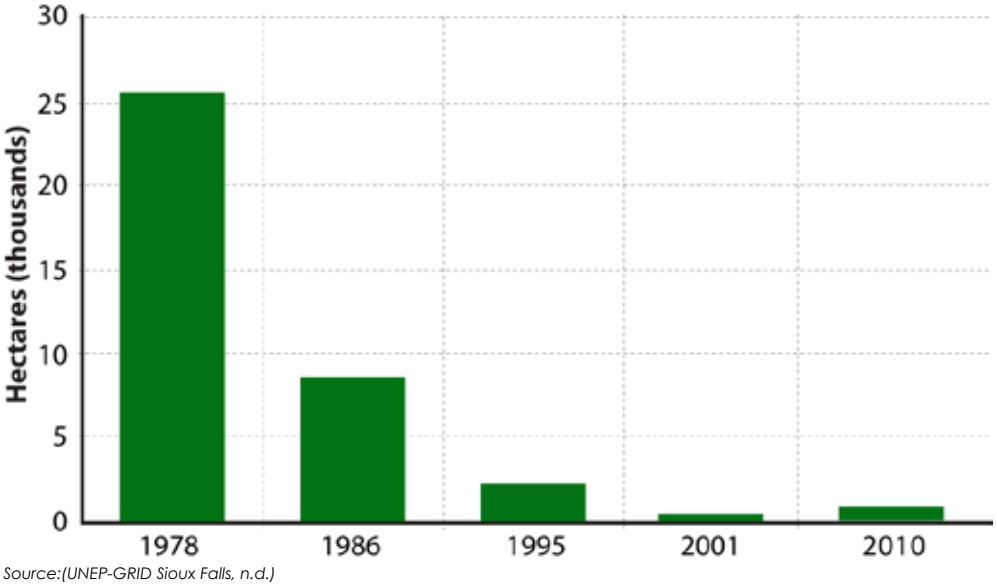
A recent Albertine Rift Conservation (ARCOS) survey updated the Mukura birds' species list from the previously known 59 species to 77 species (ARCOS, 2013). These include seven species endemic to the Albertine Rift and three IUCN threatened species, namely Grauer's Rush Warbler (*Bradypterus graueri*) (Endangered); Grey Crowned Crane (*Balearica regulorum*) (Endangered); and Kivu Ground Thrush (*Zoothera tanganjicae*) (Vulnerable) (RoR, 2014a).

Trends in forest loss

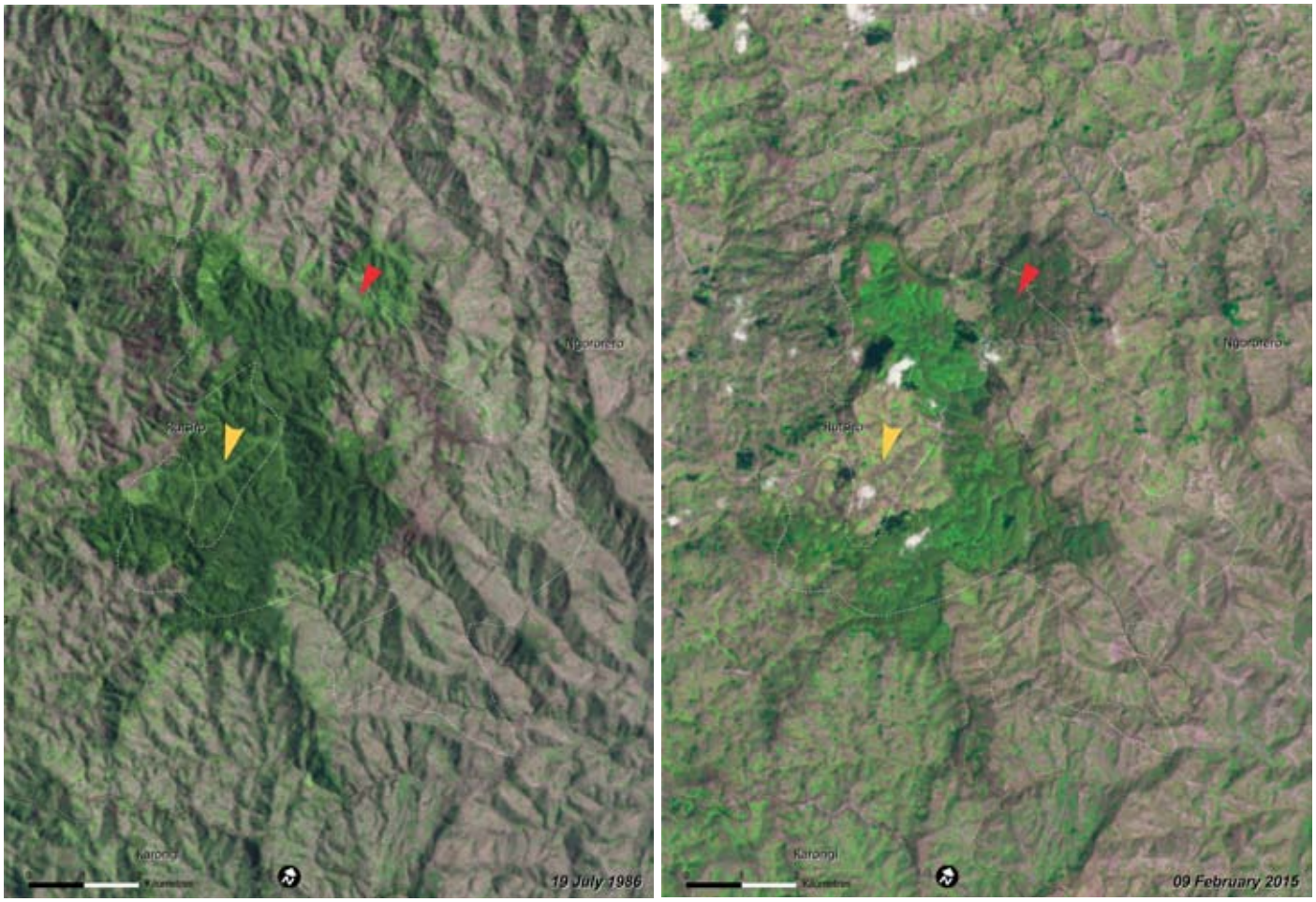
Gishwati Forest Reserve

In the past, this reserve suffered severe deforestation, which led to a loss of all three types of biodiversity (ecosystems, species and genes) and their associated ecosystem goods and services, including carbon storage. In 1970, the forested area in Gishwati covered about 28,000 ha. Extensive deforestation began with the introduction of large-scale cattle ranching projects and the resettlement of new refugees after the 1994 Genocide against the Tutsi, which in turn led to cutting for timber, charcoal and fuel (Birdlife International, 2011), cattle grazing within the forest, clearing for small-scale farming and the establishment of plantations of non-native trees (Bizoza & Ndangiza, 2013). Gradually, forest cover was reduced such that by 2001, only a small patch of native forest remained, amounting to about 550 ha (Figure 7),and by 2005 the forest covered an estimated 600 ha or about 2 per cent of the original forest.

Figure 7: Forest loss in Gishwati, 1978-2010



Source:(UNEP-GRID Sioux Falls, n.d.)



Landsat images showing the extent of tree cover in Mukura Forest in 1986 and 2015. Arrows point to areas where tree cover was lost between the two time periods.

The deforestation led to extensive soil erosion, flooding, landslides and reduced water quality, the isolation of a small population of chimpanzees and electricity shortages in Cyangugu due to siltation in the Sebeya River (REMA, 2010b). Communities living on the outskirts of the Gishwati suffered enormous losses of non-timber forest products, including huge declines in grasses for livestock, thatching and woven goods, and in the availability of wild fruits, vegetables, honey and medicinal herbs they used to collect from the forest (REMA, 2010b). Furthermore, the lack of water quality or quantity due to heavy sediment loads from eroded soils affected downstream crop production and domestic needs (RoR, 2014a); subsistence farmers lost an estimated RWF120,000 per season (REMA, 2010b).

Mukura Forest Reserve

Human encroachment of the Mukura Forest Reserve for livestock grazing; poaching; collecting wood, honey and lianas; and crop cultivation are the most significant pressures on the ecosystem. They led to deforestation and degradation and the loss of ecosystem services such as water retention and erosion control. Deforestation also caused many rivers and streams to become seasonal. In addition, small-scale mining, including uncontrolled illegal mining of coltan (columbite-tantalite), is taking place on the edge of the reserve, potentially affecting water courses running through the natural forest (World Bank, 2014); (Babijja, 2012).

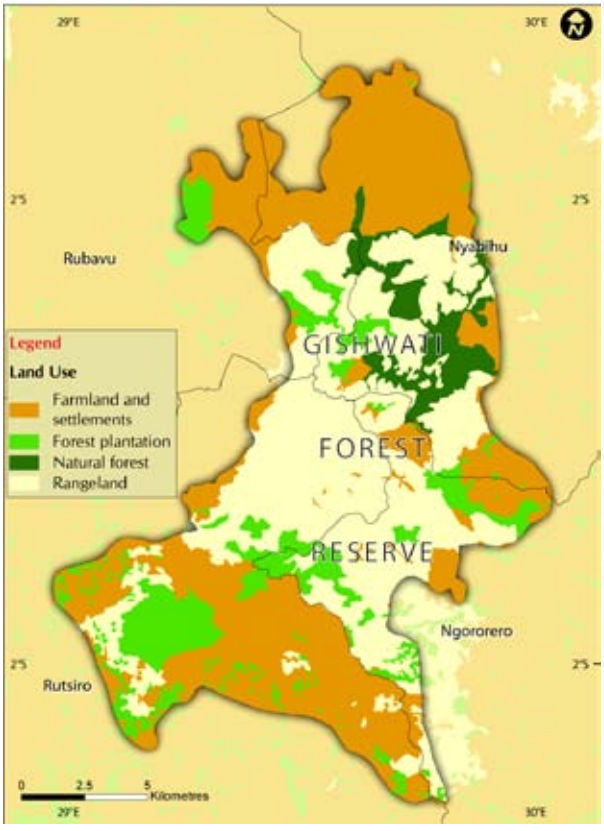
In total, about half of the forest surface in the Mukura Forest Reserve has been lost to deforestation since 1951 (Musabyimana, 2014). Between 1990 and 2006, the forest area declined from about 2,100 ha to 1,600 ha (RoR, 2015b)(See satellite images). Tree loss has resulted in a very disturbed ecosystem with a high loss of biodiversity and a high risk of soil erosion and land degradation (Musabyimana, 2014).

The rehabilitation of Gishwati and Mukura

To protect Gishwati, the Government degazetted 3,437 ha of a designated "high risk" forest zone to convert into agricultural land, leaving the remaining 3,206 ha as protected forest. A task force on irrigation and mechanization redistributed the degazetted portion to around 10,000 evicted beneficiaries. Those who depend solely on agriculture received 0.4 ha of land and those with other livelihood sources received 0.2 ha. According to EICV 3, the mean land holding size at the national level is 0.59 ha (Bizoza & Ndangiza, 2013). Figure 8 shows the large proportion of the forest reserve covered by farms and rangeland in 2010.

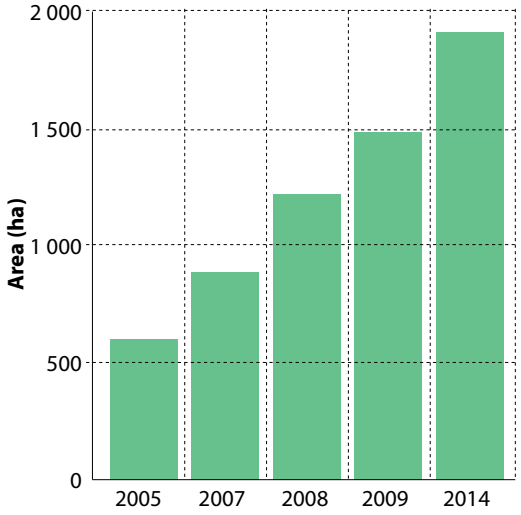
As shown in Chapter 2 (Forests), the GoR began a massive reforestation effort throughout the country. In 2005, the Gishwati was deemed to be of high conservation value and the Gishwati Area Conservation Programme began the process of forest expansion and restoration. By 2007, it had expanded by 286 ha with more land being protected every year until by 2009, the forest area had grown to 1,484 ha through both natural regeneration and reforestation to extend the Core Forest (Figure 9). By 2014, the forested area covered 1,913 ha with large tea estates occupying the reserve's central and northern parts (Musabyimana, 2014); (World Bank, 2014); (USAID, 2014).

Figure 8: Land use in the Gishwati Forest Reserve (according to the 1978 reserve boundaries) in 2010



Source: (RoR, 2015b)

Figure 9: Trend in reforestation in Gishwati, 2005-2014

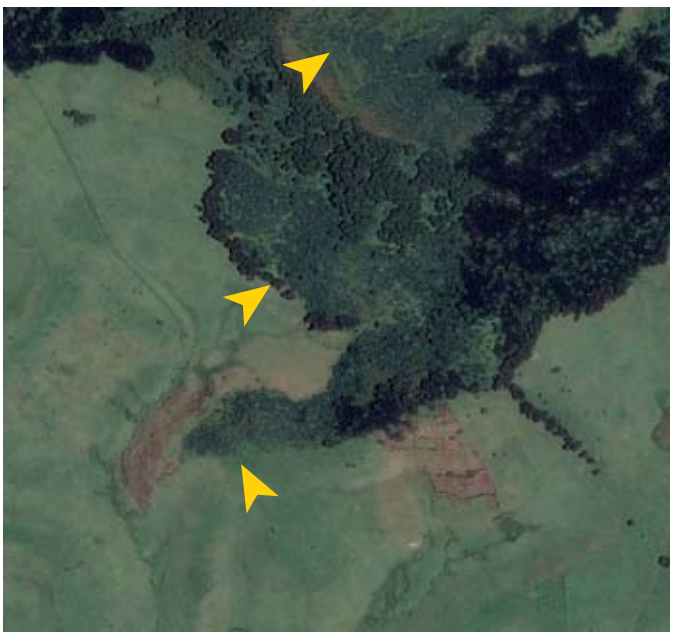


Sources: (Nyiratuza, n.d.); (World Bank, 2014)

Section of Gishwati, 2006 (dark green is forested area)

Google Earth

Section of Gishwati, 2015 (dark green is forested area)



Google Earth

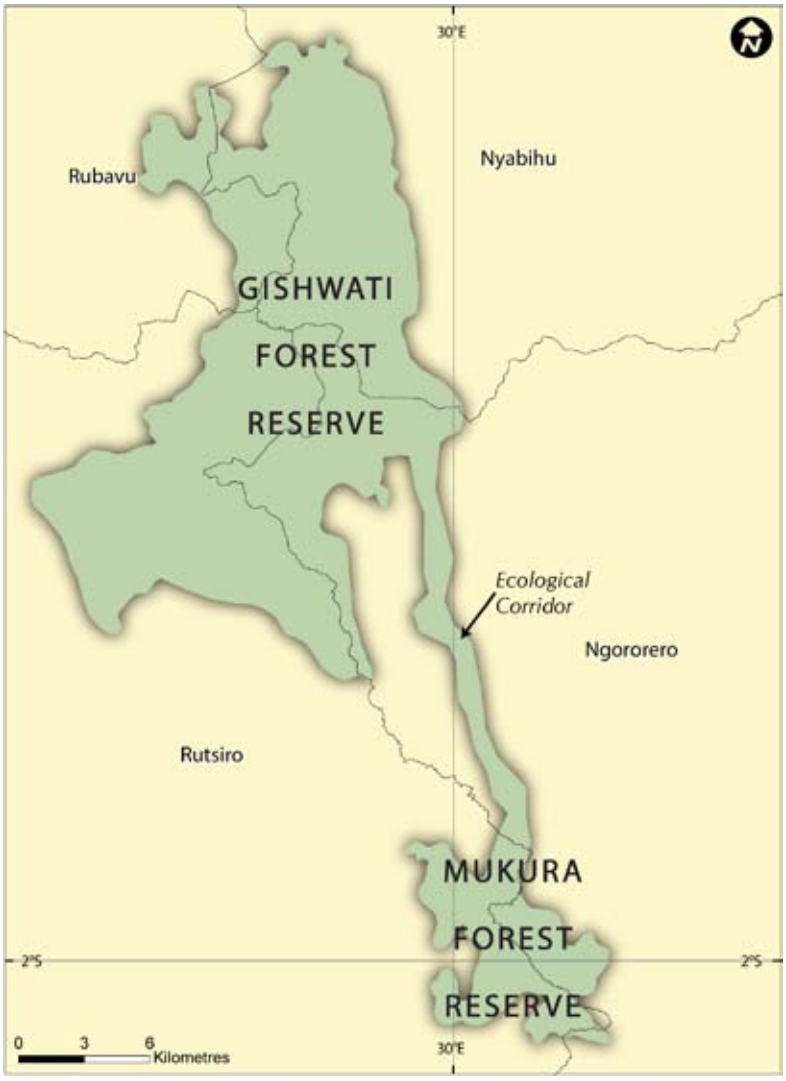
The Gishwati-Mukura National Park

In its continued effort to protect Rwanda's remaining forests and its ecosystem services, the GoR is in the process of creating the Gishwati-Mukura National Park to protect both forests from encroachment. Changing these forest reserves into a National Park will further protect both forests and their biodiversity and increase tourism revenues (MINIRENA, 2014).

The Gishwati-Mukura National Park will cover a total surface area of 3,427.46 ha. In addition, an area covering 992.48 ha has been dedicated to a subsequent buffer zone to deter human encroachment (Karuhanga, 2015).

A corridor will be established to link the two reserves into a contiguous park. Already, in late-2010, the Gishwati Area Conservation Programme (GACP) had begun a Gishwati-to-Nyungwe forest corridor. The corridor is important to allow the Gishwati chimpanzees access to other, more distantly related chimpanzee mates, without which the Gishwati chimpanzees will suffer inbreeding and increased susceptibility to disasters. It is estimated that the corridor will be 50 km long and 1,000 m wide and cover an area of 5,000 ha (GPFLR, 2013) (Figure 10). Historically, the Mukura, Gishwati and Nyungwe forests were all one ecosystem and it is likely that they were once linked to the Volcanoes National Park area. Without the protection the National Parks afford, and if the pace and scale of deforestation and land degradation were to continue as in the past, these remaining forests would completely disappear by 2020 (Musabyimana, 2014).

Figure 10: Planned ecological corridor between Mukura and Gishwati



Source: (RoR, 2015b)

Rwanda's revised and updated National Biodiversity Strategy and Action Plan (NBSAP) (RoR, 2015b) deems the Gishwati and Mukura Forest Reserves to have "High" conservation priority. Presently, to restore the Mukura forest, the following activities are being implemented:

- Forest protection by providing forest guards, building capacity and creating a wide range of public awareness campaigns on the advantages of forests;
- Identification of forestry as one of the pillars of the national economy, playing a role in supporting agriculture, tourism, environmental stability and energy;
- Involving local communities in the conservation of the Mukura Forest Reserve, including protection activities in the forest;
- Increasing income generating activities outside the forest to motivate local communities to conserve the forest;
- Creating local cooperatives to facilitate income generating activities; Involving more women and youth in the conservation and development of the forest (Musabyimana, 2014).

Creating the National Park is part of Rwanda's overall plan to increase forest cover to 30 per cent of the country's land base. It is also related to plans to foster ecotourism as another engine of "green" economic development as well as to store carbon to help mitigate climate change. A recent study estimates the Gishwati forest can absorb 200,000 tonnes of carbon dioxide. Valued at about US$5 per tonne

under UN guidelines, this means the Gishwati forests alone could already generate about a million US dollars a year if the carbon were traded for funds on the carbon market (Schlindwein, 2011).

Conclusion

Maintaining and conserving Rwanda's rich ecosystem and species diversity is critical to its goals to green the economy, reduce poverty and foster resilience to climate change impacts. For example, the Rwandan part of the Albertine rift is home to about 30 per cent of the global population of mountain gorillas. Rwanda's growing tourism industry brought in US$293.6 m in 2013, a significant proportion of which was generated by gorilla tourism, which not only protects the species and its habitat, but generates jobs and combats poverty through revenue sharing schemes. Likewise, revenues from Akagera and Nyungwe National Parks continue to grow (increasing by 65 per cent a year in the former) as Rwanda improves biodiversity protection and tourist infrastructure, and increases forest cover as well as local community involvement.

One of the most compelling stories of biodiversity gains is the recovery of the Gishwati forest; through forest expansion and regeneration, forest cover grew to 1,484 ha by 2009 and 1,913 ha by 2014, resulting in fewer floods, landslides and river siltation, and improved soil fertility, water quality and local livelihoods. The creation of the Gishwati-Mukura National Park will further protect the forests from encroachment and increase tourism revenues.

With rising temperatures and uncertain rainfall patterns due to climate change, it is essential to protect the country's forests that act as water towers. Protecting the Nyungwe forest, for example, will help to ensure it continues to supply at least 40 per cent the Nyabarongo River system's dry season water flow and 70 per cent of Kigali's water supply.

Rwanda is moving forward to further protect and enhance its biodiversity as it aims to establish a National List of Threatened Terrestrial Ecosystems and Species in Need of Protection.

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Chapter 4: Water Resources

4.1 Status and trends

Rwanda has abundant water resources. Although its dense drainage network allows most of the country to receive water, it is unevenly distributed both spatially and temporally: the west receives most precipitation and the eastern part of the country is relatively dry, while there are long dry periods between rainy seasons. Other challenges include changes in climate that are already disturbing normal temperature and rainfall patterns and the need to supply more of the country's population

with water for improved domestic supplies and sanitation. Water use will also rise with the needs of a growing population and for planned irrigation and hydroelectricity developments. As well, water quality needs to be protected from sources of pollution.

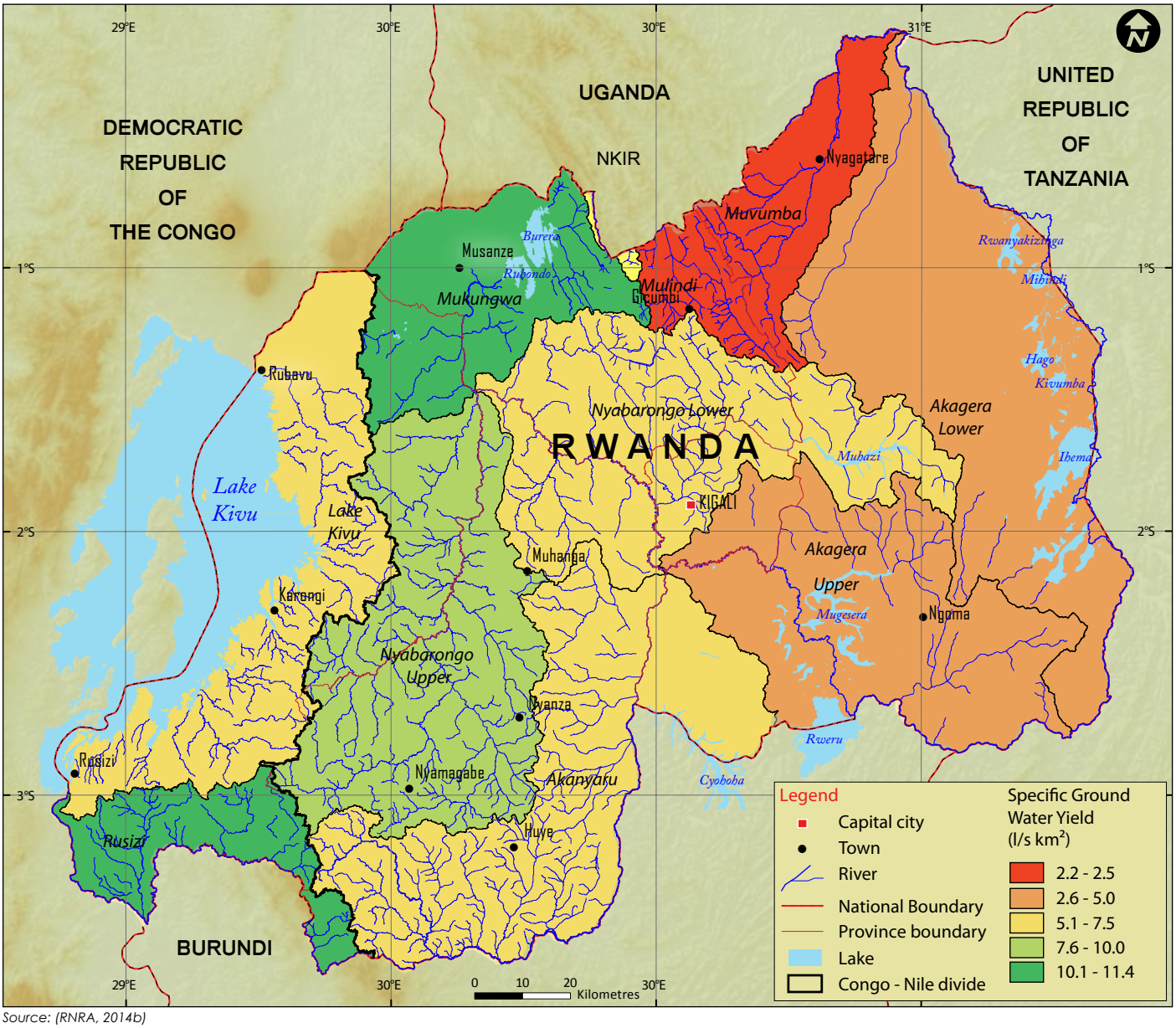
Rwanda's hydrological network

There are two main hydrographical basins in Rwanda that lie on either side of a north-to-south watershed line known as the Congo-Nile divide — the Congo and Nile River Basins. Catchments, or hydrographical, river or drainage basins, are defined as "a part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water" (Langbein & Iseri, 1995). A watershed is the high point dividing drainage basins, but the term is often used to describe a drainage basin or catchment area. A drainage divide is the boundary between one drainage area and another (Langbein & Iseri, 1995).

The Congo-Nile divide is more-or-less perpendicular to the volcanoes that serve as a natural barrier to the catchment basins in Rwanda, North Kivu and southwest Uganda (REMA, 2011a). The Congo River Basin lies to the west of the divide, covers 33 per cent of the national territory and receives 10 per cent of the total national waters. The rivers on the west side of the divide — the Sebeya, Koko, Ruhwa and Rubyiro Rivers in Rwanda — drain into the Congo River basin via the Rusizi River, then into the Atlantic Ocean. Lake Kivu is part of the Congo Basin; it is shared with the DRC and covers an area of 102,800 ha within Rwanda alone.

The Nile basin lies to the east of the Congo-Nile divide, covers 67 per cent of the total national territory

Figure 1: Rwanda's hydrological network showing nine catchments and groundwater yield



Source: (RNRA, 2014b)

Table 1: The nine water catchments in Rwanda

Catchment	Surface (km^2)	Description
Lake Kivu	2,425	A headwater catchment, Lake Kivu is transboundary with the DRC. It is a series of small catchments draining into Lake Kivu. There is one hydropower station.
Rusizi	1,005	A headwater catchment that comprises Rusizi, Rubyiro and Ruhwa rivers; it is transboundary with both the DRC and Burundi.
Nyabarongo upper	3,348	An inland headwater catchment of the Nyabarongo River and its tributaries springing from the Nyungwe Forest.
Mukungwa	1,887	Essentially an inland headwater catchment that drains the lava region, the Ruhondo and Burera Lakes and the protected Rugezi wetlands.
Nyabarongo lower	3,305	An inland downstream catchment that drains the area from the confluence of the Nyabarongo with the Mukungwa River down to the confluence of the Nyabarongo with the Akanyaru River. The Nyabugogo, which falls into the Nyabarongo near Kigali, is an important tributary and inland headwater.
Akanyaru	3,402	A transboundary (with Burundi) upstream catchment that springs in the Nyungwe forest and features a long, flat and wide, peat-based wetland that drains the Cyohoha South lake along with a series of lakes in Burundi.
Akagera upper	3,053	A transboundary (with Burundi and Tanzania) downstream catchment that drains the area from the confluence of Nyabarongo and Akanyaru Rivers down to the Rusuma Falls. It features numerous lakes with significant evaporation losses and the confluence with the Ruvubu River (from Tanzania/ Burundi).
Akagera lower	4,288	A transboundary (with Tanzania) downstream catchment that drains the area downstream of Rusumo Falls up to the confluence of the Akagera with the Muvumba River. It features numerous lakes and two tributaries that typically run dry during the dry season.
Muvumba	1,565	An intricate transboundary (with Uganda) upstream catchment. The Muvumba catchment drains the Mulindi River that runs into Uganda to enter Rwanda after a 50 km detour as the Muvumba River that eventually forms the border with Uganda.

Source: (RNRA, 2014b)

and drains 90 per cent of Rwandan waters, mainly through the Nyabarongo and Akanyaru Rivers. The latter merge and make up the Akagera River, Lake Victoria's principal tributary, which has an average flow of 256 m^3/s and is considered to be the White Nile's main source, contributing 9 to 10 per cent of the total Nile waters (NBI, 2005). With a length of 6,695 km, the Nile River is the world's longest watercourse. Its main tributaries are the White Nile and the Blue Nile (REMA, 2011a).

Within Rwanda's portion of the Congo and Nile Basins are nine smaller catchments, identified in the National Water Resources Master Plan (NWRMP) as illustrated in Figure 1 and Table 1 (RNRA, 2014a).

Lakes and rivers

Rwanda's dense hydrographical network consists of 101 lakes covering 149,487 ha, 860 marshlands with a total surface area of 278,536 ha and 861 rivers with a combined length of 6,462 km (REMA, 2011a).

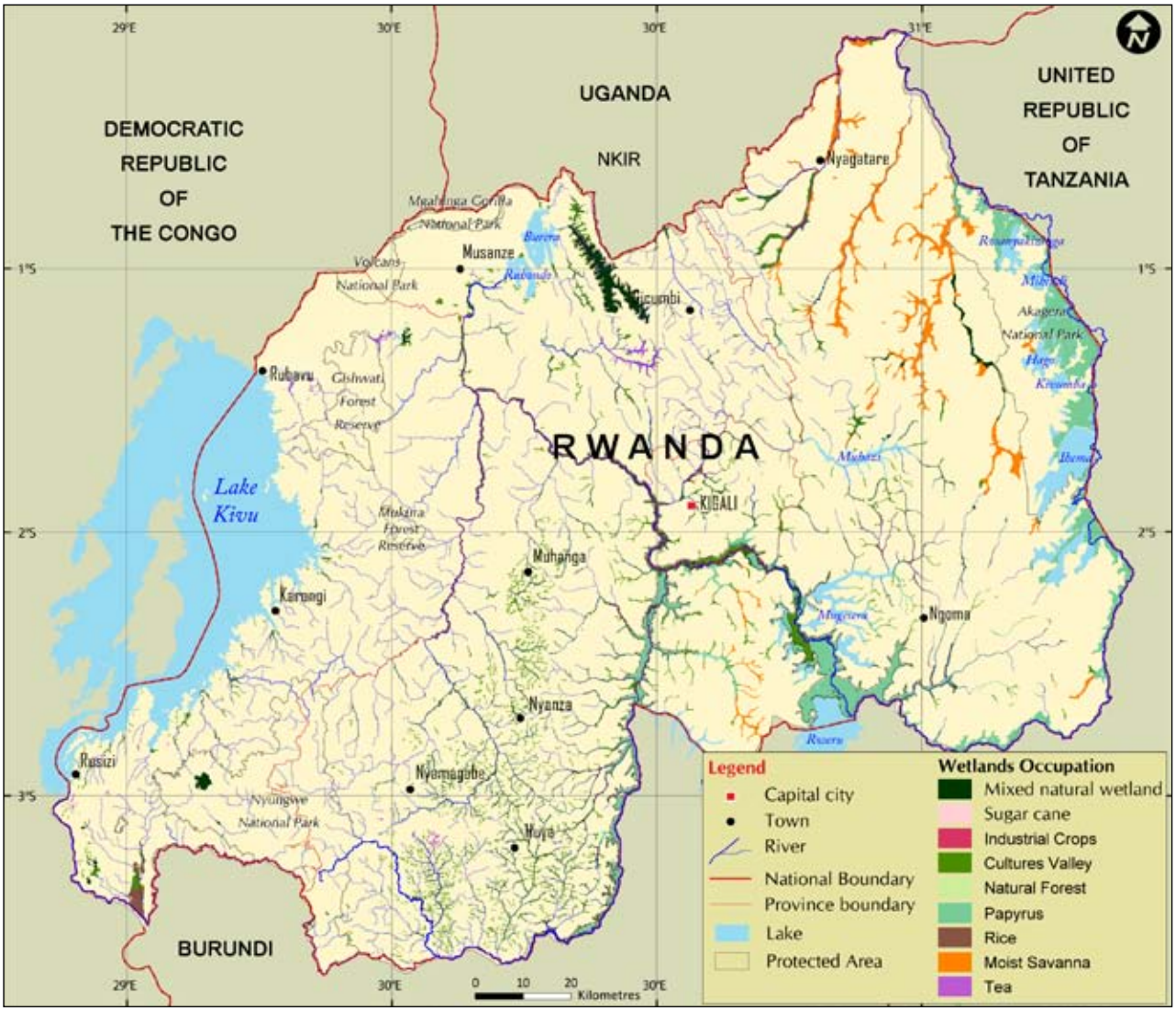
Rwanda's many lakes vary in their levels of productivity and biodiversity. Lakes Burera, Ruhondo and Kivu are deeper than 50 m (MINAGRI; Ebony Enterprises Ltd.; ICRAF, 2010). Burera and Ruhondo lakes have low nutrient and productivity levels. Lake Kivu is a stratified lake with large volumes of dissolved carbon dioxide and methane in its lower layers. It has low productivity and biodiversity levels compared to other Rift Valley lakes such as Victoria, Tanganyika and Malawi (USAID, 2014).

Lakes Mugesera, Sake, Bilira, Cyohoha, Rweru and Ihema are no deeper than 10 m (MINAGRI; Ebony Enterprises Ltd.; ICRAF, 2010). Lakes associated with wetland ecosystems, such as the shallow Akagera, Rweru-Mugesera and Nyabarongo lakes, contain high nutrient levels, species diversity and productivity.

Marshlands

Rwanda's 860 marshlands cover an estimated 278,536 ha and represent 10.6 per cent of the country's territory

Figure 2: Rwanda's wetlands



Source: (REMA, 2011a)

(Figure 2). They support various species of aquatic vegetation, such as Typha, Papyrus, Miscanthus and Cyperus (REMA, 2011a) and perform multiple crucial ecosystem services, including storing and purifying water, helping to control flooding by releasing water gradually to allow year-round stream flow; absorbing sediments; and helping to regulate the climate by recirculating moisture that cools the surroundings. They also contain large valuable peat deposits that help store and release water, store carbon and also have energy production potential (Kabalisa, 2012).

Given their high productivity and flat topography, as well as Rwanda's high population numbers and lack of available land, large tracts of the country's marshlands have been converted to agricultural fields to grow rice, cereals, vegetables and other crops (Kabalisa, 2012); (Nabahungu, 2012). Fields cover about 53 per cent of the wetland area and 6 per cent is agricultural area that lies fallow. The rest (41 per cent) is covered by natural vegetation (REMA, 2011a).

The Rwanda Irrigation Master Plan (2010) classifies the country's marshlands according to their altitude, as follows:

- High-altitude marshes: Typically these have narrow shapes and develop organic soils that ultimately become peat. These marshes serve as buffer zones, facilitating water retention and storage. Some of them are cultivated or exploited for tea plantations;
- Medium-altitude marshes: These are often large, extending over the central plateaus. Traditional agriculture is practiced in these areas;
- Low-altitude marshes: These are known as collecting marshes. They are the largest and occur in the central and eastern parts of the country. They extend along the main rivers, such as the Nyabarongo, Akanyaru and Akagera. They act as buffers, filling up during the rainy season and promoting a constant outflow

rate during the following dry season. They are covered by papyrus and are scarcely exploited for agriculture (MINAGRI; Ebony Enterprises Ltd.; ICRAF, 2010).

The major wetlands are as follows:

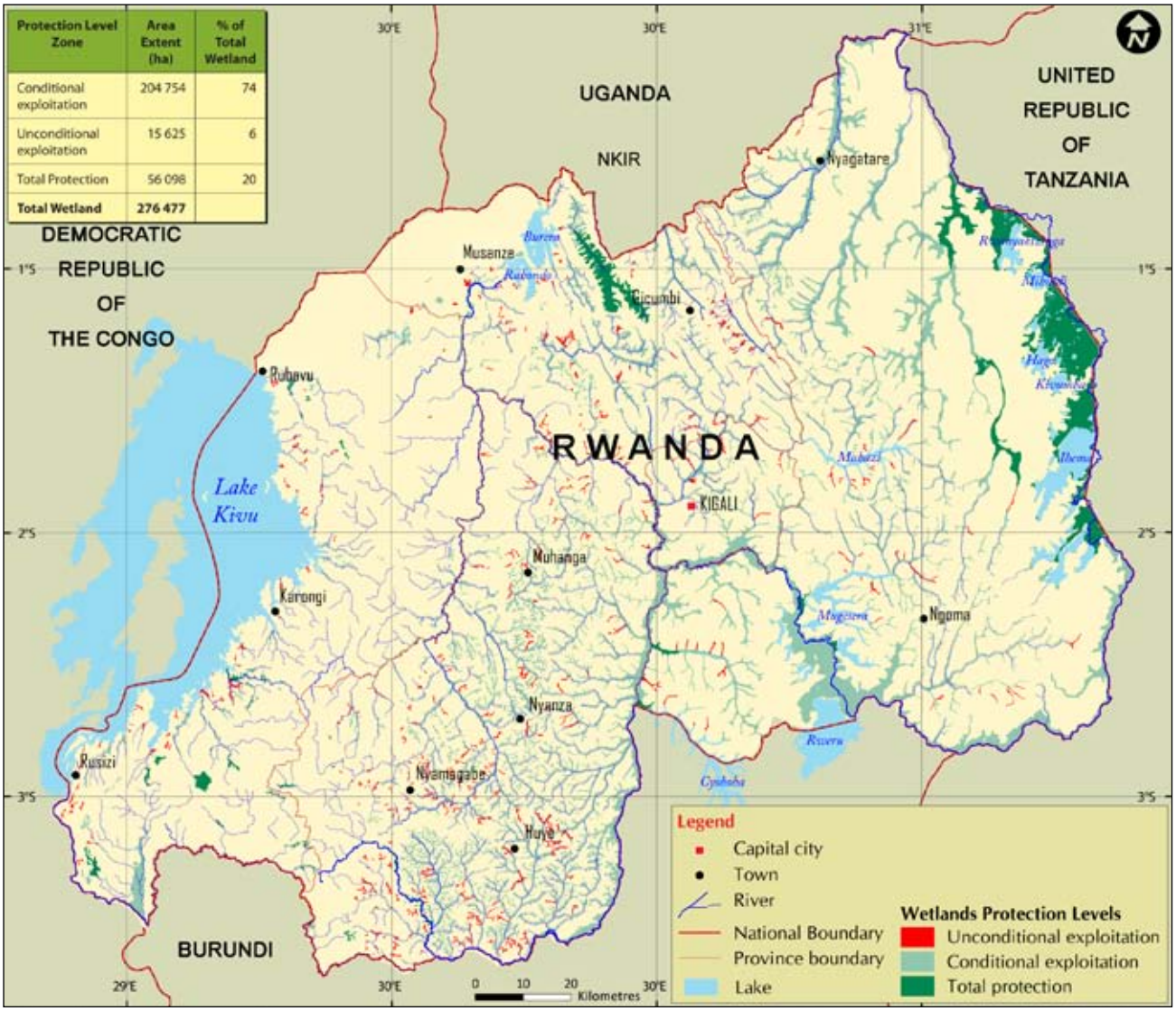
- Nyaborongo complex: 24,698 ha in the central plateau towards the southern plains where agricultural activities take place all along its vast watershed; it supplies some medium-sized hydroelectric plants;
- Rugezi complex: 6,294 ha in the north. It drains into and recharges Lakes Burera and Ruhondo, supplying water for hydroelectricity and for large agricultural activities; it moderates the local climate;
- Akanyaru: 12,564 ha along the southern border with Burundi, this wetland supports agriculture and artisanal fishing;
- Akagera complex: 12,227 ha in the southern plains and along the Tanzanian border in the east. It supports hydropower generation, agriculture, transport and tourism (Kabalisa, 2012); (REMA, 2011b).

Wetland categories for sustainable development

In 2010, Rwanda established a list of the country's swamps or wetlands, mapped their geographic limits and undertook to regulate their management and use. Increasing concern to protect wetlands from overuse led Rwanda to categorize them according to their potential for sustainable development, as shown in Figure 3. This is a wetland protection levels map that assigns the wetlands to different categories according to three types of prescribed best use, as shown in the table within the map (REMA, 2011a).

Unconditional exploitation (6 per cent of total wetland area) allows use under certain conditions; conditional exploitation (74 per cent) requires a basic Environmental Impact Assessment (EIA); and total protection, covering 20 per cent of total wetland area, is reserved for the most vulnerable wetlands (REMA, n.d.).

Figure 3: Wetland protection and exploitation levels



Source: (Rugege, 2012)

Groundwater and water balance

Moisture in the hydrological cycle returns to earth as precipitation. Rwanda's average annual precipitation is 1,200 mm, with variations from a low of about 700 mm in the Eastern Province to about 2,000 mm in the higher altitudes in the north and west. Almost half of total precipitation occurs between February and May and another third falls between late September and December (Muhinda Mbonigaba & Smiet, 2011). The country's natural water towers, which feed its rivers, are the highlands in the Albertine region, Nyungwe Mountain Forest and Volcanoes National Park as well as the Rugezi wetland (Kabalisa, 2012).

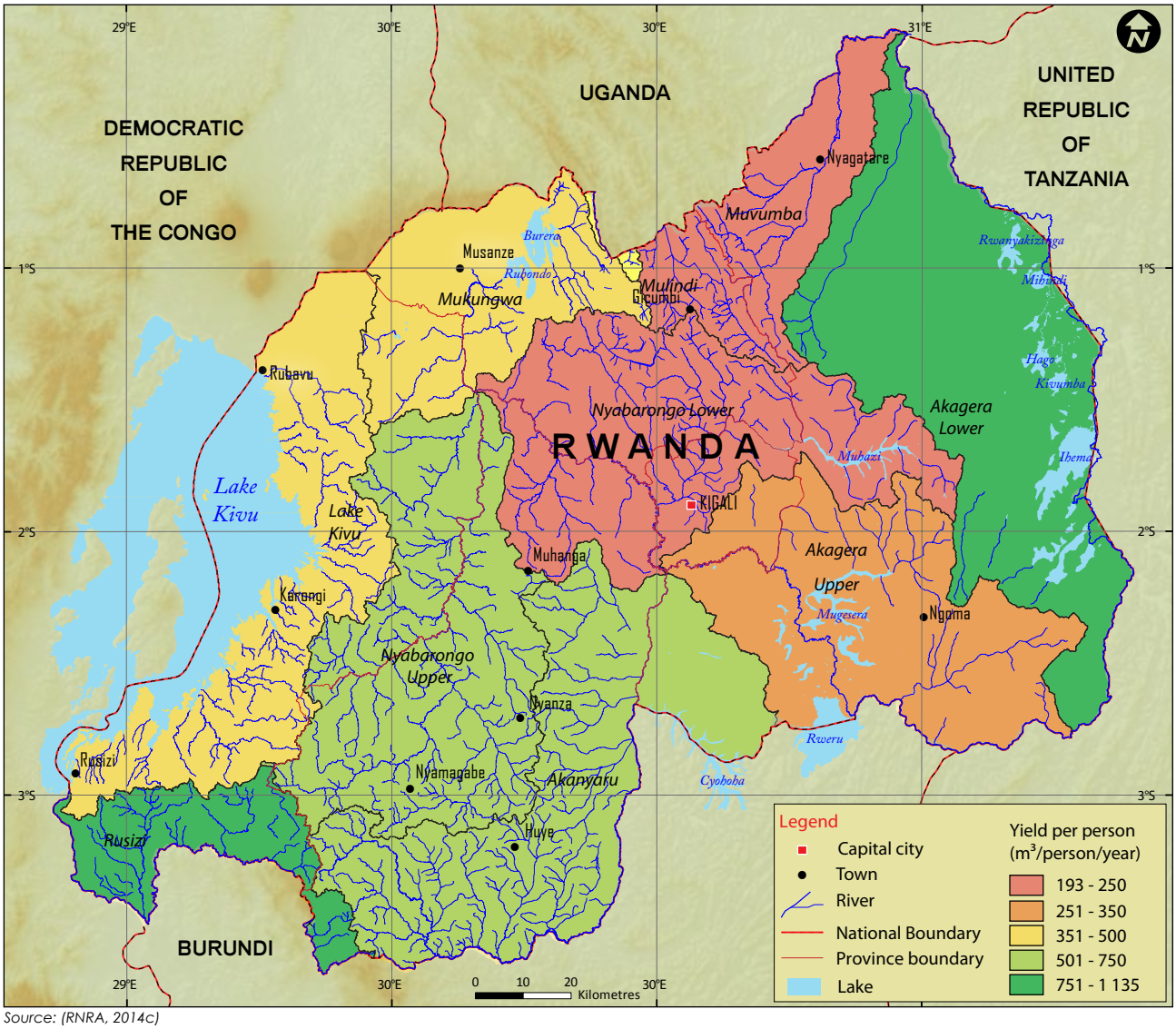
Table 2: Water statistics, 2012 and 2013

	2012		2013	
Items	**Status**	**Potentials**	**Status**	**Potentials**
Surface water	101 lakes covering an area of 149.48 ha	7-6 billion m^3/ year	101 lakes covering an area of 149.48 ha	6.826 billion m^3/year
	861 rivers of a total length of 6,462 km		861 rivers of a total length of 6,462 km	
Ground water	-	5-4.5 billion m^3/ year	-	4.554 billion m^3/year
Rainfall water	-	28-25 billion m^3/ year	-	27.505 billion m^3/year
Water yield/ person	-	1,135 - 193 m^3/ person/year	-	670 m^3/person/ year
Water storage/ person	-	7-5 m^3/person/ year	-	447 m^3/person/ year

Source: (NISR, 2014)

Water balance (also called the hydrologic budget) is "an accounting of the inflow to, outflow from, and storage in, a hydrologic unit, such as a drainage basin, aquifer, soil zone, lake, reservoir, or irrigation project" (Langbein & Iseri, 1995). Figure 1 illustrates the water balance in different water basins, showing

Figure 4: Per capita water availability by drainage basin, 2013



Source: (RNRA, 2014c)

low groundwater levels in the eastern part of the country compared to the high water yields in the north-to-south band corresponding to the Nyaborongo River.

The total renewable surface water in Rwanda is about 9.5 billion m^3/yr (Muhinda Mbonigaba & Smiet, 2011) and total groundwater storage is about 7 billion m^3/yr (Table 3). More than three-quarters of Rwanda's surface water depends on the water resources stored underground (RNRA, 2014a).

Table 3: Water availability, 2011

Estimated water availability in Rwanda		
Water availability parameter	**Unit**	**Amount**
Average precipitation in depth	mm/yr	1,212
Total renewable surface water	Billion m^3/yr	9.5
Total renewable groundwater	Billion m^3/yr	7
Total renewable water	Billion m^3/yr	9.5
Per capita renewable water (actual)	m^3/yr	977.3
Per capita renewable water (Africa)	m^3/yr	4,008

Source: (Muhinda Mbonigaba & Smiet, 2011)

Water supply

Table 2 provides the most recent data on the status of Rwanda's water resources. It reveals that in 2012, Rwanda was water stressed; in 2013, it was a water scarce country, with average annual per capita renewable water resources estimated at 670 m^3 (RNRA, 2014c). The United Nations deems an area to be experiencing water stress when annual water supplies drop below 1,700 m^3 per person. When an area declines below 1,000 m^3 per person, the population faces water scarcity, while below 500 m^3 signifies "absolute scarcity" (UNDESA, 2014).

Figure 4 is a map of the distribution of per capita water availability, showing that in 2013 the catchments coloured red faced absolute scarcity according to the UN definition.

Table 4 is a summary of the water balance findings of the NWRMP, including the sources of the main demands for water and projections of water balances to 2040. Lake Kivu and the Rusizi, upper Nyabarongo and Mukungwa catchments will continue to have excess water balances until 2040 and the main demands will come from rural and urban water users and small hydropower. The lower Nyabarongo catchment will have the same types of demands for

Table 4: Summary water balance findings of the National Water Resources Management Plan

Catchment	Water balance projections to 2040
Lake Kivu	Excess water balance up to 2040; the main demand for rural and urban water supply is small hydropower; limited irrigation scope.
Rusizi	Excess water balance up to 2040 with demand characteristics similar to the Kivu catchment; the internal Rubyiro catchment is already under stress due to rice irrigation.
Nyabarongo upper	Excess water balance up to 2040 with main demand for rural and urban water, small hydropower, dam construction and irrigation development.
Mukungwa	Excess water balance up to 2040 with main demand for rural and urban water and small hydropower.
Nyabarongo lower	Equilibrium water balance up to 2040 with main demand for urban (Kigali) and rural water, small hydropower, dam construction and optimized (limited) irrigation development.
Akanyaru	Ecologically vulnerable to drought conditions, resources are insufficient and there is no scope for interbasin water transfer. Main demand categories are rural and urban water supply, small hydropower, dam construction and optimized (limited) irrigation development, notably regarding hillside irrigation.
Akagera upper	Insufficient resources but an interbasin transfer from upper Nyabarongo and Mukungwa catchment by natural river flow is possible. Main demand is for urban and rural water supply, dam construction and optimized irrigation development.
Akagera lower	Insufficient resources but an interbasin transfer from upper Nyabarongo and Mukungwa catchment by natural river flow is possible. Main demand is for rural water supply, livestock, dam construction and optimized irrigation development.
Muvumba	Insufficient resources and there is no scope for interbasin water transfer. Main demand is for rural and urban water supply, dam construction and optimized irrigation development regarding hillside irrigation.

Source: (RNRA, 2014a)

Farmlands close to Rugezi marshland. Eugene Apindi Ochieng

Table 5: Overview of water use in the different catchments of Rwanda, 2014

Level 1 basin	Surface area level 1 basin (km²)	renewable resource ('000 m³)	Potable water supply use ('000 m³)	Irrigation water use ('000 m³)	Total water use in ('000 m³)	2012 Total water use over resource
Lake Kivu	2,180	898,000	5,917	440	6,357	0.71%
Rusizi	504	432,000	954	890	1,844	0.43%
Nyabarongo Upper	3,162	1,290,000	8,400	1,193	9,593	0.74%
Mukungwa	1,586	905,000	3,659	0	3,659	0.40%
Nyabarongo Lower	3,269	899,000	11,983	7,983	19,967	2.22%
Akanyaru	3,265	798,000	10,815	21,195	32,010	4.01%
Akagera Upper	2,939	504,000	9 776	16,034	25,809	5.12%
Akagera Lower	3,223	907,000	880	8,404	9,284	1.02%
Muvumba	1,587	193,000	875	9 742	10,617	5.50%

Source: (RNRA, 2014a)

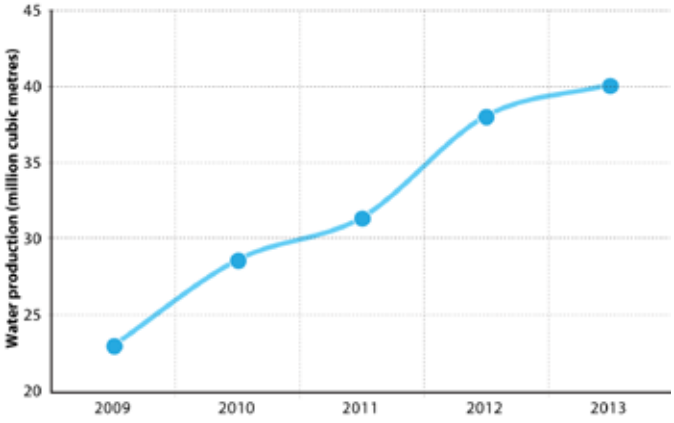
water but will be in a state of water equilibrium until 2040. The Akagera catchments will have insufficient water supplies by that date, but they have the potential for interbasin transfers. The Akanyaru and Muvumba are the most vulnerable since resources are insufficient and there is no scope for interbasin water transfer. The Akanyaru is also naturally vulnerable to drought conditions. Thus in these latter two vulnerable catchments, there is an especially crucial need for superior water management and implementation to optimize water development and allocation and to protect wetlands, such as the Akanyaru floodplain and Cyohoha Lake, from irreversible degradation (RNRA, 2014a).

Water production and consumption

The NWRMP notes that data on water consumption in Rwanda is scarce and incomplete. To calculate an estimate of the most current water use, it assessed each catchment based on a number of assumptions: water availability and discharge from springs or boreholes; the production capacity of piped water supply systems; the water capacity of rainwater harvesting irrigation ponds and marshlands; the different yearly supply of irrigation from surface or groundwater resources for western and eastern areas; and the different volumes of irrigation water expected from dam sites in eastern and western areas. The assumptions contain much uncertainty, but the plan balances likely overestimations in certain assumptions with likely underestimations in others. Results are presented in Table 5.

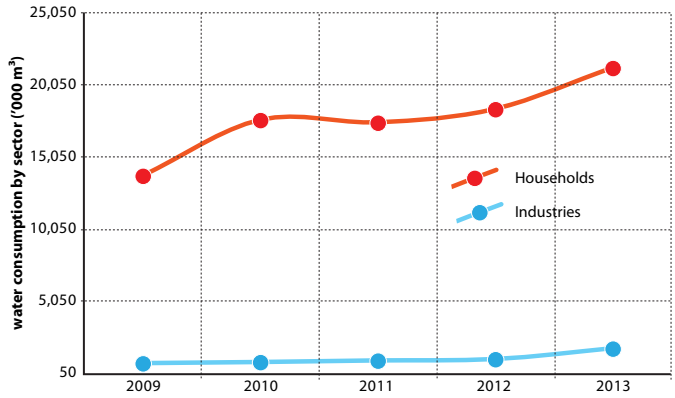
The lower Nyabarongo and upper Akagera catchments register higher water use due to the amount of water consumed by the city of Kigali and for irrigation development in the Nyabarongo valley. There is a significant supply of potable water and irrigation development in the Akanyaru catchment (mainly tributaries of Akanyaru valley). The Muvumba catchment has the highest water use, which is exclusively related to irrigation development. The NWRMP concludes that since data are so scarce, actual water use will no doubt exceed these data; nevertheless, the results of the estimations show that water use is still very low. Thus, there is room for further and accelerated water resources development, which is a necessity to provide the Rwandan population with adequate improved water supplies and sanitation and to furnish the water necessary for new development, business and industrial opportunities and agricultural irrigation to further green the Rwandan economy (RNRA, 2014a).

Figure 5: Total water production in Rwanda (m^3), 2009-2013



Source: (NISR, 2014)

Figure 6: Trend in water consumption by sector, 2009-2013



Source: (NISR, 2014)

As the Rwandan population grows, so the country needs to supply ever more water to municipalities, new settlements, industry, agricultural irrigation and other uses. Figure 5 shows the rise in water production from 2009 to 2013.

Rwanda actually only uses 2.23 per cent of its available water resources. This means that Rwanda loses almost all of its water resources through evaporation or runoff to other downstream countries. Of the water it does use, irrigation is the main use, accounting for 1.57 per cent of available water and 80-90 per cent of all water consumed in the country, Figure 6 shows the trend in water consumption by households and industry (RNRA, 2014c); (Kathiresan, 2011).

The most common source of drinking water is protected spring water, which accounts for 38 per cent of usage, followed by public tap/standpipe (26 per cent). Only 5 per cent of households have running water in their dwelling or courtyard. The proportion of households with improved drinking water rose from 64.1 per cent in 2000 to 84.8 per cent in 2013/14 (NISR 2015).

Sanitation provision also uses water. During the same period, the proportion of the population using improved sanitation facilities rose from 51.5 per cent to 83.4 per cent (NISR 2015).

4.2 Pressures and impacts

Although there is ample water and water quality is still generally good, there are a number of challenges to water provision and threats to water quality. Drivers of these threats include poor water resource management, population growth, urbanization, droughts and floods that will be exacerbated by climate change and a lack of education about

REMA

The vertical drop between Lake Burera and Lake Ruhondo is used to generate hydro-power. Water is directed using this pipe. Eugene Apindi Ochieng

safe water consumption. Rwanda's Water Resources Master Plan cites the following main pressures on water quality:

- Municipal effluents and untreated sewage, easily degradable matter from some food processing factories and some industrial activities that reduce the amount of available oxygen in water;
- Nutrients released by degrading organic matter and sewage (nitrogen and phosphate) modify the aquatic chemistry and biology of standing water or where water has a high residence time;
- Mining has local impacts on water quality with the potential for heavy metals (lead, cadmium, zinc, copper) to accumulate in soils and enter the food chain, especially in floodplains used for agriculture and irrigation (RNRA, 2014b).

Pressures include water uses that affect water quantities. Industrial water users include the coffee industry that needs at least 30 m^3 to produce one tonne of fully washed coffee, bottled water and fruit processors, abattoirs, mineral processing, leather tanning and textiles, among others. The tourism industry exploits water outside protected areas, such as activities on lakes Muhazi and Kivu, with potential impacts on fish and aquatic biodiversity as well as water for human consumption (Muhinda Mbonigaba & Smiet, 2011). Increases in irrigation, tourism and recreation, hydropower developments and municipal services, among others, are already creating increased demands for water resources (REMA, 2010); (Hove, Parry, & Lujara, 2011). Modifications in catchments from afforestation, invasive alien plants, irrigation, over-abstraction and human settlements have led to declines in water quantities in natural runoff and groundwater (REMA, 2011b). Water availability is declining in the Nile basin and is expected to drop even further (UNEP, 2013) and climate change is already altering precipitation patterns, with as yet uncertain impacts on future water supplies.

Water use will continue to rise if Rwanda is to meet its Vision 2020 goals for economic development and increased irrigation and agricultural productivity. Another challenge is to balance Rwanda's own current and projected water use with that of neighbouring countries that rely on inflows from water resources in Rwanda and so are sensitive to any changes in its internal water use (Muhinda Mbonigaba & Smiet, 2011).

Water pollution

Rwanda's water resource are generally still of relatively good quality, with pH values between 6 and 7.5. Industrial and agricultural inputs are not yet significant polluters except locally (NSO, 2014). Increasing pollution from agro-inputs, including ammonia, nitrate, phosphate and pesticide residues (through leaching and erosion) is affecting groundwater locally and the ability of ecosystems to naturally purify water is a concern (MINIRENA, 2011); (RNRA, 2011). There are also localized problems from high sediment loads; toxic and acidifying materials, including heavy metals, from mining; and untreated domestic sources that cause micro-biological pollution and threaten human and ecosystem health (NBI, 2010).

The NWRMP concludes that the main water quality issues are as follows:

- High *e. coli* and coliform bacteria loads (and others that have not been measured) from untreated sewage;
- High organic loads, high biological oxygen demands (BOD) and chemical oxygen demands resulting in low concentrations of oxygen (mg/L); and
- Very high sediment loads and turbidity (RNRA, 2014a).

In addition to compromising water quality for ecosystems and their services, the impacts of untreated sewage and wastewater include the risks to humans of water-borne disease. Globally, an estimated 94 per cent of the diarrhoeal burden of disease is attributable to the environment, associated with risk factors such as unsafe drinking water and poor sanitation and hygiene (Prüss-Üstün & Corvalán, 2006). The use of water that is likely to be contaminated (such as unprotected spring water) increases the risk of contracting disease. According to Rwanda's 2010 DHS, the prevalence of diarrhoea is especially high

among children age 12-23 months and 6-11 months (25 per cent and 22 per cent, respectively) (NISR; MOH; ICF, 2012).

Regarding sediment as a form of pollution, heavy rains, unsustainable agricultural practices, deforestation and steep slopes contribute to erosion and the consequent siltation of water bodies. The waters of the Bugesera and Gisaka lakes in which the Akagera River traverses turn brown during rainy seasons due to heavy siltation (Rutaisire, 2011). Siltation in wetlands affects their ability to regulate water flow and filter physical and chemical pollutants (Kabalisa, 2012).

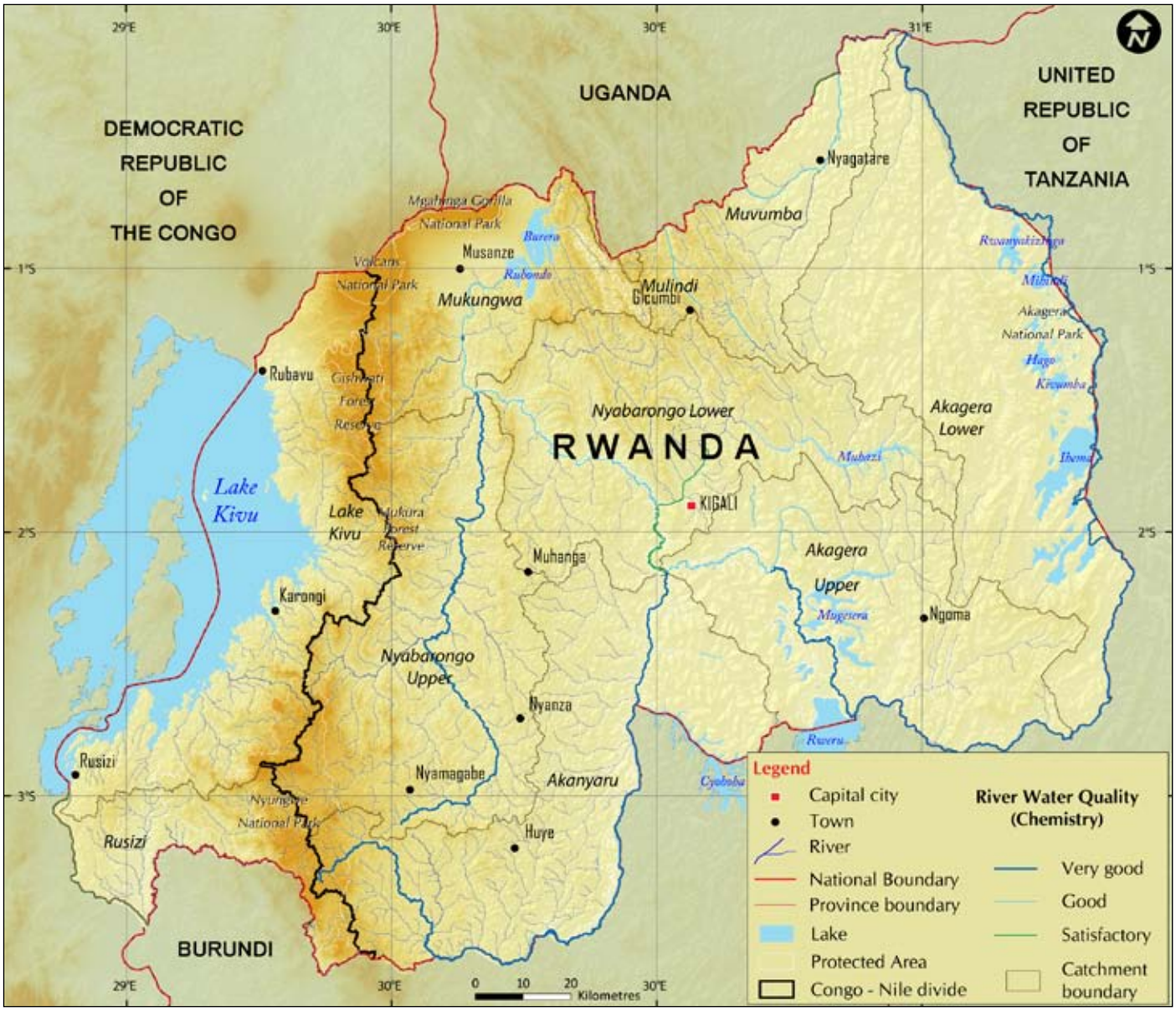
The NWRMP summarizes the areas that are most affected by declining water quality, noting that headwater qualities are typically good to very good but that water quality rapidly degrades in intensively used rivers and floodplains. Because of their large flow, and the capacity of large floodplains to purify water, larger river systems, such as the upper and lower Akagera, recover their water quality well. The areas with modified water quality are as follows:

- The Sebeya River has high sediment loads and high bacteria counts, probably due to degradation in its catchment area;
- The Nyabugogo River suffers from nutrient contamination, likely caused by intense farming in the floodplain and settlements in the immediate catchment area in combination with the river's relatively low base flow (RNRA, 2014a).

Figure 7 indicates river quality based on chemical pollution and measurements of pH, major ions and fluoride according to a scale from "strongly modified" to "very good" (RNRA, 2014a).

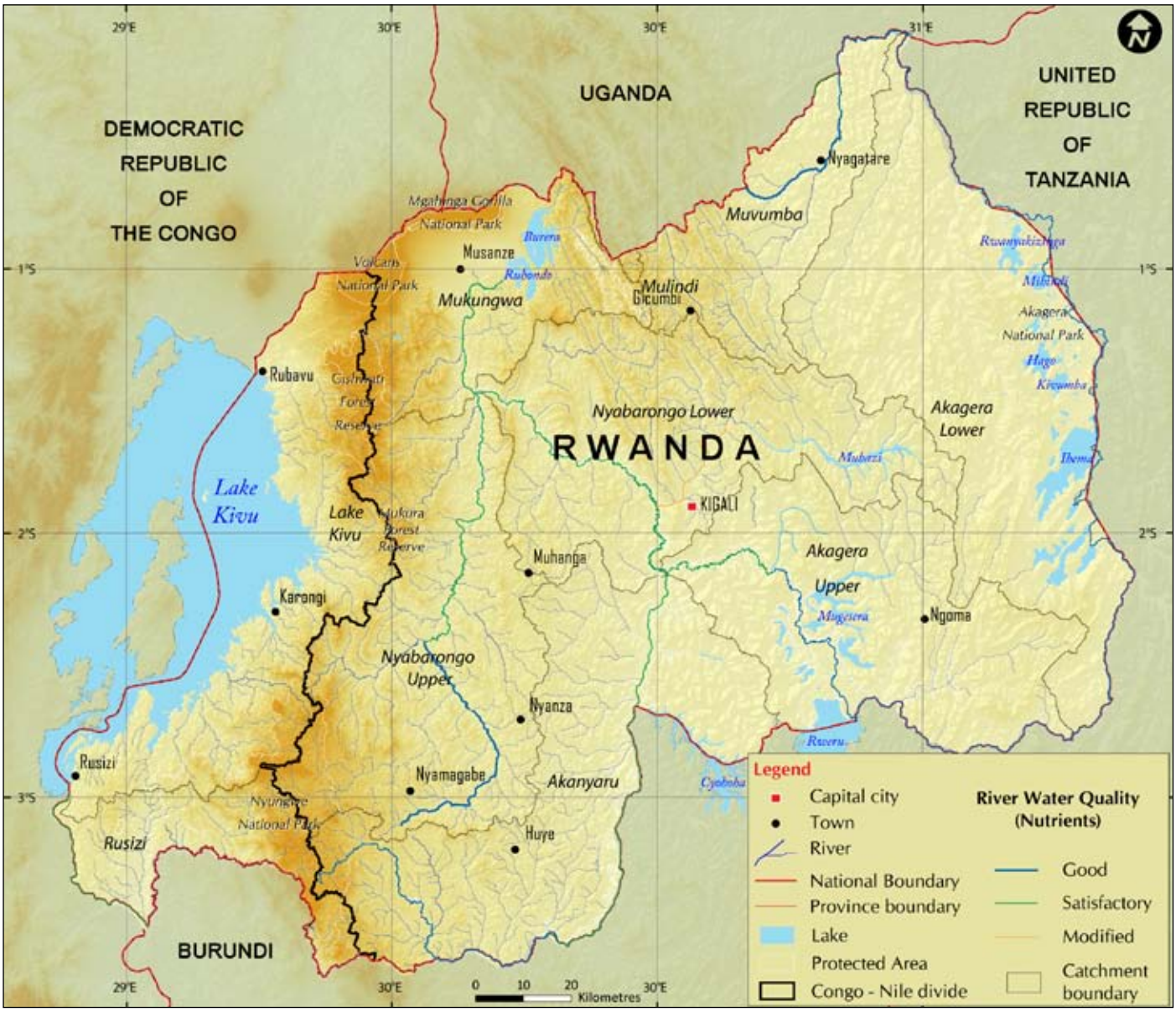
When used improperly, runoff from fertilizer applications can increase nutrient loads and affect water quality. REMA's report on the *Impact of Fertilizer Use in Rwanda*,

Figure 7: Chemical surface water quality situation in Rwanda (index of pH, major ions, fluoride)



(RNRA, 2014a)

Figure 8: Nutrient water quality situation in Rwanda (including nitrogen, phosphorus, COD, BOD)



(RNRA, 2014a)

specifically related to the Rweru-Mugesera Wetland Complex, notes that under the land consolidation programme, farmers based fertilizer applications on uniform rates and national recommendations for fertilizing different crops such as maize, wheat and rice. Ideally, however, it is best to establish the local soil's specific fertility needs and apply the right dose of fertilizer in consequence. Many farmers also preferred the ease of applying chemical fertilizers to the labour intensive use of organic ones and the associated best practices for cropping. The report concludes that "the impact on the aquatic systems is clearly linked to the increasing use of mineral fertilizers and decreasing use of organic manure and good conservation practices by farmers". It notes that the Rweru-Mugesera lakes-wetland complex suffers from pollution and habitat degradation due to the loss of soil fertility and runoff of mineral fertilizers through erosion and leaching (REMA, 2014). Figure 8 indicates river quality based on nutrient pollution and measurements of nitrogen, phosphorus, chemical oxygen demand (COD) and biological oxygen demand (BOD) (among others), according to a scale from "strongly modified" to "very good" (RNRA, 2014a).

Dams and impoundments

Hydro and irrigation dams and impoundments in Rwanda bring enormous socioeconomic benefits. They also have important deleterious effects on ecosystem services and on local inhabitants. On the other hand, with proper Environmental Impact Assessments, the potential impacts can be mediated by planning sustainable watershed management — or the project can be cancelled or modified if the trade-offs are too great.

Box 1 illustrates the potential positive and negative impacts of dams constructed for irrigation purposes.

Box 1: Potential impacts of dams in Rwanda

Positive:

- Physical impacts: catchment rehabilitation and management, flood control, water resources conservation, improved soil conservation;
- Ecological impacts: revegetation, environmental protection, birdlife and fish habitat;
- Socioeconomic impacts: increased farm incomes from crop output, food security, poverty alleviation, rural employment, market creation, appreciation of the value of land, capacity building of farmers;
- Impacts on local and national production and the economy: increased exploitable area and productivity, crop diversification, employment generation and poverty alleviation, livestock development, multiplier effects, increased public revenues, contribution to national crop production and the national economy, provision of fuel wood.

Adverse:

- Physical impacts: soil erosion, topsoil stock piles, destruction of water points, borrow pit impacts, reduced water flow/downstream flooding, water wastage, changes in hydrology, surface water resource pollution, sub-surface water contamination, concern about water overflows during heavy rains, internal seepage control measures, land-use change, canal siltation, seepage and leakage;
- Biological environment: destruction of hillside biodiversity, water weeds;
- Social environment: resource-use conflict, population migration, increased spread of water-borne diseases, drowning of livestock and children, dam safety impacts, emergence of pests and crop diseases.

Source: adapted from (MINAGRI, 2013)

4.3 Response

Vision 2020 and 2050

Vision 2020's water-related goal is to continue investing in protecting and efficiently managing water resources, as well as water infrastructure development to ensure that by 2020 all Rwandans have access to clean water. Box 2 shows the Vision of Water Resource Management in 2050 (SSEE, 2011).

Although Rwanda only uses 2 per cent of its renewable freshwater, demand is on the rise and the government aims to increase access to water and its use by various

Vegetated lakeshore buffer, Lake Ruhondo islands REMA

Box 2: Establishing Rwanda's Water Resource Management Vision 2050

- Water security for a 2050 Rwanda achieved across the country
- Riparian rights framework
- Supply charges and taxes contribute to watershed management, and infrastructure
- Energy derived from viable rivers at micro and pico scales
- Secure catchments and water storage facilities
- Innovation in community water engineering and agriculture for integrated irrigation supporting climate and carbon smart agriculture
- Efficient irrigation
- Minimum environmental flow, for conservation of wetlands and biodiversity
- Micro drip and spray technology introduced to high quality/high profit agriculture
- Potable water available everywhere
- Domestic rainwater harvesting
- Water treatment and recycling in industry and commerce
- Recycled waste water utilized for agriculture, recreation and public gardens
- Recycled water for consumption in cities
- Groundwater treatment for safe use
- Integrated water distribution network eliminating physical or vehicle transport
- Rwanda a responsible user of water and contributor to regional basins, a leader in best WRM practice and innovation in water re-use technologies
- National water databases are authoritative, up to date, and available for use by all key stakeholders for WRM
- Advanced Weather Forecasting and Climate Observatory, provides decision support to guide sustainable water management nationally and regionally
- Flood Resilient Settlements and Infrastructure
- Innovation in water conservation, shared experiences from downstream partner States
- Improved management of water resources through better monitoring and integrated analysis of water use

Source: (SSEE, 2011)

economic sectors. For example, the goal is to increase access to safe water to 100 per cent by 2017, which implies 0.5 million new people connected every year. In addition, there are plans to develop at least 330 hydro sites of varying sizes and at least 2 geothermal sites. The greatest use will be for irrigation, with EDPRS goals to increase irrigated areas from 24,000 ha in 2012 to 100,000 ha in 2018 (RoR, 2013). In all, 25 billion m^3 of water will be required annually (Muhinda Mbonigaba & Smiet, 2011).

The NWRMP sets forth some recommendations for increasing irrigation in a sustainable way that will improve agricultural productivity, increase hydropower, help to decrease poverty, and at the same time, ensure the continued integrity of ecosystem goods and services. For example, it calls for increasing water storage and efficient water use, especially for irrigation, domestic water use and hydropower development. This can be achieved by mobilizing financial resources and investments. As well, water information sharing between water institutions and the extension of water monitoring throughout the country and especially in the Eastern Province are needed (RNRA, 2014c).

Access to drinking water and sanitation

Rwanda's commitments to Vision 2020, the EDPRS as well as to the Millennium Development Goals have resulted in good progress in extending water supply and sanitation coverage over the past decade (AMCOW, 2011). This will help to address the pressures related to water pollution, especially where urban runoff drains into wetlands, and it will also help to reduce the incidence of water-borne disease. The MDG targets for drinking water and sanitation have already been achieved (Table 6).

Integrated Water Resources Management (IWRM)

As a response to the water quality and quantity issues described above, Rwanda is establishing an effective water resources governance framework (Muhinda Mbonigaba & Smiet, 2011). It has instituted a number of laws, policies and other arrangements to oversee water management and foster sustainable and resource efficient measures. For example, the Water Law of 2008 prescribed the creation of a National Water Authority and in 2011, the GoR formulated the Water Policy using an Integrated Water Resources Management

Table 6: Rwanda's progress towards the MDG goal 7C related to drinking water and sanitation

MDG target	Baseline 2000	EICV 2 2005/6	EICV 3 2010/11	EICV 4 2013/14	2015 target	Target status
Target 7c: Halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation						
7.8: Proportion of population using an improved drinking water source (%)	64.1	70.3	74.2	84.8	82	Already exceeded
7.9: Proportion of population using an improved sanitation facility (%)	51.5	58.5	75	83.4	74.5	Already exceeded

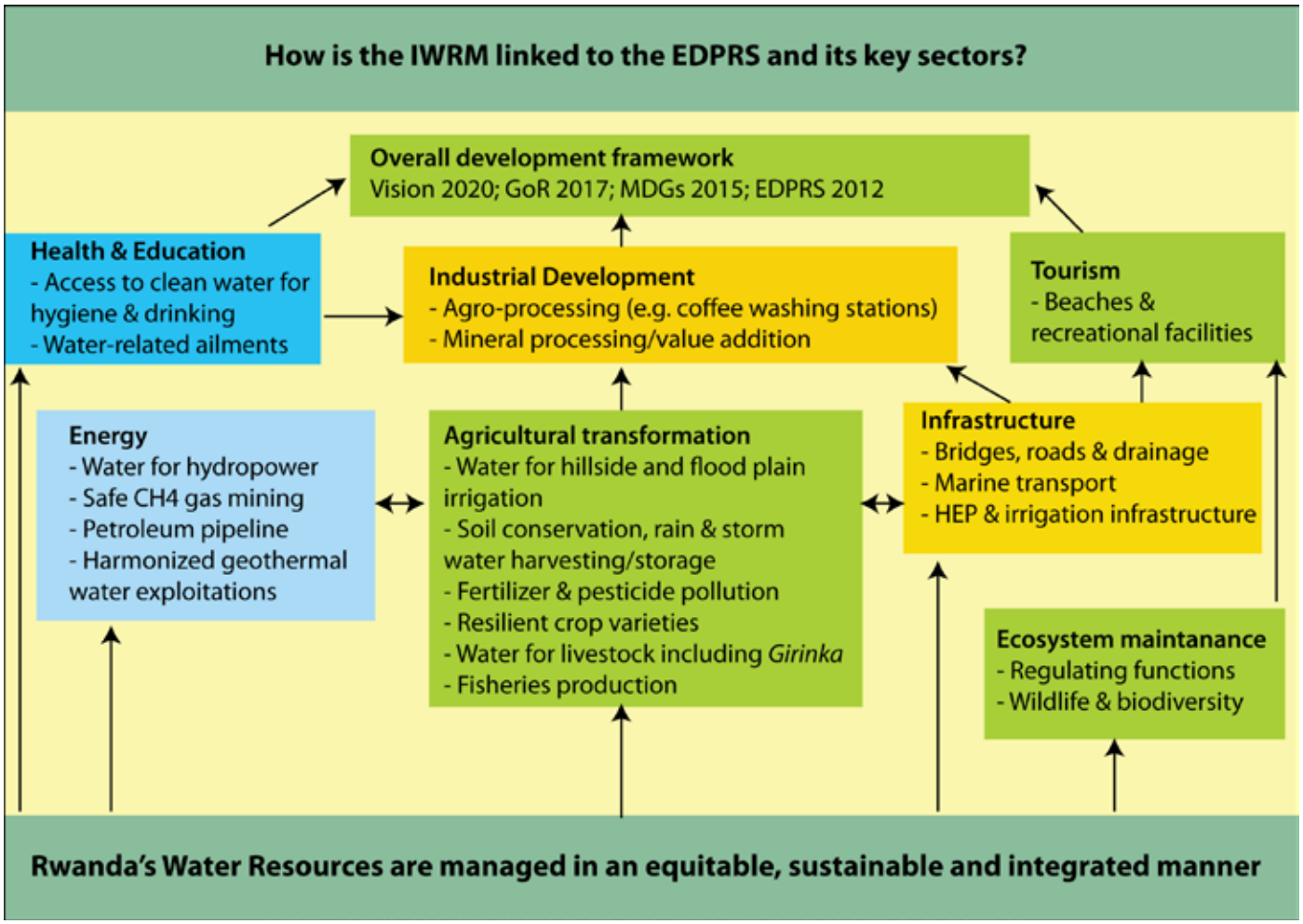
Source: (UNDP, 2014) and NISR data

(IWRM) approach (SSEE, 2011); (MINIRENA, 2011). The Global Water Partnership defines IWRM as a process that "promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP, 2010).

IWRM is an important target for the EDPRS. Figure 9 shows how water is integral to many economic and social sectors, thus requiring an integrated approach to water management responding to Rwanda's high-level visions and strategies.

The IWRM Policy as described by the Ministry of Natural Resources has three main objectives: 1) to protect, conserve, manage and develop Rwanda's water resources in an integrated and sustainable manner; 2) to ensure that water resources are available in adequate quantity and quality for socioeconomic and ecological needs of present and future generations; and 3) to ensure that decisions affecting water resources management are made in a coordinated manner and with the participation of all stakeholders at local, national and trans-boundary levels (MINIRENA, 2011).

Figure 9: Integrated water management aligns with Vision 2020 and the EDPRS



Source: (Muhinda Mbonigaba & Smiet, 2011)

Table 7: Key climate change adaptation measures for IWRM

Possible adaptation measures	IWRM function	Anticipated effect
Water pricing, cost recovery, investment	Economic/financial management	Reduced per capita consumption Improved efficiency
Seasonal water rationing, re-allocation, managing water use	Water allocation Pollution control	Availability and access improved Uninterupted flow Purification function secured
Flood and drought risk mapping, infrastructure, scenario development	Basin planning	Reduced impact of extreme events
Increase capture and storage of surface runoff	Basin planning	Improved availability Reduced polluters in the system
Reuse and recycle, better regulation, pressure for improvised sanitation	Pollution control Water allocation Basin planning	Improved availability Reduced groundwater pollution
Ground water usage	Water allocation Basin planning	Improved availability
Rainwater harvesting, warning systems	Water allocation Stakeholder participation	Improved availability Reduced drainage damage
Improving drainage systems and water treatment	Pollution control Basin planning	Reduced pollution Improved availability and recovery
Better monitoring	Information management Monitoring	Improved action responding to real needs

Source: (SSEE, 2011)

The Organic Law N° 04/2005 determining the modalities of protection, conservation and promotion of the environment also protects water resources. To protect wetlands, it requires that all planned activity in wetlands be subject to an Environmental Impact Assessment (EIA) (REMA, 2011a). In fact, EIAs are required for any proposed project or activity with a potential impact on water in all the country's main hydrographic basins (MINIRENA, 2013a). It prohibits the construction of buildings and sewage plants and the dumping of untreated wastewater and hazardous waste (REMA, 2011a). In addition to EIAs, Strategic Environmental Assessments (SEA) are now increasingly used to evaluate the potential environmental impacts of proposed policies, plans and strategies that affect wetlands (REMA, 2011a).

Climate-change adaptation

Since rainfall and evapotranspiration affect water availability and quality, adaptation to climate change should be incorporated into IWRM at all levels (Table 7). Rwanda considers IWRM a key approach to climate change adaptation and building resilience to future water insecurity (SSEE, 2011). Indeed, as stated by REMA, Rwanda is incrementally implementing IWRM "to strike a sustainable balance between abstraction and regeneration levels and to vigorously respond to the impacts of climate change that threaten to jeopardize Rwandans' access to water" (REMA, 2011a).

Strategies to attain Rwanda's water-related vision and targets emphasize rainwater harvesting as an essential resource-efficient, low carbon and climate resilient practice (see Table 7 and Box 2). Rwanda is promoting and fostering the implementation of RWH, especially in arid and semi-arid areas (Box 3).

Conclusion

Rwanda is endowed with abundant water resources, but their uneven distribution over the country's area and throughout the year, coupled with as yet inadequate water management, has resulted in per capita water stress. Nevertheless, the country uses only about two per cent of its renewable freshwater. Thus, there is room for further and accelerated water

Box 3: Rainwater harvesting in Rwanda

Rainwater harvesting (RWH) is one of the key IWRM methods to address flooding, drought and erosion and improve agricultural livelihoods in Rwanda. It is "a method of collecting surface runoff from a catchment area and storing it in surface reservoirs, or in the root zone of a defined area" (Benimana, Wali, Nhapi, Anyemedu, & Gumindoga, 2015).

Research conducted in 2012 in Kirehe District that compared households with the same essential characteristics found that those with rainwater harvesting ponds had higher incomes than those without ponds (Ariane & Guthiga, 2012). Another study in the arid District of Bugesera in the Eastern Province, where climatic risks include both dryness in hilly areas and floods in marshes, assessed the potential for rainwater harvesting to improve agricultural production. It estimated that collected runoff (leaving a third for ecosystem benefits) had the potential to produce between 400 x 103 and 530 x 103 tonnes of paddy rice or between 1,390 x 103 and 1,620 x 103 tonnes of maize annually, which would significantly improve food security and livelihoods (Benimana, Wali, Nhapi, Anyemedu, & Gumindoga, 2015).

As early as 2007, Rwanda's National Food security Strategy promoted RWH to mitigate the impacts of erratic rainfall and help raise agricultural productivity in the country's arid and semi-arid areas (Ariane & Guthiga, 2012). EDPRS II promotes RWH technologies and ways to encourage their use among farmers through participatory and cost-sharing mechanisms that allow them to access special credit facilities, partial subsidies and revolving funds to pay for the technologies (MINIRENA, 2013b). A key target of the Water Resources Management Sub-Sector Strategic Plan (2011–2015) is that all institutions and at least half of all households have RWH facilities (MINIRENA, 2011).

Suggested RWH interventions and targets under the Environment and Natural Resources (ENR) Sector are to triple the total storage capacity of constructed structures, which would save Rwanda an estimated RWF 519,000,000 every year that would otherwise be spent on other ways of supplying water, while also providing environmental benefits (MINIRENA, 2013b).

In recent years, the Ministry of Natural Resources (MINIRENA) and its partners have developed RWH through a number of activities, including a demonstration and capacity building pilot project, training 960 local technicians on RWH techniques, building 408 tanks for both households and public institutions and constructing 28 ponds for agricultural use. A National RWH strategy was also developed and there is an ongoing National RWH Programme to upscale and sustain the pilot phase's achievements. Finally, MINIRENA initiated the rainwater harvesting loan scheme, a new Public Private Partnership, to help local communities obtain financial support for RWH systems; projects are being implemented in Rubavu, Nyabihu, Musanze and Kigali City Districts (MINIRENA, 2013c).

resources development to provide the Rwandan population with adequate improved water supplies and sanitation, to increase the sustainable use of water for irrigation to boost agricultural output, and to supply water for new developments, businesses and industrial opportunities to further green the Rwandan economy. The GoR's vision, targets and strategies are all aligned towards this goal, focusing especially on IWRM. In addition to strategies to collect and store water to address water quantity issues, action plans include addressing water quality and the causes and impacts of pollution. For example, wetlands are increasingly protected from agricultural incursions and the impacts of runoff from fertilizers, untreated sewage, and domestic and industrial wastewater. The resource efficient, low carbon and climate resilient agricultural practices highlighted in Chapter 9 are also oriented to conserving water, especially in light of the impacts of climate change on rain-fed agriculture in Rwanda.

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Chapter 5: Urban Areas

5.1 Status and trends

Urban population and urbanization rates

In 2014, 54 per cent of the world's population lived in urban areas; by 2050, the proportion is expected to rise to 66 per cent. Africa is urbanizing faster than most other regions in the world; the proportion of the population living in Africa's cities is expected to increase from 40 per cent

in 2014 to 56 per cent by 2050 (UNDESA, 2014a) (Figure 1).

The development of cities in Rwanda is very recent, but its current annual urban growth rate of 4.5 per cent far exceeds the worldwide average of 1.8 per cent (MININFRA, 2011). Figure 1 illustrates its late urban growth and its rapid rise starting in the mid-1990s, measured as the percentage of its population living in urban areas.

Migration patterns

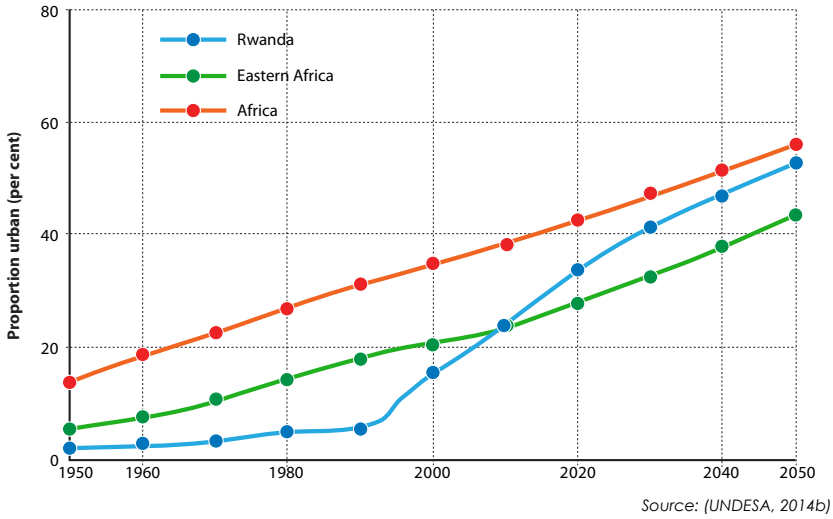
Rwanda is experiencing considerable internal migration, both within and between provinces, and from rural to urban areas. Although it is often assumed that most migration is from rural to urban areas, rural-rural, urban-rural and urban-urban migration flows are also important. In the last five years, the proportion of the migrant population moving to Kigali increased from 19 to 27 per cent; most migrants relocate looking for work (MININFRA, 2011). Most western districts show negative migration patterns and eastern ones show positive trends (GGGI, 2015a).

Urban versus rural population growth

Projections predict continued exponential urban growth to an urban population of about 4.5 million by 2020 from the current 1.5 million. Figure 2 shows the trend in the total numbers of urban and rural populations and Figure 3 presents the trend in the proportion of people living in urban versus rural areas; both extend the trend to 2050. Figure 3 illustrates the simultaneous dramatic rise in urban growth and decline in the percentage of Rwandans living in rural areas (MININFRA, 2011).

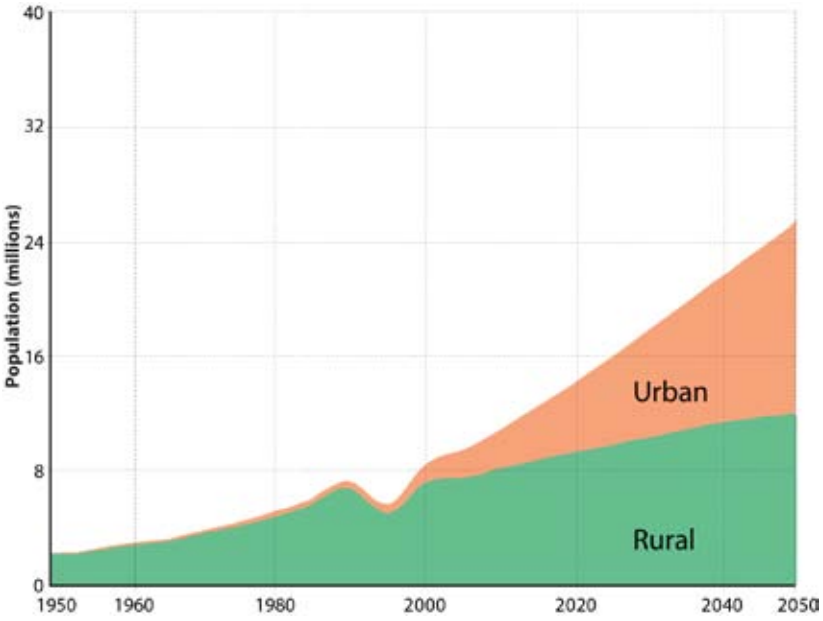
With 415 inhabitants/km^2 (2012), Rwanda's population density is the highest in Africa (NISR, 2014). Figure 6 in Chapter 1 (Geographical and Socioeconomic Context) shows the distribution and concentration of people in cities from 1990 to 2015, illustrating the concentration of people in Kigali, where almost half of the nation's urban population resides.

Figure 1: Urban population growth (percentage) in Rwanda compared to Eastern Africa and Africa in general, 1950 to 2013, with projections to 2050



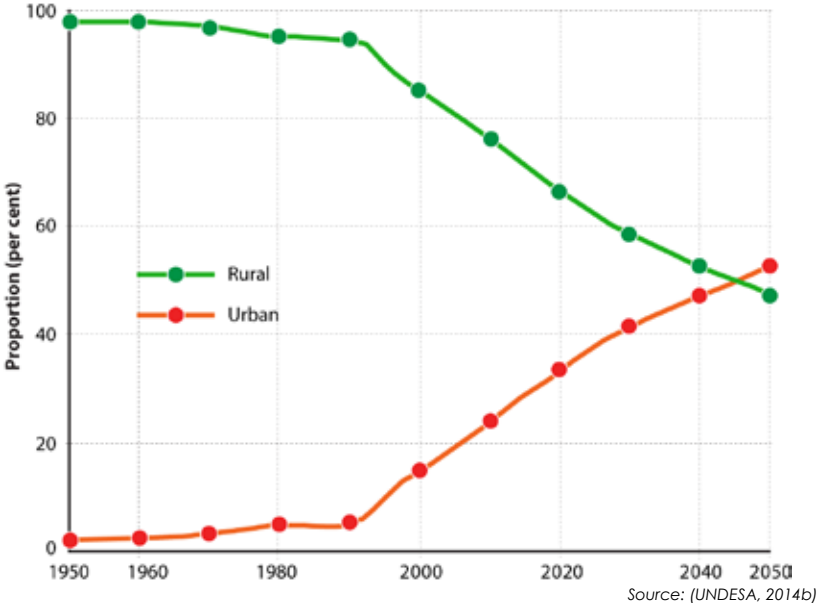
Source: (UNDESA, 2014b)

Figure 2: Trend in total population numbers in urban and rural areas, 1950 to 2013, with projections to 2050



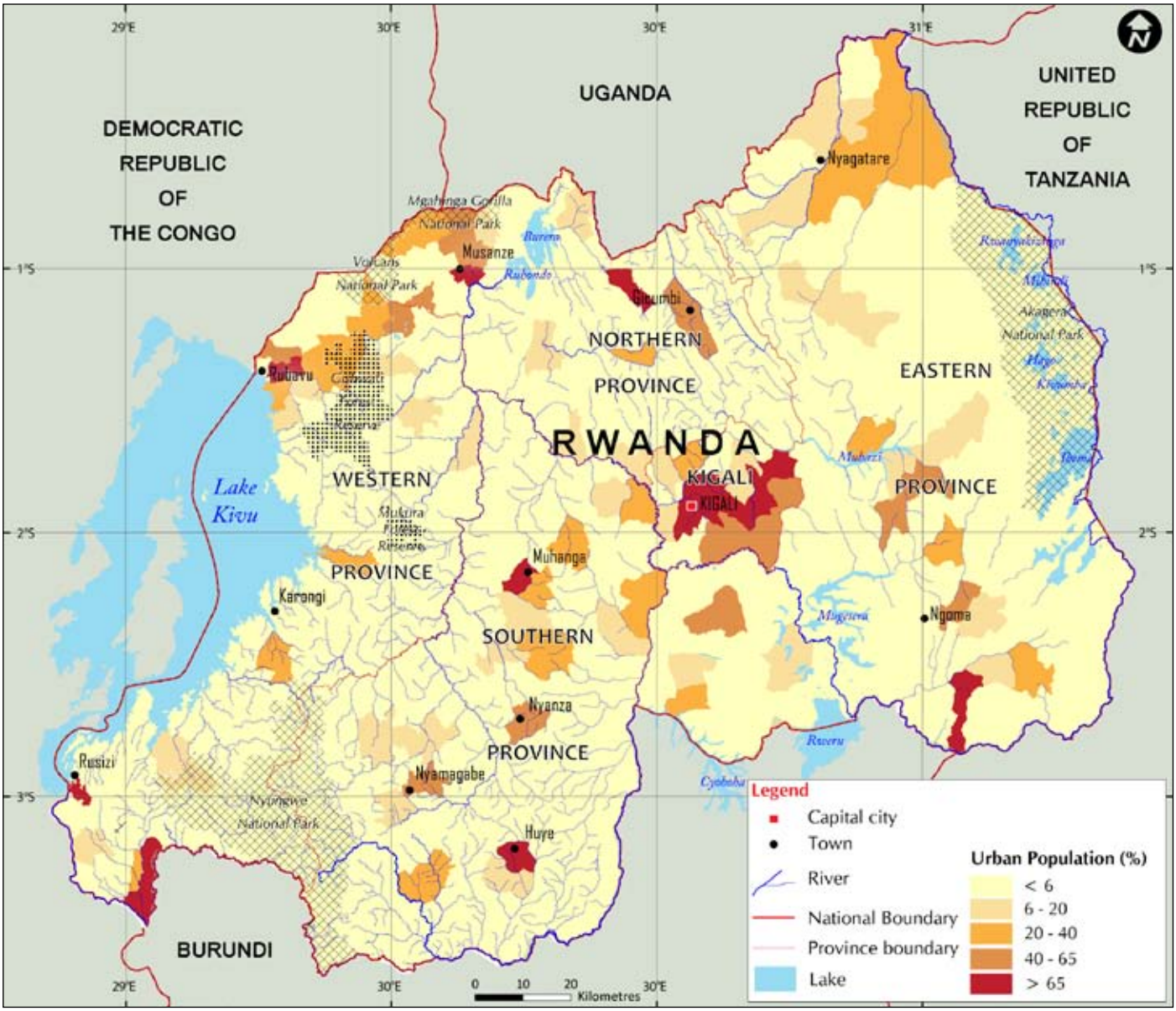
Source: (UNDESA, 2014b)

Figure 3: Trend in the proportion of Rwanda's urban and rural populations, 1950 to 2013, with projections to 2050



Source: (UNDESA, 2014b)

Figure 4: Urban population of Rwanda



Source: (NISR, 2012a)

Distribution of the urban population

There are 30 districts in Rwanda, each with an administrative centre with the same name as the district. Excluding the three districts that make up the City of Kigali, all have rural populations in the range of 150-400,000 but only 23 out of the 30 have urban populations greater than 10,000. Ten districts have urban populations of over 20,000. Figure 4 illustrates Rwanda's population distribution by district. It shows the predominance of the three districts forming the city of Kigali in terms of urban population. The population of Rubavu, Rwanda's second-largest city, is under a fifth of Kigali's population size (NISR, 2012a).

Currently, secondary cities represent about 25 per cent of the country's urban population. They sit within districts that have a much larger rural populations and are still mainly dependent on farming to provide livelihoods and support the local economy. The largest of the secondary cities, Rubavu, contains about 36 per cent of the district's population; Musanze houses nearly 28 per cent of its district's population. Nyagatare city has just 10 per cent of Nyagatare District's population, while Huye, Muhanga and Rusizi each have around 16 per cent of the population of their districts. By contrast, the three districts that make up the City of Kigali represent nearly 76 per cent of the country's urban area (GGGI, 2015a).

Although opportunities in Rwanda's secondary cities are attracting people from other areas, only Nyagatare and Rubavu Districts currently have population growth rates higher than the national average. Population density, however, is higher than the national average in all of the six cities, with the exception of Nyagatare (GGGI, 2014).

The National Land Use and Development Master Plan (NLUMP), which provides national guidelines for the better use and management of land in Rwanda as well as guidelines to develop detailed District Land Use Plans (DLUP), notes there are three approaches to defining an urban area, namely in terms of the following:

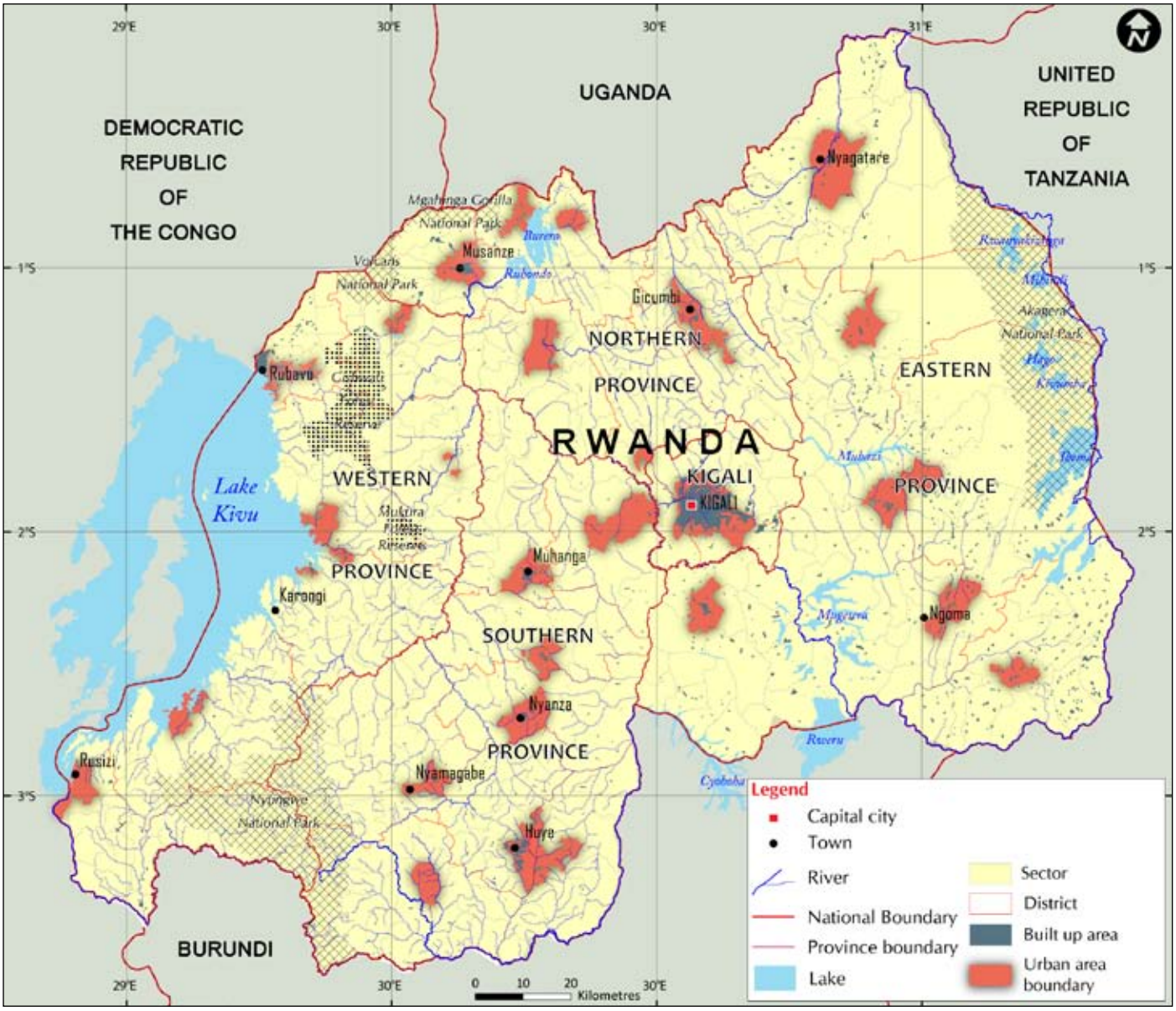
- The built-up area;
- The functional area, which comprises all areas for which public services and facilities are provided; and
- Density (population density or built-up area).

The NLUMP proposes the following definition of an urban area: a built-up agglomeration with an area of more than 20 km^2, and a population of more than 10,000 permanent residents, which results in a population density higher than 500 inhabitants/ km^2. The plan demarcates 33 District Centers Urban Development Areas, including consolidated urban areas and land reserved for future development (MININFRA, 2011). Figure 5, from the NLUMP, shows urban area boundaries in red.

Access to infrastructure services

Currently, access to infrastructure services is usually high in Kigali and low in rural areas. Ninety per cent of urban households have access to an improved water source, compared with 83.7 per cent of households in rural areas (NISR, 2015). In 2013/14, 60.5 per cent of households in urban areas were within 200m of an improved drinking water source compared to 19.4 per cent in rural areas; 78.3 per cent and 47,3 per cent, respectively, were within 500m of such a source (NISR, 2015a). Between 2005/6 and 2013/14, the percentage of urban households with access to improved sanitation increased from 74.9 to 93.5 per cent (NISR 2015b).

Figure 5: Directives for sustainable land use planning, 2010-2020



Source: (MININFRA, 2011)

Vegetation around a lake. REMA

According to EICV 4, 71.8 per cent of urban households have electricity compared with 9.1 per cent of rural households, but the service is improving gradually, especially in Kigali. Nationally, 15.2 per cent of households use charcoal while 83.3 per cent use firewood as the main cooking fuel. The use of crop waste is only 0.8 per cent (NISR, 2015a).

Green spaces

Green urban spaces, meaning city parks, tree-lined streets and other vegetated areas within built-up areas, have a significant potential to improve the quality of life of city and town dwellers. Benefits range from improved air quality, lower noise levels, aesthetic qualities and economic gain. They also improve human well-being by facilitating social interaction, providing space for recreational activity and peaceful retreat as well as habitat for local wildlife. Green spaces also help to offset the urban heat island effect, among others. Research on amenity trees and green space structure in Kigali published in 2014 estimates that tree cover averages from 10 to 35 per cent of the city and that alien species dominate the plant assemblages in the city's network of green spaces. The dominant types of green spaces are cultivated forests, urban woodlots and tree stands in domestic gardens (Seburanga, Kaplin, Zhang, & Gatesirea, 2014).

5.2 Pressures and impacts

Solid waste generation

Prior to 2010, there was no national policy or harmonized regulatory framework addressing solid waste management; households, communities, NGOs, the private sector, community associations and district authorities performed this service with limited technical and financial means. Kigali and other towns, however, have made considerable efforts to maintain a clean urban environment (MININFRA, 2010).

In 2010, 70 per cent of Kigali's waste was still organic, biodegradable matter and waste sorting, composting and recycling activities were still in the early stages of introduction. The absence of plastic bags in the household waste stream has helped with landfill management, although the country's landfills are not yet environmentally sound (MININFRA, 2010). EICV 3 reports that municipal solid waste collection services in urban areas had improved substantially in only five years, with 30 per cent of houses served compared to 23 per cent during EICV 2 (NISR, 2012b).

Sewage, waste-water and storm-water systems

The country has not yet invested in collective urban waste-water and sanitation systems, except for three small sewerage systems in Kigali that serve about 700 households. Major hotels, hospitals, new real estate developments and some industries have installed their own treatment systems. A conventional sewerage and treatment system for Kigali is in the planning process (MININFRA, 2010).

In most urban areas, the storm-water drainage systems, which limit flooding during heavy rainfall events, are inadequate since they haven't kept pace with the growing population. Local results have been erosion of unstable land, increased flooding and threats to private and public infrastructure. Combined with poor liquid and solid waste collection in urban settlements,

Hotspot: Nyabugogo transport hub

The Nyabugogo wetland occupies parts of Nyarugenge and Gasabo Districts in Kigali. It is fed by the entire Nyabugogo catchment. The wetland receives untreated sewage; runoff from urban streets; wastewater from houses, schools, markets and other urban structures; and wastewater, hazardous oils and heavy metals from car-washing areas and garages within the city. Domestic sewage, wastewater containing detergents, wastes from a slaughterhouse and fertilizer runoff is discharged into the wetland on a regular basis. Flower farming, a sugar-cane plantation, legume and rice cultivation, a textile factory and quarrying and mining activities further afield within the catchment also release effluent that makes its way into the wetland (CST, 2014).

These effluents have polluted the wetland waters. An assessment of groundwater quality in the Nyabugogo wetland to determine its suitability as a supply for domestic drinking water and irrigation activities found that the water was acceptable for irrigation, but average values of some physical parameters, such as turbidity, exceed recommended drinking water standards and that the average of total phosphorus values ranges from 1.08 ± 0.70 at the Nyabugogo where it leaves Muhazi lake, to 10.73 ± 5.36 at Nyabugogo before entering Nyabarongo River (CST, 2014). In addition, regular flooding occurs along the Nyabugogo flood plain causing major disruption to traffic circulation on the adjacent roads and inundating properties in this market area (RNRA, 2014).

Nyabugogo transport hub at night #Rwandaphotos / Flickr / CC BY 2.0

This Google image shows part of the Nyabugogo Valley and wetlands surrounded by dense settlements in all directions including a taxi/bus park and commercial developments to the south and southeast.

runoff also carries pollutants such as hydrocarbons, heavy metals, bacteria, sediment, pesticides and fertilizers into streams or groundwater, threatening environmental and human health (MININFRA, 2010).

Roads and traffic

Rwanda is becoming a more car dependent society. The number of cars is increasing rapidly along with vehicle-kilometres travelled. Serious traffic congestion is still confined to rush hour and is very localized, but it is expected that it will become much more widespread, with up to a four-fold increase on heavily congested roads by 2020 (RNRA, 2013).

Air pollution

Air pollution is a growing problem in Rwanda's urban areas. The major emission sources are the transport sector; manufacturing industries such as cement, and steel mills; quarrying activities that contribute dust to the air; domestic cooking; soil-blown dust: and waste combustion. Transportation is one of the largest sources of air pollution, especially in Kigali City. The combustion of fossil fuels to power vehicles and engines — cars, trucks, buses, motorbikes, aircraft and water craft — has major adverse impacts on the environment and human health (RNRA, 2013), with implications for climate change due to the release of CO_2 and for respiratory ailments from the inhalation of small particulates.

A 2011 study of air pollution in Rwanda, and of Kigali City in particular, focused on emissions from vehicles. The drivers of rising emissions include high levels of in-migration to Kigali City, unplanned urban development, increased consumption patterns and a rise in urban infrastructure. The main pressures that lead to higher emissions include the following: rising vehicle density in urban centers; a predominance of older vehicles; inadequate inspection and vehicle maintenance facilities; adulterated fuel and fuel products; lack of proper traffic management systems; poor road conditions; and the lack of effective mass rapid transport systems and intra-city railway networks (Nsengimana, Bizimana, & Sezirahiga, 2011).

The study found that levels of suspended particulate matter in Kigali City exceeded WHO recommendations, especially during the dry season. Ground-level ozone levels were also higher than the normal standard. Sulphur dioxide emissions are generally low by East African standards but rise above recommended limits during the dry season. Nitrogen oxide and lead levels were below acceptable limits. Compared to most cities in the world, air quality in Kigali was therefore deemed to be favourable, but increases in traffic density and industrial activities will require more stringent traffic management, public transport options, vehicle inspections and other responses (Nsengimana, Bizimana, & Sezirahiga, 2011). To date, Kigali already has a modern vehicle testing centre and other towns in Rwanda are beginning to have access to inspection and maintenance facilities (UNEP, 2014); (RNP, 2014).

5.3 Response

The Rwandan government is addressing the fact that as the population grows, the amount of productive agricultural land per capita will reduce and people will be forced off the land into urban areas in search of employment opportunities. Unplanned urban growth carries the risk of urban slums developing and creating associated health and social problems. On the other hand, if properly managed for sustainability and coupled with industry and services, urbanization can be an instrument to create wealth and green the economy. The GoR thus determined the necessity for proper management to foster higher density and resource-efficient settlements (RoR, 2011).

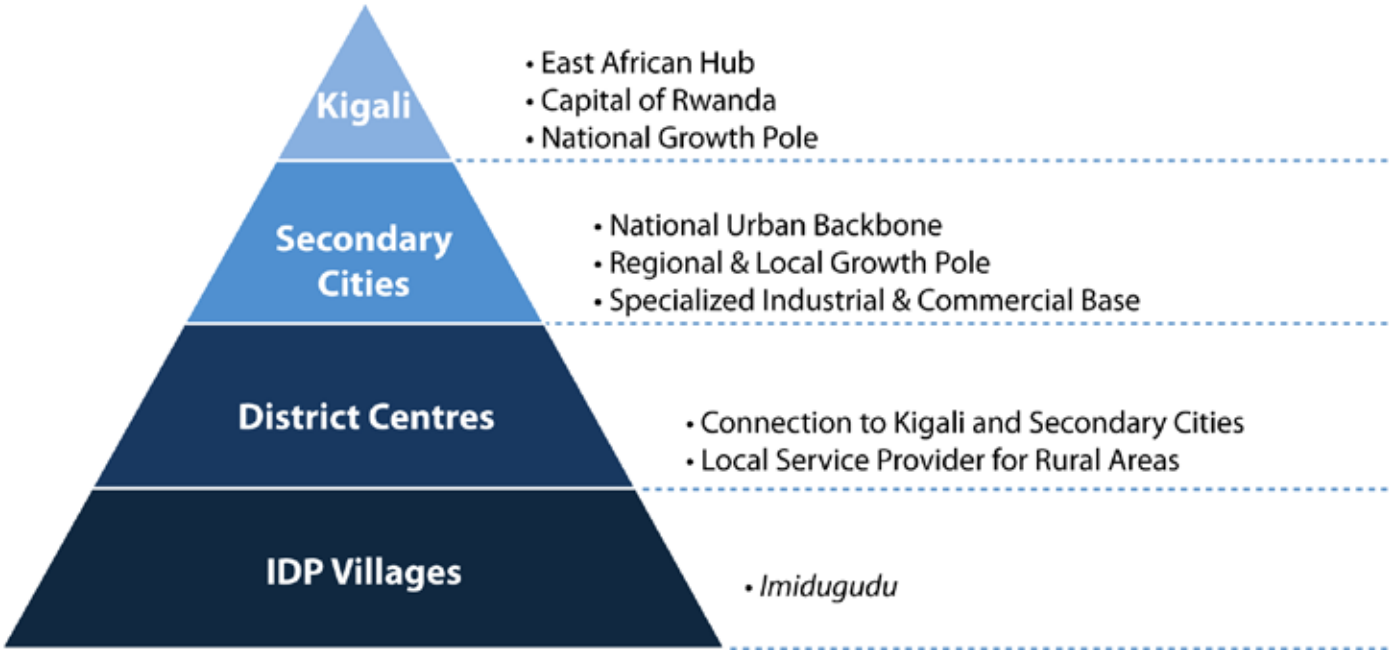
Vision 2020 and EDPRS

In the early 2000s, urban policies focused on beautifying and greening the urban landscape, providing security, removing waste, constructing and paving roads, installing street lighting, constructing drainage channels and developing modern housing (MININFRA, 2008).

Vision 2020 and the EDPRS stressed the importance of adequate water supply and sanitation services as drivers for social and economic development, poverty reduction and public health. Vision 2020 also called for each town to have a regularly updated urban master plan that included developing basic infrastructure. It also stipulated that Rwanda pursue a harmonious policy of grouped settlements based on economic activity (RoR, 2012).

By the late 2000s, the emphasis in urban planning was on developing major downtown commercial areas and on deconstruction and redevelopment of historical properties in secondary cities (MININFRA, 2008). To leverage urbanization as a key factor in the nation's economic transformation, Vision 2020 fixed a target urbanization rate of 35 per cent by 2020. This would require a growth rate above 15 per cent in all cities and emerging cities, including Kigali.

Figure 6: Conceptual hierarchy of the national human settlement network



Source: (MININFRA, 2013)

Urban and rural strategic plan, 2013-2018

To implement the EDPRS II and support emerging cities in attracting economic activities while mitigating over-concentration in Kigali City, the Urbanization and Rural Settlement Sector Strategic plan for 2013 to 2018 (MININFRA, 2013) promotes a harmonized hierarchical network of urban and rural centres (Figure 6) and guides municipal governments in using different spatial and economic policies and plans to better allocate limited national resources into urban infrastructure.

Secondary cities

Kigali already faces inadequate housing supply and there is a basic infrastructure backlog. It cannot continue to absorb a high level of rural in-migration. To encourage urban and economic growth in the country's other regions, priority 4 under the theme for economic transformation of the EDPRS II (2013-2018) called for developing six secondary cities as poles of growth. These are Huye, Muhanga, Musanze, Nyagatare, Rubavu and Rusizi (RoR, 2013).

The GoR recognizes that planning future urban development is critical in its goal to achieve low carbon growth. Once an urban form has been defined and infrastructure built, retrofitting to introduce resource efficiency and low carbon elements is complicated and costly. Thus, Rwanda has a unique opportunity to envision, plan and implement green cities and its Land Use and Development Master Plan reflects this goal (Jeong, 2014).

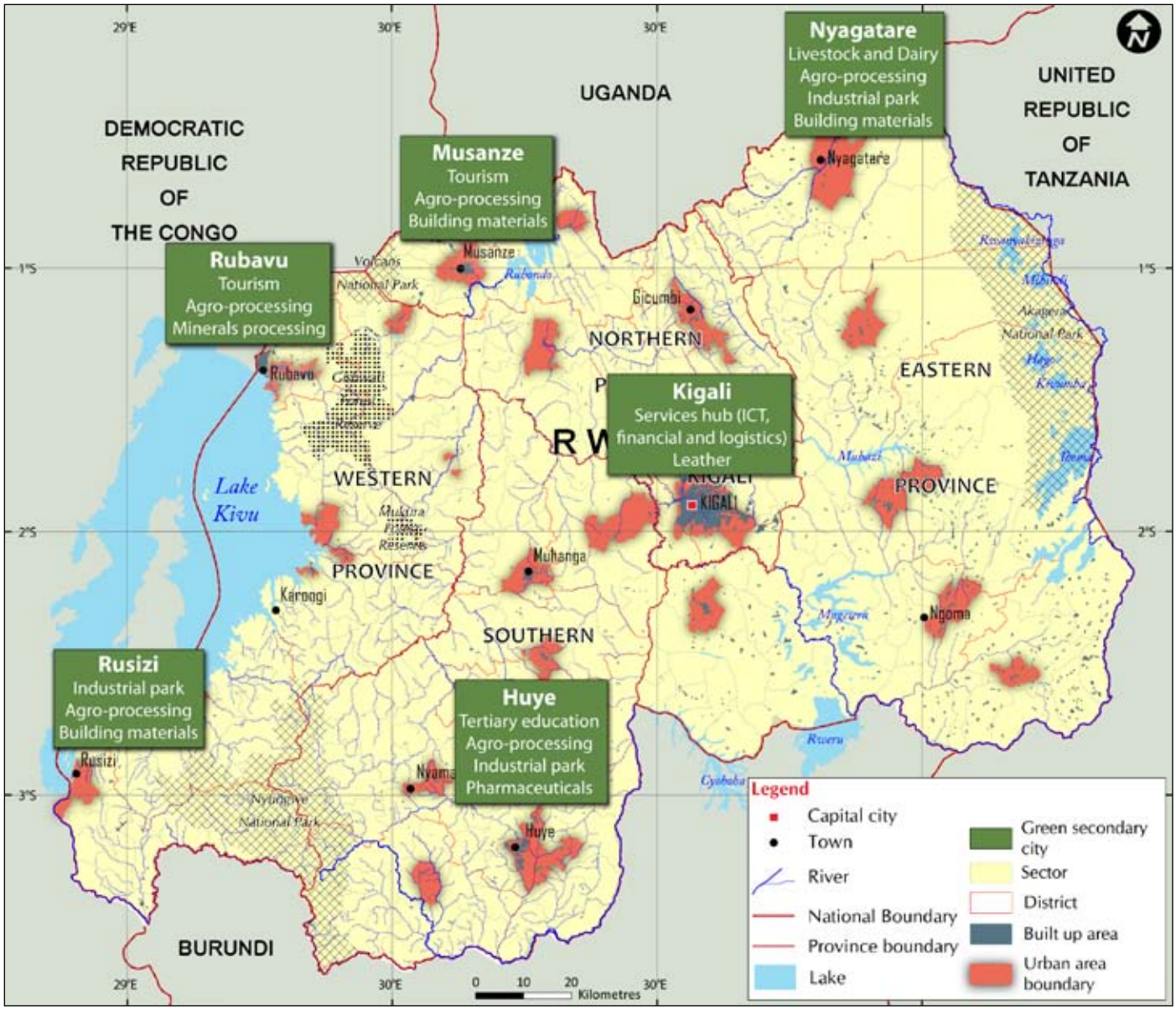
The six cities were selected based on agreed criteria as poles of urban growth (Figure7). The development of these cities will ensure more balanced regional growth and opportunities for increased access to off-farm employment for a larger proportion of the population. One of the strategic investments to increase their attractiveness includes improving the road network linking secondary cities to rural areas. It is expected that in 30 years, the sizes of these cities will vary between 100 - 800,000 inhabitants (UN-Habitat, n.d.)

The GoR began a project in January 2014 for *Developing Rwandan Secondary Cities as Green Model Cities with Green Economic Opportunities*. The project defined four pillars for green growth:

- Climate resilient and low carbon city;
- Integrated urban planning;
- Local green economy; and
- City governance and wellbeing.

To ensure sustainability, the project recommended that the GoR begin planning green secondary cities by identifying the desired green economy outcome

Figure 7: Plan for green secondary cities

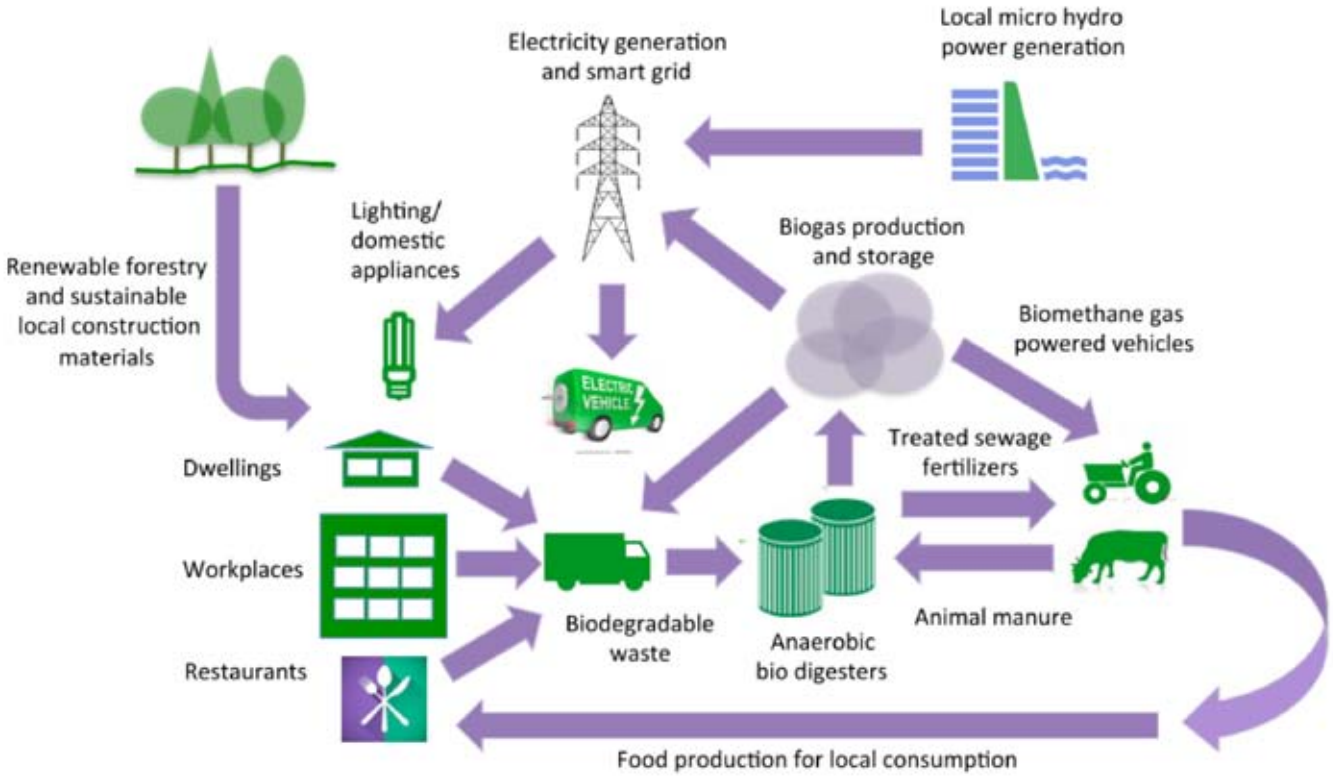


Source: (GGGI, 2014); (MININFRA, 2011)

and targets, then developing integrated land-use and infrastructure plans to achieve those outcomes (GGGI, 2015b).

The project based the development potential of each city, as shown in Figure 7, on first identifying the industries currently located in each of the secondary cities that could become anchors and drivers for future development. The study noted that although many current industries in these cities are not yet environmentally sustainable, there is significant potential for all secondary cities to become green in the future. The opportunities to green the cities include facilitating a region-wide adoption of decentralized photovoltaic solar energy and energy efficient cooking stoves. Municipal waste collection, recycling and the production of sustainable construction materials would also foster the greening process. These and other environmentally sound technologies would help secondary cities to leapfrog over high-carbon and unsustainable growth before it becomes entrenched (GGGI, 2014). Using the by-products of one sector of a city's economy as a resource for another is an integrated way of managing urban areas that reduces or even eliminates waste by creating a "circular metabolism", as opposed to a linear one in which waste products are considered useless and are disposed of. This is illustrated in Figure 8, which suggests that urban waste from dwellings, offices and restaurants in Rwanda's secondary cities could be used to produce biogas that would feed energy into the electricity grid as well as to power vehicles, for example (GGGI, 2015c). Implementation will require substantial public and private sector support and financial inputs (GGGI, 2014).

Figure 8: Integrated resource management for greening Rwanda's secondary cities



Source: (GGGI, 2015c).

In mid-2015, MININFRA and the GGGI jointly produced a preliminary *National Roadmap for Green Secondary City Development (NR)* as the next step in the project. The NR focuses on providing green guidelines for the fundamentals, pillars and pull factors of urbanization, which it defines as follows:

- Fundamentals: good governance, urban planning and environmental and social safeguard policies (the latter ensure a more inclusive spread of benefits to both the environment and citizens);
- Pillars: building sector, energy, urban mobility, production and distribution of water, sanitation and waste management;
- Pull Factors: economic development and job creation, quality of life.

The NR was developed in consultation with stakeholders at all government levels, development partners and the private sector. It matches the guidelines with key proposed actions at national and local levels (GGGI, 2015d).

Piloting a green city

In prioritizing the green economy approach to economic transformation, EDPRS II favours a number of innovations, including piloting a green city as a flagship project for green urbanization. The pilot green city will test and demonstrate the potential for sustainable cities in the future. The aim is to implement the project by 2018 (RoR, 2013). The GoR is already involved in a "Climate Smart Cities" initiative, funded by the International Growth Centre and coordinated by the Centre for Low Carbon Futures (IGC, 2015); (CLCF, 2015). The project will focus on Kigali and assess trends in energy use, energy expenditure and emissions between 2000 and 2032, evaluate the economic and climate implications of a wide range of low carbon and water efficiency measures and the realistic potential for implementing each measure in terms of costs and benefits. The results will eventually inform various policy documents and plans. Green practices are already being demonstrated in pilot "Green Villages" (Box 1).

The Green Growth strategy and protecting green urban spaces

Urbanization can be a powerful driver of sustainable development. For example, because of economies of scale, cities can provide essential services at lower costs per capita. Urbanization can also reduce energy consumption, particularly in transport and housing (UNEP, 2011).

Box 1: Green Villages

Pilot green villages, such as Rubaya and Muyebe Green Villages, are demonstrating green practices such as generating biogas from consolidated domestic human and livestock waste for cooking and lighting and rainwater harvesting for domestic use and household-level irrigation for kitchen gardens. To help upscale the green village approach, the Rwanda Environment Management Authority (REMA) under the UNDP-UNEP Poverty and Environment Initiative (PEI) programme has published A Toolkit for the Development of Smart Green Villages in Rwanda. It includes instructions in green practices for sustainable agriculture, water access, energy efficiency, sanitation and hygiene, settlement and housing design, value-chain addition for agricultural products, solid waste management and the development of a village knowledge hub (REMA, 2015).

One of the 14 Action Plans of the Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development (GGCR) is to create low carbon urban systems. Its strategy is to promote high density, walkable cities, for the following reasons:

> "Designing high density cities with corridors for pedestrians and cyclists and green public spaces, would reduce the need for energy intensive transport, improve quality of life and reduce the risk of flooding. Not only will this reduce GHG emissions and oil dependency, but also reduce the burden of transport costs to citizens. It also has adaptation benefits, as reduced urban sprawl limits the development of housing on steep slopes which are vulnerable to flooding and landslides" (RoR, 2011).

To protect green spaces in urban areas, Rwanda's forest policy recognizes the need to increase urban tree planting and has put forward several strategies to accomplish this, including creating mandatory boulevards in all trading centres, towns, municipalities and cities and including urban forestry in urban planning (RNRA, 2011). In addition, Rwanda's public acquisition policy is an instrument used for protecting open space. It can create recreational areas and protect the existing open spaces like forests and wetlands. Another incentive to protect urban green spaces is the provision that the land allocated for agriculture or gardening is free of taxes (MININFRA, 2013).

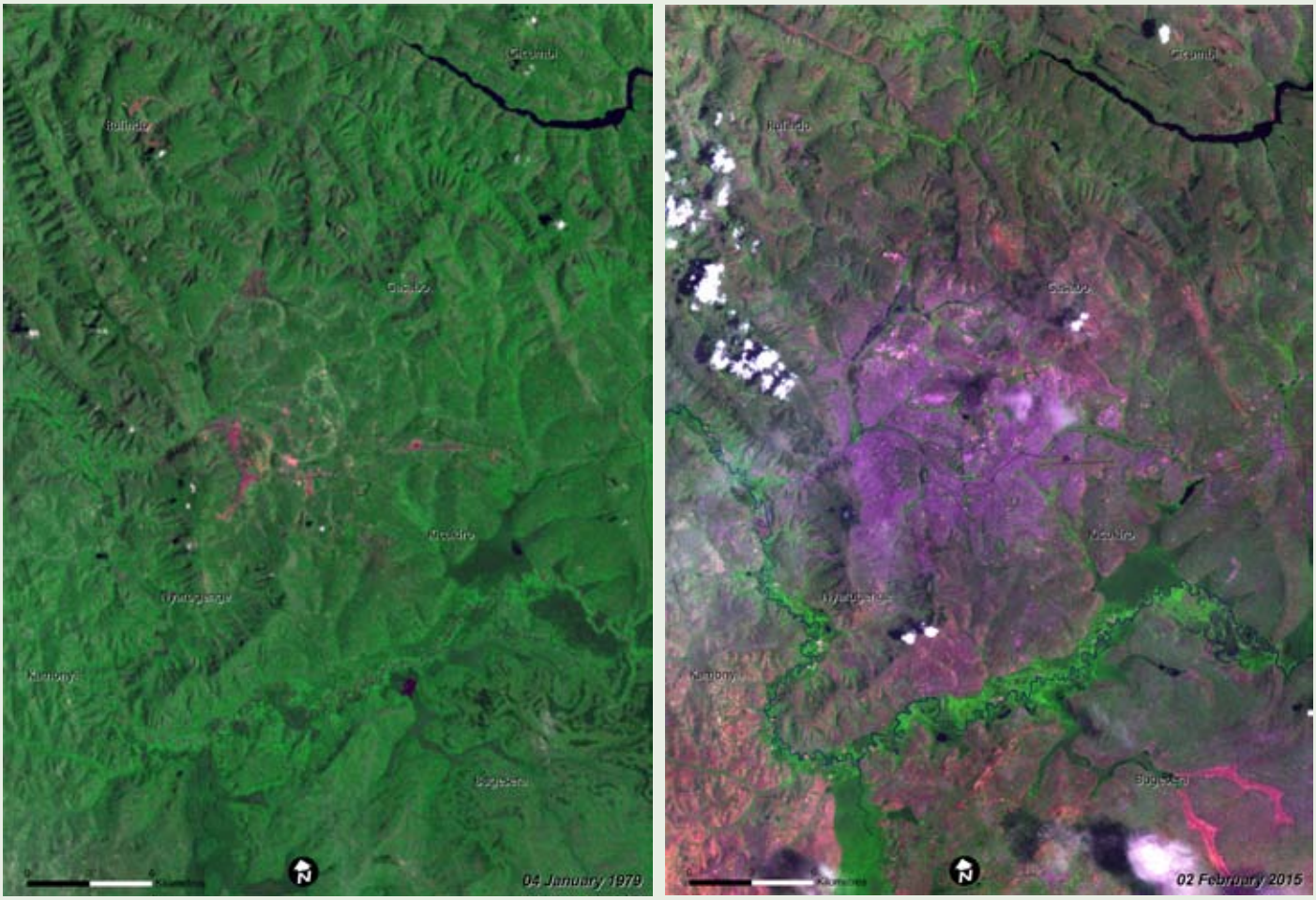
Green buildings for resource efficiency

Rwanda is implementing a number of approaches to improve the resource and energy efficiency of its housing stock in light of its GGCR goals. It has made significant progress in applying green building principles and technologies (MININFRA, 2011). For example, it promotes the use of renewable energies, such as biogas or waste materials such as coffee husks, and local materials such as bricks and tiles from local businesses, for private or non-governmental construction initiatives, but also for the Umudugudu (MININFRA, 2011); (MINALOC, 2013). Its green building principles mean assessing a new building's life cycle: its energy consumption from the production of the construction materials until final demolition and recycling. Green buildings should feature reduced CO_2 emissions; reduced waste; environmentally sound waste disposal; reduced use of treated potable water and rainwater harvesting (MININFRA, 2013).

Urban water and sanitation provision

Rwanda's 2010 National Policy and Strategy for Water Supply and Sanitation Services is oriented to delivering on Vision 2020's goal to attain 100 per cent service coverage by 2020, in collaboration with other key government bodies and development partners (MININFRA, 2010). The goal of EDPRS II is to attain universal coverage by 2018. In terms of urban targets, it aims for all urban households to have access to an improved water source within 200 m (RoR, 2013).

The Water and Sanitation Corporation (WASAC) is in charge of water supply in urban areas. In March 2015, the government signed a 27-year contract with a private company to invest US$75 million to provide 40,000 m^3/day of bulk water from a wellfield next to the Nyabarongo River to Kigali. It is the first contract of this type in sub-Saharan Africa (WASAC, 2015).



Landsat images of Kigali City 1979 and 2015 showing dramatic urban expansion (purple is built-up areas)

Case Study: Kigali City

Kigali is Rwanda's major urban center, assimilating most rural-urban migration, providing about a third of all job opportunities in the country, accounting for one-tenth of the country's entire population and housing almost half of its urban population. A detailed state of environment report on Kigali was published in 2013 (REMA, 2013); this box illustrates some of the most recent developments in city planning to make it a more sustainable urban centre. It also highlights the city's expansion up to 2015 through a series of satellite images.

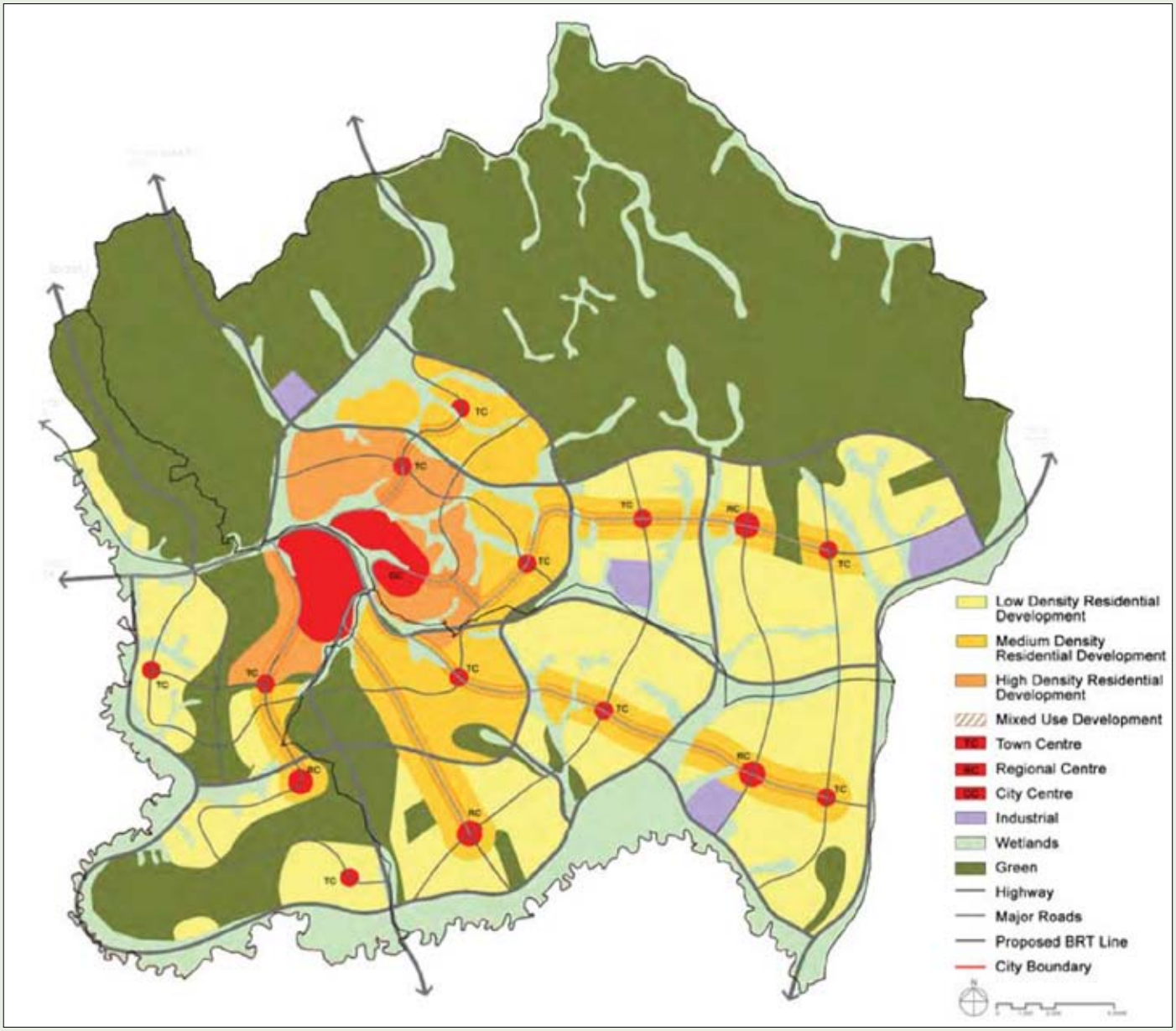
Kigali City urban development and policy framework

In 2013, the Kigali City Master Plan (KCMP) was published, based on the 2007 Kigali Conceptual Master Plan. It was followed by Detailed District Master Plans for Nyarugenge, Gasabo and Kicukiro. The KCMP provides a long-term vision for the city based on fundamental pillars of sustainable urban development, such as the protection of wetland, slopes and forest areas. In addition, it contains detailed land use and zoning plans to guide the city's urban development. The zoning regulations stipulate the types of land uses, land development intensity and the setting and height of buildings. The KCMP also provides guidelines, strategies and schematic designs for the various urban sectors, including transport and infrastructure (water, sanitation, sewage, power, etc.) and is supported by a comprehensive implementation strategy (Surbana, 2012).

In 2012 and 2013, detailed plans for Gasabo and Kicukiro Districts were completed as well as designs for urban centers and the Kigali Transportation Master Plan (Figure 9). Together, these documents form the Kigali Master Plan 2013, which won the Singapore Institute of Planners' Best Planning Project award (MININFRA, 2013).

Kigali faces a severe housing shortage; it requires about 34,000 new dwellings annually, the vast majority of which are for low-income people (GGGI, n.d.). There is little available land to accommodate low-density suburban housing in Kigali, which is also an environmentally unsound approach to urban growth, given its impact on land, energy and water resources.

Figure 9: Kigali Master Plan, 2013

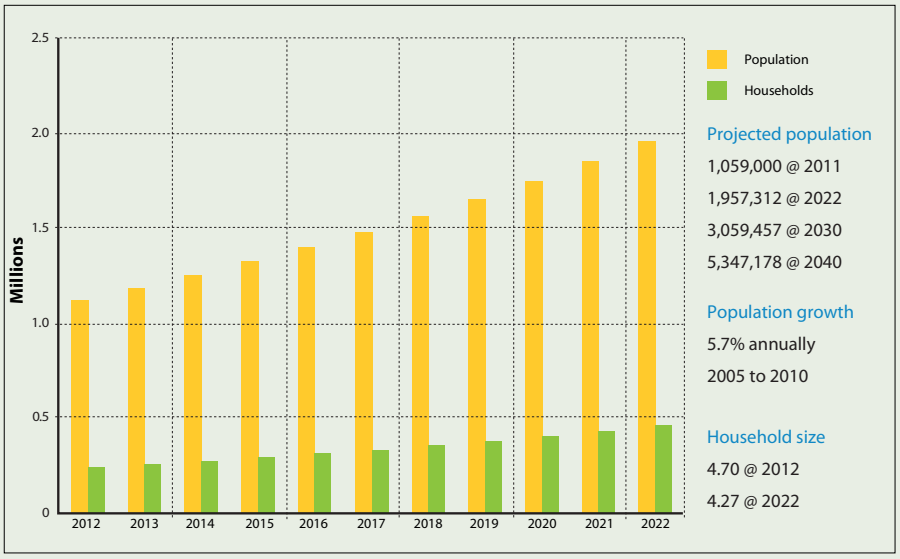


Source: (MININFRA, 2013)

Thus, the Kigali Conceptual Master Plan contains a strategy to increase housing density in the city. Figure 10 shows the high population growth versus the controlled growth in the number of households.

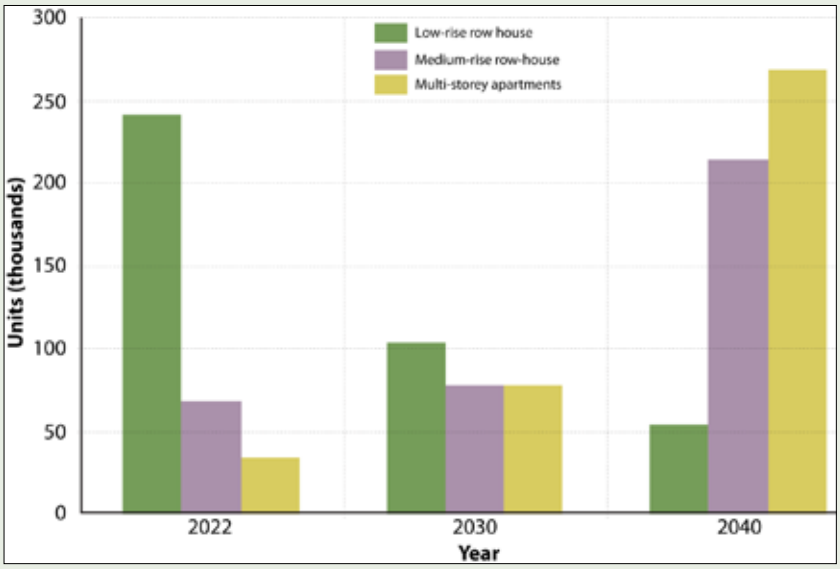
The Rwanda Development Board proposes three basic types of dwellings, based on an analysis of existing housing, cultural traditions, density needs, costs, household income and topographic factors: low-rise row houses, medium-rise row

Figure 10: Status and projections of population growth and housing needs in Kigali City, 2012-2022



Source: (MININFRA, 2013)

Figure 11: Plans for the gradual introduction of high-density housing in Kigali, 2022-2040



Source: (RDB, n.d.)

houses and multi-storey apartments (RDB, n.d.). Figure 11 shows the plan to increase the proportion of higher density apartments while decreasing low-rise housing.

All construction in the city's wetlands has ceased and all industrial activity is being relocated from wetlands (Gikondo) to the new "Kigali industrial zone" in the Rusororo area. A public acquisition policy using incentives, such as tax breaks and non-responsive instruments, such as demolishing illegal developments and charging fines for constructing contrary to approved plans, are being implemented to protect green spaces.

In accordance with the city Master Plan, in August of 2015, Kigali introduced its first car-free zone in part of the Central Business District (CBD) as a first step towards making the CBD entirely car-free and creating a network of pedestrianized areas (Karemera, 2015).

Conclusion

Rwanda's urban areas are growing rapidly. Its annual urban growth rate far exceeds the worldwide average and population density is the highest in Africa. By 2020, its urban population will have grown from 1.5 million today to about 4.5 million. Kigali is the main urban area, assimilating most rural-urban migration, providing about a third of all jobs and accounting for one-tenth of the country's entire population and almost half its urban population.

Because there are already housing and basic infrastructure shortages in Kigali, its waste water, sanitation and solid waste systems as well as treatment plants for industrial effluents and storm-water drainage systems are still inadequate, and traffic and air pollution are growing problems, the GoR has made the development of six secondary cities a priority. Currently, about a quarter of the country's total urban population is distributed among these cities and Rubavu, Rwanda's second-largest city, is only one-fifth the size of Kigali. The government is committed to encouraging urban and economic growth in these urban centres to take the pressure off Kigali and more evenly distribute employment opportunities.

Vision 2020, EDPRS, the GGCR strategy and the Urbanization and Rural Settlement Sector Strategic plan for 2013 to 2018 aim to implement Land Use and Development Master Plans and district plans to create low carbon, high density, walkable cities. In collaboration with the Global Green Growth Institute (GGGI), Rwanda is moving forward with plans to develop Green Model Cities with Green Economic Opportunities. Rwanda also intends to pilot a green city and is investigating the costs of implementing various practices that could be introduced in Kigali under the Climate Smart Cities programme. Already, it has ambitious Master Plans for Kigali that will make it a world-class sustainable city.

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Tungsten mine, Rwanda.

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Chapter 6: Mining and Industry

6.1: Mining

6.1.1 Status and trends

Rwanda has known mineral deposits of gold, tin, tungsten, coltan and gemstones, but its total reserves are still unknown due to minimal exploration. Although the mining industry is small, it has the potential to triple production by 2020. In 2010, it contributed US$96.4 million of Rwanda's export earnings, representing 38 per cent of the total (RoR, 2011) and in 2014, export revenues rose to US$210.6 million (MINIRENA, 2015b). Rwanda plays

a significant role in the world's production of tantalum, tin, and tungsten, with its share of world output in 2010 at about 12 per cent, 2 per cent and 1 per cent, respectively (USGS, 2014). According to the fourth Integrated Households Living Conditions Survey (EICV 4), in 2014/15, the mining and quarrying sector employed about 1.1 per cent of the Rwandan population (NISR, 2015).

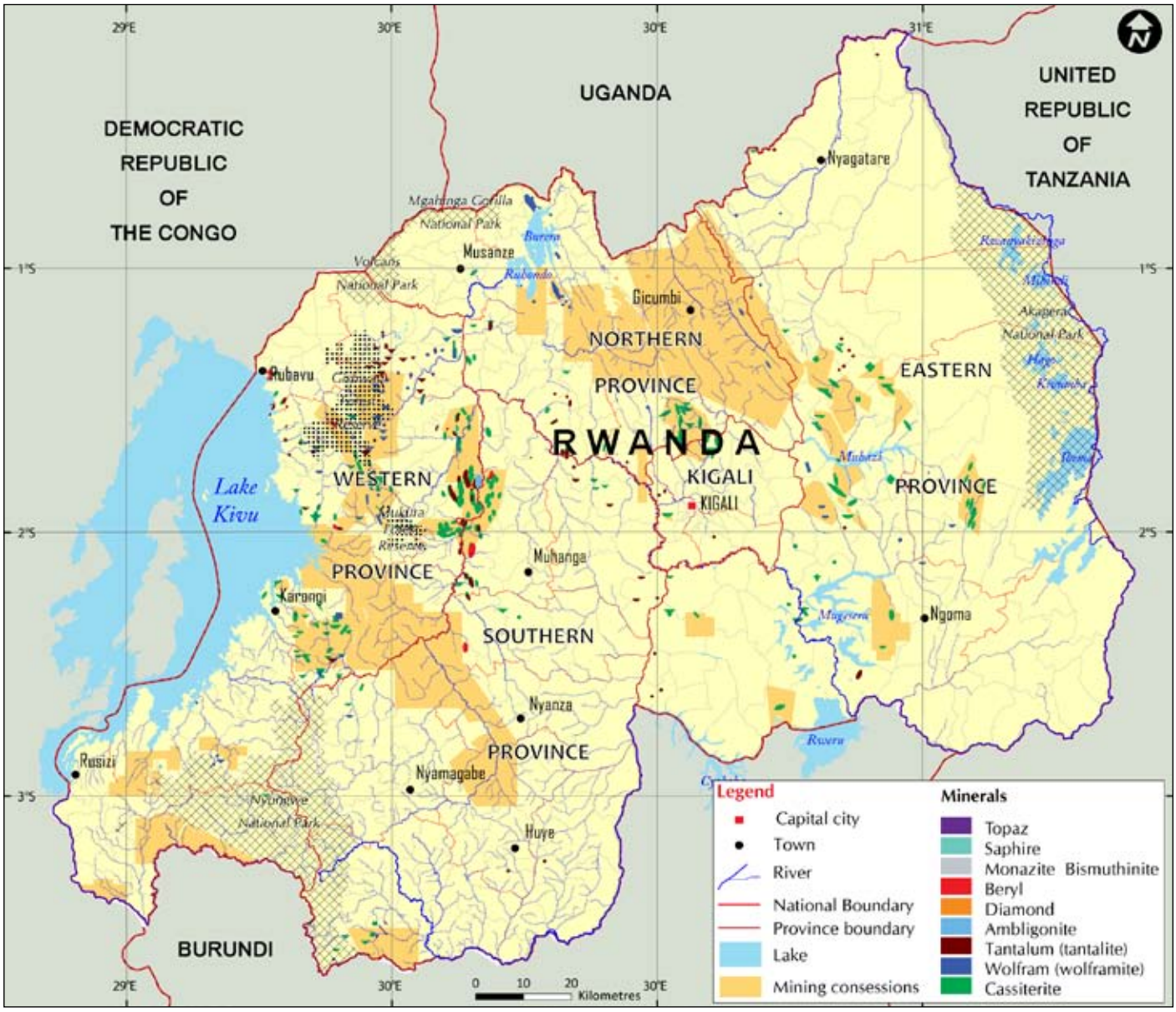
Rwanda has goals to both increase revenues from its mining resources and to accomplish it with high environmental standards and sustainable green innovations in the industrial and private sectors (RoR, 2013). Vision 2020 points to mining as one of the sectors that should be developed to expand the country's economic base, especially through exports (MINIRENA, 2015a).

Rwanda's main minerals

The Kibaran Orogeny rock system is the main geological basis of Rwanda's landscape. It extends from northern Tanzania through southwestern Uganda, underlying almost the whole of Rwanda and Burundi, then it extends through southeastern DRC up to Angola (RNRA, 2012a). The Kibara Belt is characterized by the mineralization of tin (Sn), niobium-tantalum (Nb-Ta), tungsten (W) and gold (Au) (Haidula, Ellmies, & Kayumba, 2011).

Mining in Rwanda mainly refers to the "3T minerals" — tin, tungsten and tantalum ores (cassiterite, coltan and wolframite) — which are associated with the Kibaran system (MINIRENA, 2013a). Tin, or cassiterite (SnO_2), is used in solders, tin plating, electrical

Figure 1: Map of mineral potential and exploitation in Rwanda



Source: Data provided by Republic of Rwanda, 2015

Mining for tungsten, Rwanda.

FairPhone / Flickr / CC By-ND-SA 2.0

conductors and electronic components. Wolframite (WO_4) is often associated with cassiterite. It is an iron manganese tungstate mineral from which tungsten (W) is derived. Tungsten and its alloys are important electrical conductors. Columbite and tantalite have similar features and when grouped together are often referred to as coltan. Tantalum (Ta) occurs in the minerals tantalite, columbite and coltan and is used in making capacitors for electric products (World Bank, 2014).

The other key minerals currently being mined and traded in Rwanda are gold and to a lesser degree, ambrigonite, beryl and semi-precious stones such as tourmaline, topaz, corundum, chiastorite, amethyst, sapphires, opal, agate and flint (RNRA, 2012b) (Figure 1).

State of the mining industry

Private companies began mining for cassiterite and wolframite in Rwanda in the 1930s. In 1973, the mining sector was nationalized but mismanagement resulted in its collapse in the 1980s-1990s. In 1997, mines were privatized and the mining sector began to recover, aided by increased foreign investment in exploration and mining between 2006 and 2009 (Haidula, Ellmies, & Kayumba, 2011).

Today, Rwanda's mining sector is characterized by private sector and small-scale/artisanal mining operations, usually organized as cooperatives. There is still minimal use of mechanized techniques, except for gravity systems for processing at a few mines and the use of explosives and bulldozers to access core geological veins, so most extraction is done by manual labour (World Bank, 2014).

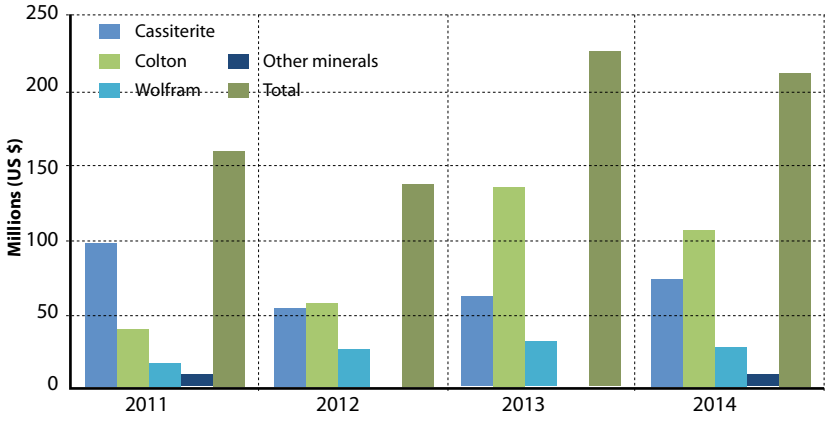
The privatization of concessions coupled with proactive government policy has created a conducive investment environment, driving the sector's evolution from a regional trading industry to a local extraction and exporting industry (RoR, 2000). By 2014, Rwanda had issued 548 mining permits to 213 registered mining entities, most of which covered surface areas averaging less than 4 ha. The Ministry of Natural Resources (MINIRENA) has a target for three medium-scale mines and 100 more small-scale mines to be in operation by 2017–18 (World Bank, 2014).

Mining's contribution to the Rwandan economy

Mining revenues in 2014/15 were US$251.2 million, up from US$164.7 million in 2011 (MINIRENA, 2015c). Figure 2 shows the trend in revenues for the key minerals.

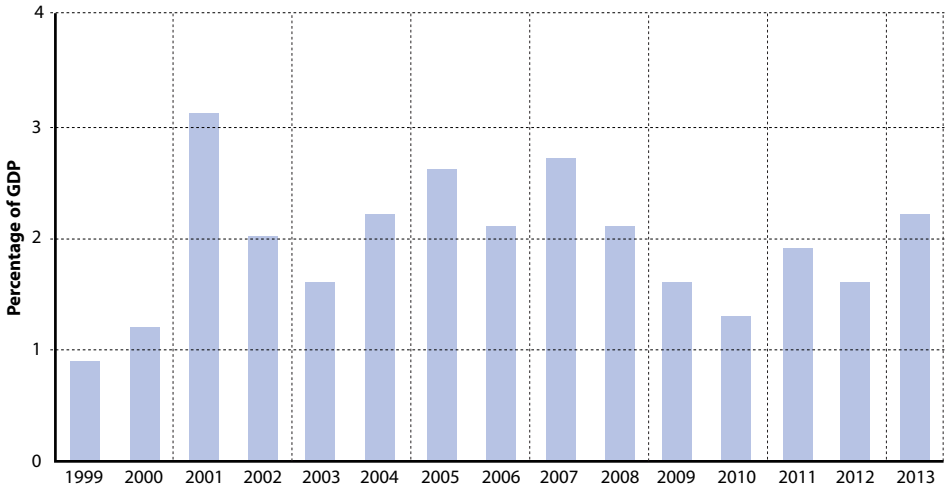
The mining sector's proportion of the country's GDP fluctuated over the past decade or so, registering an overall rise from just under 1 per cent in 1999 to over 2 per cent in 2013 (Figure 3). By 2018, the Government of Rwanda (GoR) through its EDPRS II intends to increase the mining sector's contribution to GDP to 5.3 per cent and to increase foreign investments in the sector from US$150 million in 2012 to US$500 million (MINIRENA, 2013b).

Figure 2: Mining's contribution to the economy (US$ millions), 2011-2014



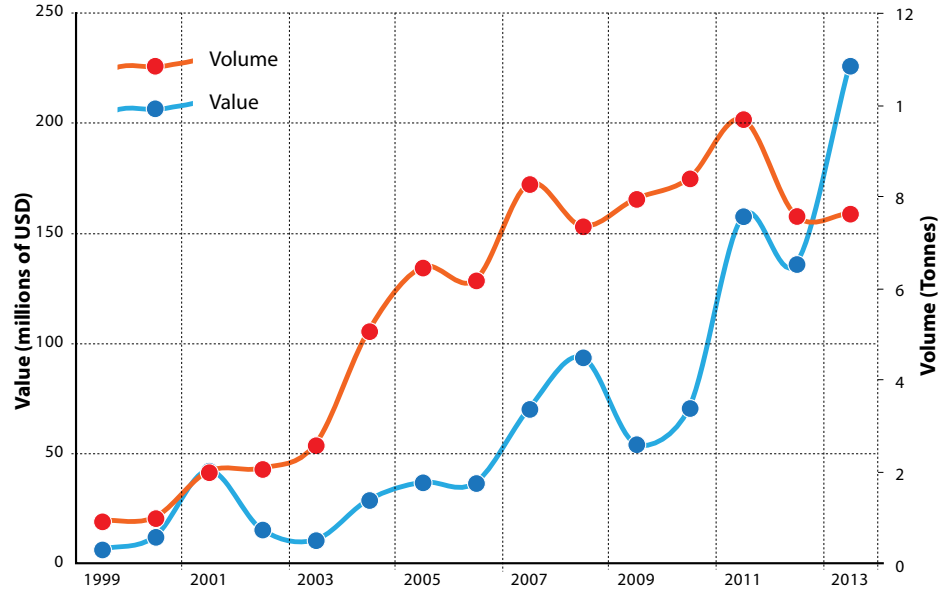
Source: (NISR, 2014) (MINIRENA, 2015b)

Figure 3: The mining sector's contribution to overall GDP, 1999-2013



Source: (World Bank, 2014)

Figure 4: Export earnings from mining, 1999-2013



Source: (World Bank, 2014)

From January to December 2014, Rwanda exported a total of 16,357 tonnes of cassiterite, coltan and wolframite and other minerals such as iron ore (MINIRENA, 2015b). In 2013, mining exports were valued at about US$226.2 million, making mining the largest foreign exchange earner (Figure 4). Export earnings from mining have been rising, largely due to positive mineral prices (World Bank, 2014). The EDPRS II aims to increase the value of mining exports to US$400 million a year by 2018 (MINIRENA, 2013b).

Mining provides an opportunity for off-farm jobs, with the potential to contribute to Rwanda's goal to diversify income, decrease dependence on farming and reduce poverty. Data from the EICV 3 indicate that in early 2014, there were 33,638 miners registered, representing just over half of the GoR's target of 60,000 by 2018 (World Bank, 2014).

6.1.2. Pressures and impacts

During the colonial era and immediately after independence, mining operations had little regard for their environmental impact. Their legacy of waste dumps and degraded land gave the industry a bad reputation (Blore, 2011). Without environmental impact studies and proper controls, mining sites in Rwanda can compete with agricultural land uses and mining and processing activities can create unsightly, unstable and dangerous waste dumps and disturb soils enough to trigger landslides and release toxic waste into water bodies, affecting the health of local communities and their crops and livestock (Haidula, Ellmies, & Kayumba, 2011).

In 2011, a field study was conducted on the environmental impacts of small-scale artisanal mining in all of the country's main mining areas. Generally, these mines are situated close to farms with some agricultural activities taking place directly on mine-waste deposits. The research found that the mining and/or processing activities at all of the studied mines release waste into rivers, onto adjacent agricultural lands and close to settlements (Haidula, Ellmies, & Kayumba, 2011).

The research found that the main threats are from dumps of mine tailings and waste released from processing plants. These materials were found to contain arsenic and lead. As a result, concentrations of arsenic were found in soils and stream sediments downstream of the mines in Masoro/Rutongo (near Kigali), Rutsiro (Western Province), Gifurwe (Northern Province) and Rwinkwavu (Eastern Province). Farm soils downstream of the Gifurwe tailings dam had the highest arsenic concentrations, at 533 mg/kg, which greatly exceed East African Standards for Drinking Water, and arsenic levels in river water downstream of the Rwinkwavu site slightly exceeded those standards. There appeared to be little to no downstream impacts

of the other mines; the authors speculate that the reason may be high rainfall diluting the contamination rather than good environmental management. Arsenic can bioaccumulate so irrigating with contaminated water and using it as a potable water source could be dangerous (Haidula, Ellmies, & Kayumba, 2011).

6.1.3 Response

Vision 2020

Overhauling Rwanda's mining sector is one of the five key interventions to attain Vision 2020's plan to grow the country's average annual export rate by 28 per cent from 2012-2020, based on the new mining law, a new investors' model contract for mining operations and targeted investments in exploration. Mining production is expected to triple by 2020 and the potential for a mining services industry for the country and the region will be developed through adding value and diversifying mineral products by processing domestic and imported ores and manufacturing construction materials and jewellery (RoR, 2011).

The Rwanda Mining Policy

The Rwanda Mining Policy has five strategic pillars that support the growth of the mining industry (MINIRENA, 2010). Vision 2020 recognized that if the policy were carried out as "business as usual" mining would contribute significantly to energy use, greenhouse gas (GHG) emissions and water use in Rwanda (RoR, 2000). Thus, a sixth strategic pillar related to low carbon, climate resilient development will be added to the Mining Policy to reduce GHG emissions, improve energy and water security and reduce vulnerability to floods and landslides. The GoR will support the mining industry to accomplish the following:

- Implement energy efficiency at operations, through measuring and reporting, setting targets and using efficient technologies;
- Utilize electricity from renewable energy sources, either from the national grid or on-site generation;
- Employ good water management practices on operations, including water efficiency and flood management; and
- Expand the capacity building programme to account for new skills needed in energy and water management (RoR, 2000).

The regulatory framework

The GoR recognizes that mining can have significant environmental impacts, which will increase as the sector grows (RoR, 2013). The World Bank's 6th edition of the Rwanda Economic Update focuses on mining and reports that Rwanda has already made significant strides to improve its regulatory policies and practices related to mining so that they approach international best practice (World Bank, 2014). With the privatization of the mining sector, Rwanda updated its regulatory framework, the key initiative being the new Mining Law, which forms a solid basis for regulating the mining industry (MINIRENA, 2015a). The GoR also appointed a State Minister for Mines, developed a national mining policy and supporting strategic plans and instituted a national cadastral system that is in the process of becoming operational. The main outcomes so far have been the increase in geological data about national mineral potential, increased institutional capacity and adherence to social and environmental standards in mine development (World Bank, 2014); (Haidula, Ellmies, & Kayumba, 2011).

To manage the environmental impacts of mining, all planned projects have to undertake an Environmental Impact Assessment before they are authorized. REMA sets the environmental standards for inspecting mining projects and rehabilitating exhausted mines and quarries and the Rwanda Natural Resource Authority (comprised of Lands, Forestry and Conservation, Water and Mines and Geology Departments) is in charge of land titles to mining projects, expropriation and leasing, water-use licenses and standard setting, advising on reforestation and land-use master plans (World Bank, 2014).

EDPRS II and the GGCR strategy

EDPRS II focuses on Rwanda's potential to promote a state of the art "green" mining sector. Generally speaking, the two major methods to implement green mining are governmental regulation and innovative technologies. In recent years, new mining technologies and regulations have significantly improved mining efficiency and reduced the environmental impact. One of the reasons is because the more efficient the mining technology, the less waste produced (MIT, 2015). EDPRS II includes a priority area related to green growth that envisions an intervention to pilot a "model" mine fully funded through green investment that incorporates renewable energy and water treatment systems, forestry out-grower schemes and a local training centre (RoR, 2013).

Box 1: The International Council on Mining and Metals' Principles related to environmental sustainability

***Principle 6*: Seek continual improvement of environmental performance.**

- Assess the positive and negative, the direct and indirect, and the cumulative environmental impacts of new projects – from exploration through closure;
- Implement an environmental management system focused on continual improvement to review, prevent, mitigate or ameliorate adverse environmental impacts;
- Rehabilitate land disturbed or occupied by operations in accordance with appropriate post-mining land uses;
- Provide for safe storage and disposal of residual wastes and process residues;
- Design and plan all operations so that adequate resources are available to meet the closure requirements of all operations.

***Principle 7:* Contribute to the conservation of biodiversity and integrated approaches to land use planning.**

- Respect legally designated protected areas;
- Disseminate scientific data on and promote practices and experiences in biodiversity assessment and management;
- Support the development and implementation of scientifically sound, inclusive and transparent procedures for integrated approaches to land use planning, biodiversity, conservation and mining.

***Principle 8:* Facilitate and encourage responsible product design, use, re-use, recycling and disposal of products.**

- Advance the understanding of the properties of metals and minerals and their life-cycle effects on human health and the environment;
- Conduct or support research and innovation that promotes the use of products and technologies that are safe and efficient in their use of energy, natural resources and other materials;
- Develop and promote the concept of integrated materials management throughout the metals and minerals value chain;
- Provide regulators and other stakeholders with scientifically sound data and analysis regarding products and operations as a basis for regulatory decisions; and
- Support the development of scientifically sound policies, regulations, product standards and material choice decisions that encourage the safe use of mineral and metal products.

Source: (ICMM, 2015)

International Council on Mining and Metals

To build a state-of-the-art "green" model mine, MINIRENA could learn from the international principles provided by the International Council on Mining and Metal's Sustainable Development Framework, highlighted in Box 1 (World Bank, 2014).

The GGCR strategy also addresses improving the sustainability of mining through its Programme of Action 8, the goals and targets of which relate to Climate Compatible Mining (RoR, 2011).

MINIRENA has also established important national environmental and social standards and respects international standards and regulations particular to the Great Lakes region. By 2017, its goal is that all the country's operating mines have efficient water and waste management systems and that 80 per cent of its mines adhere to safety regulations and the country's "no child labour" policy (World Bank, 2014).

To contribute to poverty reduction and greening the economy through the mining sector, the GoR will also provide university opportunities abroad and develop an undergraduate geology and mine engineering programme at the University of Rwanda to increase the sector's professional educated skills base from less than 50 people to 600 (World Bank, 2014).

Certified Trading Chains (CTC) in Mineral Production

Rwanda also addressed the environmental and social challenges of artisanal mining, which include health and safety, community engagement, gender, child labour and pollution, by its participation in the pilot

project to create Certified Trading Chain scheme standards, which increased its capacity to regulate its mining sector (MINIRENA, 2013a).

The Certified Trading Chains (CTC) in Mineral Production Pilot Project took place from 2008 to 2011, during which time it developed a set of certification standards appropriate for Artisanal and Small-scale Mining (ASM) in the African context. Twenty standards were grouped into five principle areas of concern: origin and transparency of mineral flows and associated payments; working conditions; security and human rights; community consultation and gender relations; and the environment. The environmental standards include carrying out an environmental impact assessment; properly treating or disposing of hazardous material and waste; providing a plan for mine closure and providing for the full costs of rehabilitation upon closure (Blore, 2011).

Conclusion

Although its mining industry is still small, its role in the world's production of tin, tungsten and tantalum is significant and it is the country's largest foreign exchange earner. In recent years, Rwanda's mining sector has improved in terms of production, exports and contribution to the economy as well as in legislating and limiting its environmental impacts.

The GoR intends to increase the mining sector's contribution to GDP and exports, foreign investments in the sector and mining employment opportunities. Mining production could triple by 2020. The GoR also recognizes the potential environmental and human threats of industrializing its mining sector, however; it is promoting a state-of-the-art "green" mining sector and intends to pilot a model "green" mine.

6.2 Industry

Industries are usually categorized into three groupings: primary industries collect and use resources directly produced through physical processes, such as forestry, mining and agriculture; secondary industries convert raw materials into goods, such as manufacturing; and tertiary industries provide services for individuals and groups, such as advertising and tourism. This section of the chapter gives an overview of industries not discussed elsewhere in the report (other parts of the report examine forestry, tourism, agriculture and mining) and that have the most significant environmental impacts.

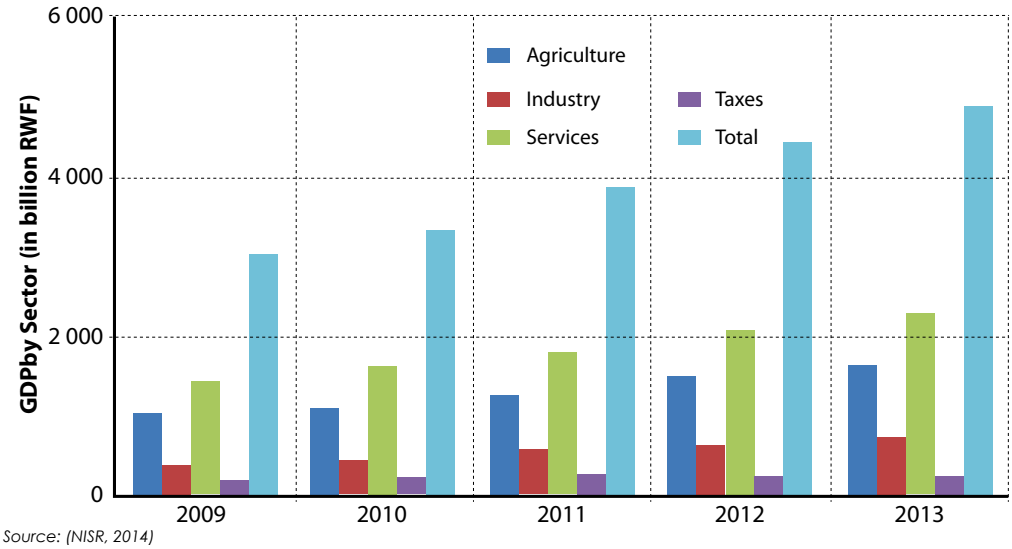
6.2.1 Status and trends

Industry's contribution to the Rwandan economy

Although agriculture remains Rwanda's largest GDP contributor, Rwanda's industrial and services sectors grew at a faster rate over the period of 1999-2010 (Figure 5). Within industry, growth was fuelled by mining and construction. Industrial products include cement, agricultural products, small-scale beverages, soap, furniture, shoes, plastic goods, textiles and cigarettes. The contribution of industry (excluding agriculture and services) to GDP grew from 12 per cent in 1999 to 14 per cent in 2014. Over that period, the contribution of mining and quarrying grew from 0 to 2 per cent, total manufacturing fell from 8 to 5 per cent and construction grew from 5 to 7 per cent. Services contributed 47 per cent of GDP with growth driven largely by tourism (hotels and restaurants) and financial services and trade (NISR, 2015).

Mud bricks drying in the sun.

Figure 5: Trend in GDP by sector, 2009-2013



Source: (NISR, 2014)

The manufacturing sector, including agro-processing, currently constitutes 34 per cent of the industrial sector (NISR, 2015). The manufacturing sector is dominated by construction materials, manufacturing and agro-processing subsectors, mainly due to the local availability of raw materials and the booming construction sector. Between 2010 and 2012, manufacturing investments, excluding agro-processing, grew from US$20 million to US$155 million (RDB, 2015).

6.2.2 Pressures and impacts

Industries can have significant impacts on the land, water and air. They take the form of toxic by-products, such as polluted solid waste, water effluents and emissions from factory chimneys. When these are not prevented, regulated or controlled and are dumped directly into the surrounding environment, there are serious impacts on human and ecosystem health. Other potential environmental impacts include the extraction of natural resources to drive industrial processes, such as fossil fuels and water and the quantities of required resources, as well as greenhouse gas emissions that contribute to climate change.

Rwanda's industrial sector is small, however, and the City of Kigali, where about 70 per cent of industrial activities are based, is addressing the main environmental impacts, such as water and energy requirements. It has established a Special Economic Zone (SEZ) especially for locating industries and businesses (RoR, 2011); (REMA, 2013).

Nevertheless, energy use by industry remains a consideration because of the greenhouse gas emissions from fuel sources. The Rwanda Industrial Survey of 2011 looked at the most common energy sources in industrial activities, which are electricity, furnace or heavy oils, petrol, wood, solar and other sources used in smaller quantities. In 2010, the highest consumption was furnace/heavy oils, representing 46.4 per cent. This fuel is mainly used in generators used in the construction and road building sectors during power failures or the threat of one (MINICOM, 2012).

Rwanda's CIMERWA cement factory uses heavy fuel oil, for example, but is modifying its plant to be able to convert to peat for energy, with the goal of using 70 per cent peat and 30 per cent oil. The emission intensity of peat, however, would exceed that of heavy fuel oil, but could be reduced through energy efficient technologies. A 2013 study by UNEP looked at the potential for reducing energy consumption in the plant by using rice husks, suggesting it could cut energy use in half. It also examined the emissions savings of using alternatives to the peat/oil fuel mix in the cement factory and found that the complete conversion to biomass residues would result in a considerable reduction in carbon dioxide equivalents per year (120,000 tCO_2e) (UNEP RISØ, 2013).

6.2.3 Response

Vision 2020, EDPRS II and the GGCR strategy

Vision 2020 goals include specific targets directly related to industry:

- Increase its annual growth rate to 11.5 per cent;
- Improve industry's contribution to the economy to more than 20 per cent of GDP;
- Create 3.2 million non-agricultural jobs; and
- Reach $1,240 GDP per capita (RoR, 2000).

The EDPRS II goals for economic transformation also include related targets for the industrial sector (manufacturing, construction and mining): the aim is for industry to contribute 20 per cent to GDP by 2018 and to grow at an annual rate of 11.5 per cent. Rwanda's National Industrial Policy intends to increase domestic production, improve export competitiveness and create an enabling environment for further industrialization. As well, the second pillar of the Rwanda Private Sector Development Strategy (PSDS) aims to build a more competitive manufacturing sector capable of competing in the East African Community (EAC) and Great Lakes region, using new technologies, improving quality and deepening the supply and value chains (RoR, 2013).

Given these goals to increase industrial activity, the GoR is also instituting precautions to ensure industry is developed in ways that prevent the usual environmental impacts of industrialization. One of the 14 Programmes of Action in the GGCR strategy is to "Green industry and private sector development". The GGCR strategy aims to transform industry in the following ways to address energy use and GHG emissions and foster low carbon development:

- Scale up resource efficiency to reduce energy and water demand, thus reducing emissions and promoting resilience;
- Employ efficient and zero waste technologies, practices and design in Special Economic Zones and provincial industrial parks;
- Establish Climate Innovation Centres to support investment in industries producing green technologies and those adopting green technology; and
- Build carbon trading capacity within the private sector to harness innovative funding opportunities provided by the Clean Development Mechanism (CDM) and voluntary carbon markets (RoR, 2011).

These responses demonstrate Rwanda's determination to address the environmental impacts of industrialization by preventing pollution and waste at the source instead of relying solely on "end-of-pipe" approaches that control pollution by diluting, dispersing or removing effluents and emissions once they have occurred. In addition to the environmental benefits, pollution prevention and using resources more efficiently can result in economic savings over the long term that provide industries with further incentives to invest in these technologies (RRECP, 2014).

Rwanda Resource Efficient and Cleaner Production Centre (RRECPC)

One of the country's most successful initiatives to improve the environmental footprint of industries is the Rwanda Resource Efficient and Cleaner Production Centre (RRECPC), which was set up in 2008. It works closely with industry to mainstream water and energy efficiency and waste recycling and has already demonstrated the financial and environmental benefits of saving energy and water within industrial processes, product development and design and also within the service sector (RoR, 2011).

The RRECPC defines Cleaner Production as "the continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment." Cleaner Production can be and has already been applied to many aspects of raw material extraction, manufacturing, agriculture, fisheries, transportation, tourism, hospitals, energy generation and information systems in Rwanda (RRECP, 2014).

One of the most important aspects of RRECPC's approach to cleaner production is to foster a change in attitude among company directors, managers and employees. The next step is to apply "know-how", which means improving efficiency, management techniques and housekeeping practices and refining company policies and procedures, which usually results in optimizing existing processes. The third feature is to improve technologies. Examples include changing manufacturing processes and technology; the nature of process inputs (ingredients, energy sources, recycled water etc.); the final product, or developing alternative products; and reusing wastes and by-products on-site (RRECP, 2014).

Among its many accomplishments to date, the RRECPP has helped five factories in Kigali City to assess their own compliance in resource efficiency and cleaner production, conducted a complete Cleaner Production intervention project in a textile factory that resulted in significant savings of raw materials, water and energy and acquired movable equipment to demonstrate how to produce high quality briquettes from suitable bio-waste (RRECPP, 2011) (Box 2).

Conclusion

Although agriculture remains Rwanda's largest GDP contributor, industry and services have been growing at a faster rate over the past 15 years. Industry (excluding agriculture and services) contributes 14

Box 2: Briquettes for cleaner and low carbon fuel

Briquettes made of various agricultural residues or waste from households or animal production can replace fossil fuels in some industrial and power production processes as well as in home cookstoves. This results in cleaner and more resource efficient production by reducing both waste and greenhouse gas (GHG) emissions and it reduces the threat of deforestation. The briquettes are produced either in automatic briquetting machines or by small-scale informal briquette-making initiatives using manual presses that compress biomass to squeeze out all moisture and form typical cylindrical shapes for burning (UNEP RISØ, 2013).

The United Nations Industrial Development Organization (UNIDO), with the Rwanda Resource Efficient and Cleaner Production Centre (RRECPC), established an Eco Briquettes Products Plant and briquetting machine, in collaboration with COPED sarl, a social, profit oriented waste collection, transportation and recycling company operating in Rwanda. The project has produced different kinds of briquettes from various raw materials and products. Currently, industrial eco-briquettes made of sawdust, maize and rice husks are now available at Nyacyonga Eco Briquette Plant, which can produce about 1,036 one-kilogramme briquettes a day and employs 12 people. It is an example of how resource efficient and low carbon industries can contribute to greening the Rwandan economy (Gajowski, Niyonzima, Buregeya, & Gatabazi, 2015).

In another briquette project, the "Coopérative pour la conservation de l'environnement", or COOCEN, in Kigali City produces briquettes from household waste. The aim is to prevent deforestation by replacing fuel wood with briquettes, reduce GHG emissions and provide employment for women, many of whom are widows. The coop members collect and bring household waste to the processing site where it is sorted and organic material is separated out and dried in the sun. The dried waste is pulverized then mixed with water and moulded into briquettes. The fuel is cheaper than charcoal and is sold to prisons, schools and factories. In addition to saving trees and reducing emissions, the initiative reduces poverty, removes unhealthy waste from homes and saves money for users. The COOCEN compost briquette project is now a demonstration site that attracts both Rwandan and international visitors. It is being replicated elsewhere in Kigali and was significantly scaled up in 2011 when Rwanda's largest waste management company began to order and promote the use of these compost briquettes (UNFCCC, 2014).

Photos from the Nyacyonga Eco Briquette Plant
Photo 1: Production of Eco briquettes; **Photo 2:** Eco briquettes storage; **Photo 3:** Eco Briquettes products burning

per cent of GDP. The manufacturing sector, including agro-processing, currently constitutes 34 per cent of the industrial sector and contributes 5 per cent to GDP. The construction industry is booming. Most industries are located in and around Kigali, and the city has been increasingly addressing the environmental impacts of industrial activities. The RRECPC is extremely influential in mainstreaming cleaner production in policies and strategies and in promoting, teaching and implementing resource efficiency and waste reduction in industries and businesses. As off-farm work opportunities increase, especially in agro-processing, local industries will grow in importance for both livelihoods and the national economy. As it develops its industrial sector, Rwanda's vision is to ensure that it contributes to greening the economy by using resources efficiently and reducing waste production and energy consumption, which have important long-term cost saving benefits.

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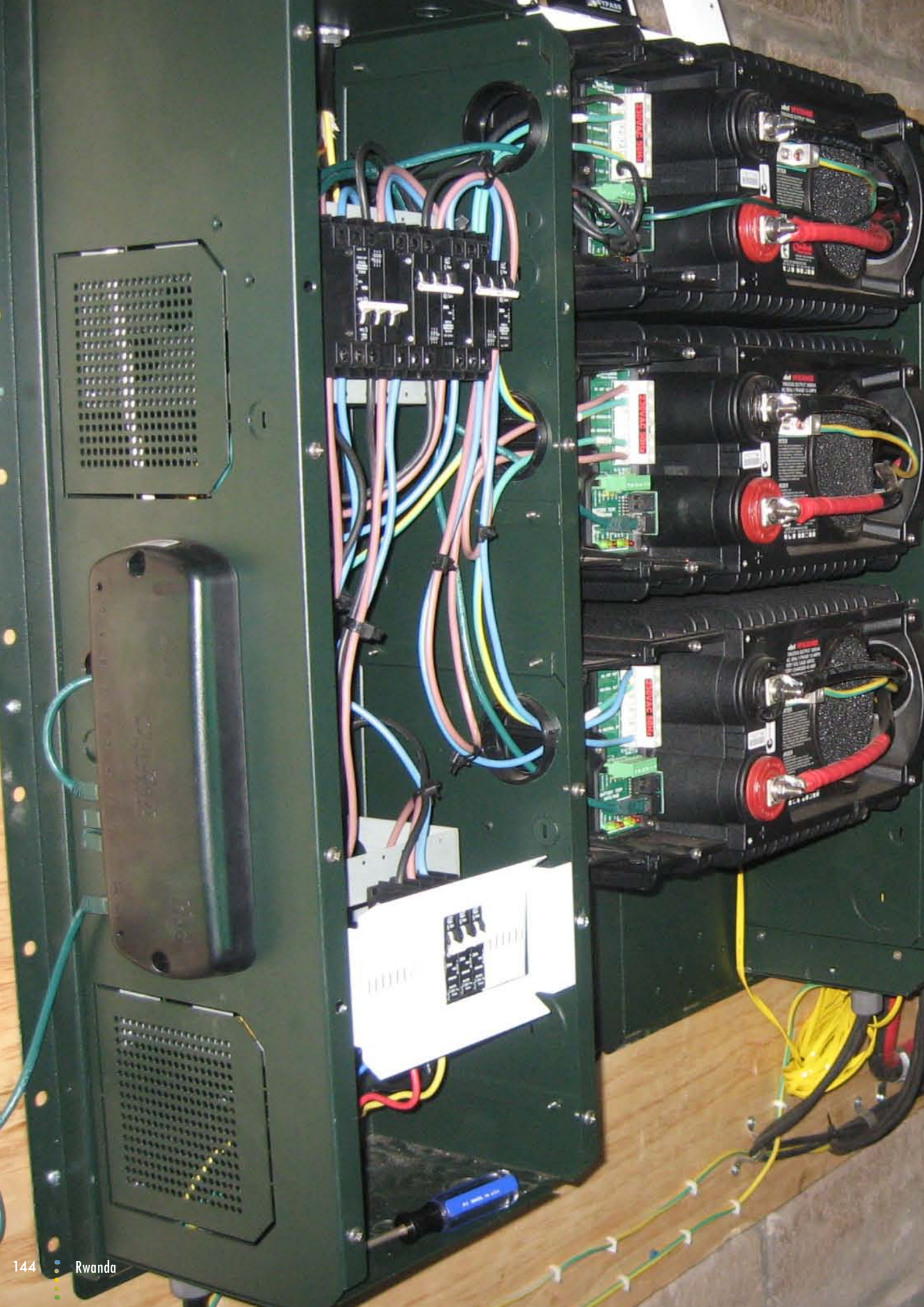

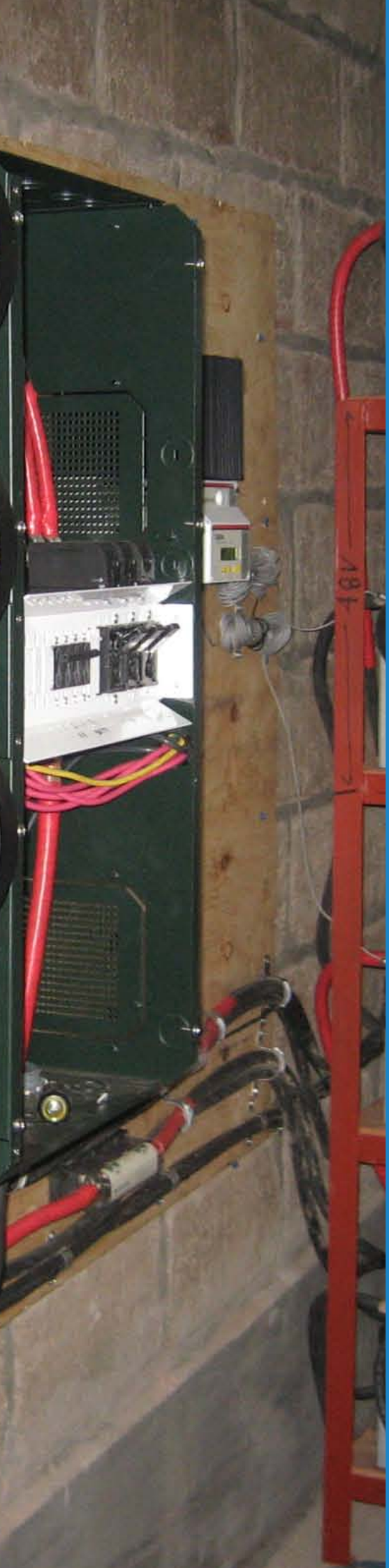

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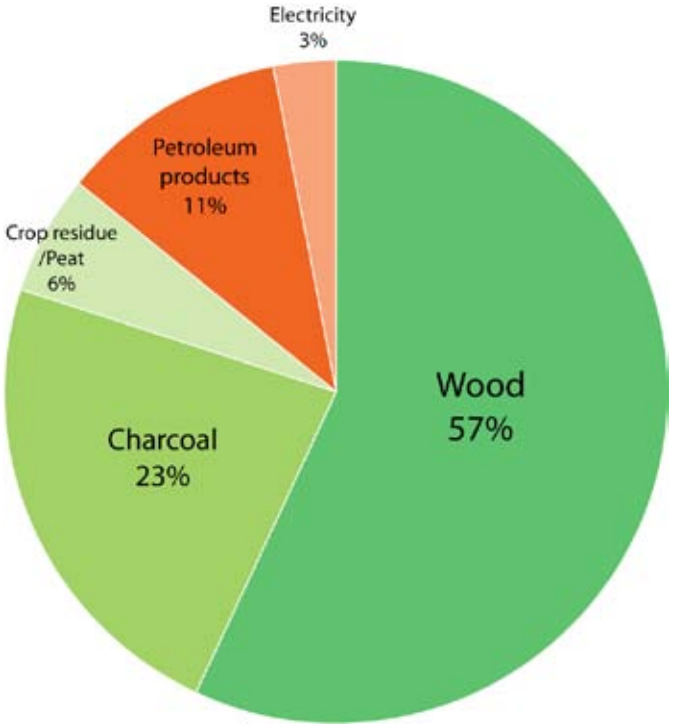
Chapter 7: Energy

7.1 Status and trends

Rwanda imports all of its oil-based products, which fuel roughly 40 per cent of Rwanda's electricity generation capacity and its entire transport sector (EWSA, 2013). As a landlocked country in equatorial Africa, transport is limited to road and air and import and export costs are very high. Any increase in oil price has a significant negative effect on GDP and economic growth (RoR, 2011a).

Figure 1: Primary energy consumption in Rwanda



Source: (MININFRA, 2014b)

Fortunately, Rwanda is endowed with both renewable and non-renewable energy sources. Non-renewable energy in Rwanda includes peat deposits and methane gas resources in Lake Kivu (both sources are under development). Renewable energy resources include hydro, geothermal, solar and sustainable biomass (MININFRA, 2015a). Together, these have the potential to exceed Rwanda's electricity needs by 2020 and replace oil-fuelled power plants. This would provide domestic energy security, reduce greenhouse gas (GHG) emissions and be a major economic stimulus, as payments abroad for oil are replaced by local expenditures for energy production and other development needs (RoR, 2011b).

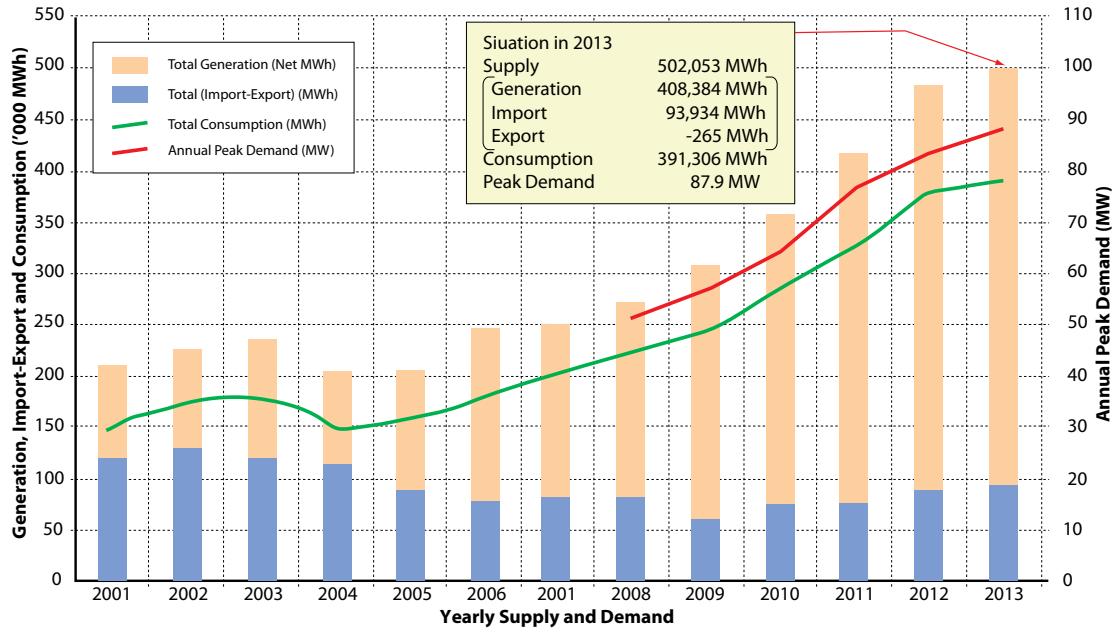
Energy consumption and production

Biomass dominates Rwanda's total energy consumption (Figure 1). The fourth EICV (2013/14) shows that 83.3 per cent of Rwandan households use wood for their cooking fuel, followed by charcoal (15.2 per cent), crop waste (0.8), gas or biogas (0.2) and other (0.6) per cent. Almost 20 per cent (19.8) of households use electricity for lighting, which is almost double the number in 2010/11 (NISR 2015).

The total equivalent installed capacity is 160 MW with an average national access rate of 23 per cent as of April 2015. The country's total estimated local electricity demand is 102 MW, while local production reached a total capacity of 103 MW. Because Rwanda has a very pronounced peak demand load, supply cannot match demand during some peak hours (MININFRA, 2015b). As part of the installed capacity, Rwanda imports roughly 15.5 MW of electricity. At the same time, Rwanda's per-capita electricity consumption is by far one of the world's lowest: it consumes about 42 kWh/year/per capita compared to 478 kWh in sub-Saharan Africa and 1,200 kWh for developing countries as a whole (AfDB, 2013).

Total energy consumption has been growing annually and according to latest statistics in 2013, peaked that year at a yearly average of 87.9 MW (Figure 2). By 2017/2018, demand for electricity is projected to reach 470 MW (MININFRA, 2015b).

Figure 2: Energy demand and supply situation, 2001-2013



Source: (MININFRA, 2015b)

Box 1: Rwanda's energy resource base for power generation

The total energy resource base for power generation is estimated at up to 1,500 MW, with the following composition:

Hydropower: 400 MW, although 98.5 MW has already been developed. The remainder, or 313 MW, is split between 130 MW of domestic hydro and ≈183 MW of regional hydro resources.

- Domestic hydro consists of small and medium-size hydropower located in specific sites and a large number of mini and micro hydro sites scattered in numerous locations.
- Regional hydropower refers to joint hydro resources such as Rusizi on the border with DRC and Rusumo Falls on the border with Tanzania. The first two phases of Rusizi have been developed and are operational, providing 15.5 MW of capacity. Rusizi III (48 MW) and Rusizi IV (98 MW) are under active consideration. Rusumo Falls could provide 20.5 MW of capacity but is in the early stage of a feasibility study.

Geothermal: Geothermal is considered the least-cost option, although the potential capacity is still to be determined. The main fields are Karisimbi, with the highest potential, and Gisenyi, Kinigi and Bugarama.

Previous scientific studies estimated the resource at 700 MW, of which 490 MW was considered feasible. However, geo-scientific studies are on-going, which will lead to the development of the necessary drilling strategy to confirm the resource. It is thus premature to estimate Rwanda's geothermal potential.

Methane: Lake Kivu has an estimated 55 billion cubic metres (bcm) of methane. There is an estimated 700 MW of potential power production capacity to be shared with DRC, of which Rwanda's share is 350 MW.

Peat: Peat resources include 40,000 ha of peat bogs of various qualities. Power production capacity is roughly estimated at 700 MW. Peat sites have been identified in Rwabusoro, Akanyaru, Murago, Gihitasi, Mashya, Gishoma, Rucahabi, Cyato, Cyabararika, Nyirabirande, Kageyo, Kaguhu, Mashoza, Gasaka, Bahimba, Bisika, Rwuya, Nyabigongo and Rugeramigozi.

Solar and Wind. Rwanda has insignificant wind potential and a moderate source of solar energy, with an average solar radiation of 4–6 kWh per square metre per day. It has had a useful experience with the 250 kW Kigali solar project and solar water heaters.

Biomass. Rwanda's energy mix is dominated by biomass, which accounts for about 85 per cent of primary energy use. Although its dependency on biomass has dropped from 95 per cent to 85 per cent in the last 20 years, the ratio is still considered too high and harmful to forest resources. The Biomass Energy Strategy for Rwanda (2009) articulates the government's objective to reduce the consumption of biomass energy from the current 85 per cent to 50 per cent of national energy consumption by 2020.

Source: (AfDB, 2013); (MININFRA, 2015b)

Although Rwanda's densely distributed population should facilitate network expansion and access to electricity, presently only 23 per cent of Rwanda's households (500,000 customers) are connected to the grid (MININFRA, 2015c). The government has launched an aggressive programme to increase access to electricity services by all sectors of the economy and all consumer categories. It started from an extremely low base (Box 1) but between 2008 and 2011, the growth in access was an impressive 160 per cent (MININFRA, 2015c). Most of the energy sources summarized in Box 1 have not yet been fully exploited.

Rwanda's high energy costs are attributed to its dependence on expensive thermal resources, in particular diesel and heavy fuel oils, which according to the Energy Sector Strategic Plan, account for approximately 40 per cent of the country's 160 MW of installed energy capacity. Hydropower accounts for 59 per cent and methane gas 1 per cent. However, with the addition of 8.5 MW of solar power recently, the share of thermal installed power has actually fallen. The GoR is targeting up to 563 MW by 2018 using methane, peat, solar photovoltaic (PV), thermal power and small and large-scale hydropower (MININFRA, 2015b), since increasing the supply,

Table 1: Existing power projects

Category	Name	Installed Capacity (MW)
Hydro (domestic)	Mukungwa	12
	Ntaruka	11.25
	Gisenyi	1.2
	Gihira	1.8
	Murunda	0.1
	Rukarara 1	9
	Rugezi	2.2
	Keya	2.2
	Nkora	0.68
	Cyimbili	0.3
	Mazimeru	0.5
	Nshili1	0.4
	Musarara	0.5
	Mukungwa 2	2.5
	Rukarara 2	2
	Giciye	4
Thermal	Jabana 1	7.8
	Jabana 2	20
	Aggreko Gikondo	10
	Aggreko Mukungwa	10
Methane	K P 1	3.6
Solar PV	Jali Solar	0.25
Hydro (imported)	Rusizi I	3.5
	Rusizi II	12
Hydro (off-grid)	Various	1.7
TOTAL		**119.4**

Source: (Adapted from EWSA, July 2014)

access and stability of electricity in Rwanda is essential for maintaining economic growth. The share of these resources will be dictated by their readiness and feasibility and be based on the recommendations of the Least Cost Power Development Plan (MININFRA, 2015b). Tables 1 and 2 show existing and planned power projects.

In addition to the projects up to 2018 listed in Table 2, the following large projects are also envisaged: Rusizi III (hydro), Rusizi IV (hydro), Rusumo (hydro), Nyabarongo II (hydro) and Akanyaru (hydro) (MININFRA, 2014a).

The generation mix, with high dependency on thermal power, has raised policy concerns, mainly because of the environmental externalities associated with diesel generation in the form of emissions and pollutants, but also because reliance on diesel imports for a substantial proportion of energy production exposes Rwanda to spikes in fuel prices (RoR, 2011b).

Current and potential energy sources

Rwanda's potential for renewable energy — micro-hydro, geothermal and solar — is considered significant (AfDB, 2013). Traditionally, hydropower has generated the bulk of electricity in Rwanda since the 1960s (MININFRA, 2015c). Future domestic generation developments for the main grid are expected to continue from both hydropower sources and thermal (heavy fuel oil and methane-based production from Lake Kivu) (MININFRA, 2014b). Geothermal and wind power resources are also being investigated, with initial geothermal estimates suggesting that further investigation of geothermal potential is warranted (RoR, 2011b).

Rusumo Falls, location of a proposed run-of-the-river hydroelectric project.

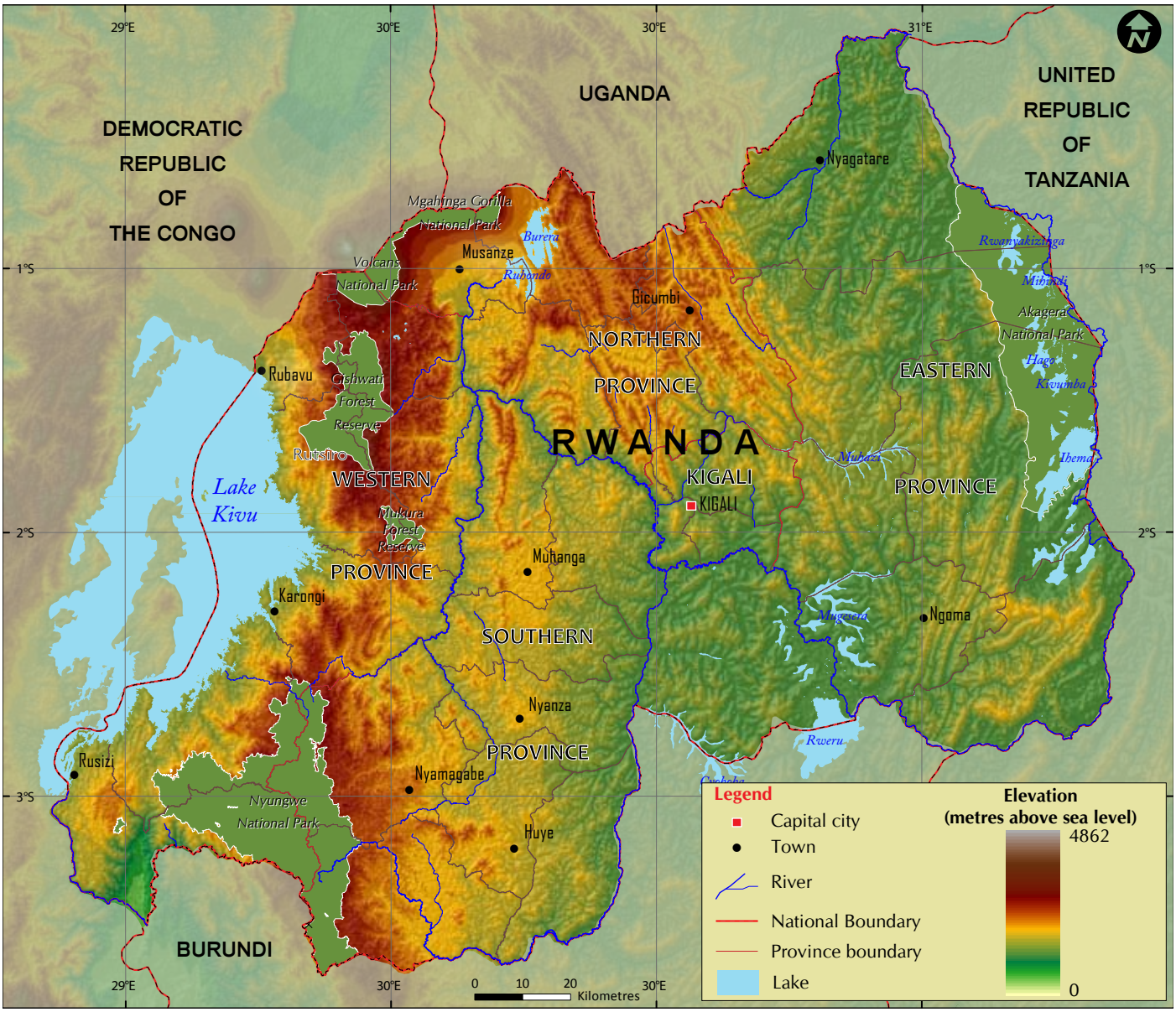
Table 2: Planned energy projects, 2013-2018

Energy source	Project	Capacity	Total Capacity
2013/14	**Installed capacity**		**119.6**
2014/15		**70.5**	**190.1**
Hydro	Mushishito HPP (Rukarara V) (Phase 1)	2	
Hydro	Nyabarongo 1 EHP	28	
Thermal	Rental (Thermal Power Plant)	4	
Solar	Rwamagana Solae Power Plant	8.5	
Methane	Kivu Watt Methane PP (Phase 1)	25	
Peat	Gishoma Peat Power Plant	15	
Hydro	Mukungwa 1 HPP	-12	
2015/16		**65**	**255.1**
Hydro	Mushishito HPP (Rukarara V) (Phase 2)	3	
Hydro	Mukungwa 1 HPP	12	
Hydro	Micro Hydro (IPPs)	10	
Solar	Rwinkwavu Solar Power Plant	10	
Import	Interconnection (Ethiopia-Kenya-Uganda-Rwanda)	30	
2016/17		**58**	**313.1**
Hydro	Micro Hydro (IPPs & REFIT)	12	
Thermal	Kigali Special Economic Zone (KSEZ) HFO	40	
Solar	Nyagatare Solar Power Plant	10	
Thermal	Rental (Thermal Power Plant)	-24	
Import	Interconnection (Ethiopia-Kenya-Uganda-Rwanda)	20	
2017/18		**251**	**564.1**
Hydro	Ntaruka B HPP	5	
Hydro	Micro Hydro (IPPs & REFIT)	14	
Solar + Bioenergy	Solar + Bioenergy (REFIT)	12	
Methane	Symbion Methane PP	50	
Peat	Hakan Peat PP (Phase 1 net Output)	70	
Import	Interconnection (Ethiopia-Kenya-Uganda-Rwanda)	100	
Total Generation/Import Capacity End EDPR 2			**564.1**

Source: (MININFRA, 2015b)

Rwanda has a significant potential to reduce both the cost and environmental impact of power generation by developing renewable energy generation sources such as hydro, geothermal and solar instead of relying on fossil fuels (RoR, 2011b). This would have major benefits in terms of reducing the cost of meeting Rwanda's development goals of increasing household access to electricity and enabling greater economic growth (IMF, 2013) as well as in achieving its green growth aims. Such a shift towards renewables would also reduce Rwanda's exposure to volatile global oil prices (AfDB, 2013). To achieve these outcomes, greater initial capital investment is required and projects will involve greater technical challenges. International financing and technical support are therefore needed to build on the internal steps that Rwanda is making towards developing green growth pathways (Blyth, Sperling, Nwamarah, & Uwella, 2014).

Figure 3: Rwanda's hilly terrain with associated rivers, ideal for hydropower

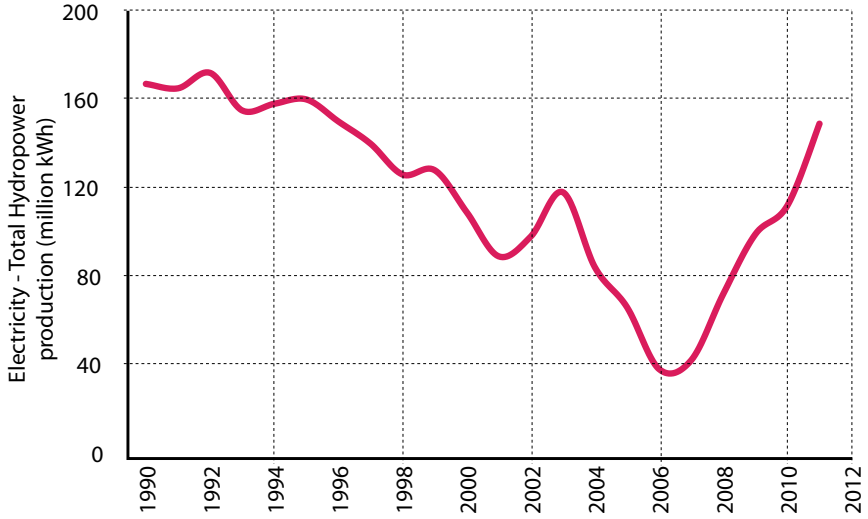


Data provided by Republic of Rwanda

Hydropower

Coupled with high rainfall (mean rainfall of 1,250 mm/year), Rwanda's hilly, and in places, mountainous terrain has very high hydropower potential (MINIFRA, 2009) (Figure 3). There has been a growing realization that electrification through mini/micro hydropower plants (MHPP) can play an important role in increasing Rwanda's capacity to generate electricity as well as in promoting socioeconomic development in remote rural areas (MINIFRA, 2009).

Figure 4: Total hydropower production in Rwanda, 1990-2012



Source: (UNdata, 2015)

Some shared hydropower projects with neighbouring countries are also underway, including a 145 MW project shared by Burundi, DRC and Rwanda and a 90 MW project to be jointly developed by Tanzania, Burundi and Rwanda (MININFRA, 2014b). To date, the majority of the mini/micro hydropower projects in Rwanda have been promoted through public schemes, which are financed by the Government of Rwanda (GoR) or by international development partners and operated by the public utility, Rwanda Energy Group (REG Ltd) (MININFRA, 2015b).

Figure 4 shows the hydropower produced in Rwanda since 1990. It can also be seen that production gradually declined until 2006 due to the continued over-exploitation of the country's hydropower resources and degradation of the Rugezi-Bulera-Rohundo watershed (Hove, Parry, & Lujara, 2011).

Rwanda's overall hydropower potential is estimated at about 400 MW, but currently the utilized hydro capacity is 98.5 MW (MININFRA, 2015b). Rwanda's domestic small-and medium-size hydropower is estimated to have a total potential of about 117 MW and is located in specific sites such as Ntaruka, Mukungwa, Gihira, Gisenyi, Rukarara and Nyabarongo (AfDB, 2013). On March 6th, 2015, a new hydropower plant (Nyabarongo I) was inaugurated and started production with a capacity of 28 MW. This is the largest domestic hydropower project in Rwanda. It makes a significant contribution to the national power grid as the country works to generate 563 MW by 2018. The current production stands at 160 MW (MININFRA, 2015c).

Biomass

Given the high energy and economic costs of Kerosene and Liquefied Petroleum Gas (LPG) for rural households, firewood and agricultural residues are used by 84 per cent of the population as the primary fuel for cooking. Eucalyptus is the primary wood source (MININFRA, 2015c). Biogas is the next major source of energy (RoR, 2011b). The internal wood market is worth more than US$150 million and is an important source of off-farm jobs (RoR, 2013). According to EICV 3, 50 per cent of urban households use charcoal compared to 3.7 per cent of rural households (RoR, 2013). Charcoal has the advantage of relatively higher energy content and can be stored. Rural areas supply the urban centres with charcoal. Some 49 per cent of the retail value of charcoal sold in Kigali stays in rural areas and 51 per cent is used to transport and distribute the charcoal product (IMF, 2013).

Biomass is the most economic option for rural households but should be used in a sustainable, safe and efficient manner. However, the biomass trade lacks clear regulation, which can sometimes stifle trade (AfDB, 2013). Cooking efficiency is low in rural households mainly due to lack of adequate technologies. Less than 50 per cent of households use improved cooking stoves (MININFRA, 2014b).

The National Domestic Biogas Programme (NDBP) was started in 2007 (Phase I). The programme's objective was to develop a commercial and sustainable domestic biogas sector, substituting firewood with biogas for cooking and increasing agricultural production by providing bio-slurry as a fertilizer (MININFRA, 2014b). As of August 2013, about 41 local companies had disseminated close to 3,365 biogas digesters to households (MININFRA, 2015c). The installation costs are borne by the consumers (on their own revenues or credit from lenders) and the government (subsidy) on a 50/50 cost sharing principle (MININFRA, 2015c). There are currently no uniform lending terms for biogas projects as previously required to protect consumers from rates higher than rate-of-return on investment (MININFRA, 2014b). The terms of lending are negotiated on a case-by-case basis depending on the negotiating position of each district (MINIRENA, 2015).

The dominant biogas plant technologies available are code-named "Rwanda I" (a foundation made of stones, round wall, dome, inlet and outlets made of bricks) and "Rwanda II" (a foundation and round wall made of stones with dome, inlet and outlet made of bricks). The cost of each technology varies, mainly depending on the size and the material inputs used in construction. The available plant sizes range between 4 m^3, 6 m^3 and 10 m^3, especially for domestic users (MININFRA, 2014b).

Geothermal

Geothermal power is a clean, renewable, reliable and large-scale energy resource. The estimated potential of the resource cannot be stated with any degree of confidence at present and it is estimated that it will take 10 years to fully develop according to the Geothermal Master Plan (MININFRA, 2015b). Its technology is already developed and it would cost four times less than diesel to generate the same electricity currently in use in Rwanda. It could be used to replace some of the oil-fuelled power plants, which currently supply 52 MW of electricity, emit high levels of GHG emissions and are vulnerable to oil price spikes. Geothermal power, however, emits almost no GHG and is thus eligible for carbon credits. It is also a fully domestic resource, not shared with neighbouring countries, and it has a relatively small land-use impact,

unlike peat. Thus, geothermal energy, together with other renewable energy sources, can provide energy security, reduce energy costs and vulnerability to external economic shocks and ultimately promote economic development (RoR, 2011b).

There are two zones with geothermal potential in Rwanda: one in the western region associated with volcanoes and the other in the southern region (Bugarama), associated with faults in the East African Rift. Based on reconnaissance surface studies, the western region has been divided into three areas with separate geothermal development prospects: Gisenyi, Karisimbi and Kinigi. It is evident from available information that Rwanda has areas that have low-temperature geothermal resources that can also be used for both power generation and direct industrial uses (MININFRA, 2014b).

Peat

Rwanda's 1993 Peat Master Plan indicates the potential to develop around 700 MW of energy from its peat resources. Rwanda has estimated reserves of 155 million tonnes of dry peat spread over an area of about 50,000 ha. About 77 per cent of peat reserves are near the Akanyaru and Nyabarongo rivers and the Rwabusoro Plains.

Peat reserves in Rwabusoro marshland and around Akanyaru River can fuel 450 MW of electricity generation for 25 years. The Rwabusoro marshland and Rucahabi in Nyanza and Bugesera districts present significant opportunities for large-scale peat harvesting for power generation (MININFRA, 2015b). A new study is underway to provide a more detailed understanding of the extent of Rwanda's peat reserves (MININFRA, 2014b).

The GoR is currently developing a 15 MW peat-to-power plant in Rusizi District in the Bugarama Sector. It is negotiating with a strategic partner to develop a 100 MW peat-fired power plant in South Akanyaru as a Public Private Partnership (PPP) (MININFRA, 2014b). It is also planning an 80 MW peat-to-power project in Rwabusoro, with an additional option for 40 MW more if successful; it will be a private initiative (MININFRA, 2014b).

Peat projects during EDPRS II

During the EDPRS II period (2013-2018), Rwanda envisages to implement the following peat projects to deliver the energy-demand-driven roadmap (MININFRA, 2014b):

- Gishoma Peat to Power (15 MW) expected to deliver in fiscal year 2015/16; and
- Hakan (80 MW), expected to deliver in 2017/18.

Gishoma is currently under construction with some works, including water and transmission lines, requiring completion. Implementation is already underway for Hakan with detailed work on hydrology and peat testing on-going. The project has the option for a 40 MW extension to be exercised at a later stage.

A peat energy strategy action plan will be prepared to further explore the resource, assess its economic potential, its environmental and social impacts and develop private sector participation. The action plan will also ascertain the optimal use of peat across a range of applications: power generation, direct industrial heat, steam applications or use as a domestic charcoal substitute. As part of the activities, the REG will undertake a detailed resource assessment of remaining existing bogs and create a national resource database.

Methane gas

The 2,400 km^2 Lake Kivu in the Eastern African Rift Zone contains high concentrations of naturally occurring methane gas (CH_4) and carbon dioxide (CO_2), with the highest concentrations at depths ranging from 270 m to 500 m. The lake's oxygenated upper layer, from the surface to a depth of 60 m, supports the lake's biology. The resource is shared equally between Rwanda and the DRC. Lake Kivu contains about 300 billion m^3 of CO_2 and 60 billion m^3 of CH_4 (MININFRA, 2014b). Rwanda wishes to develop methane-to-power projects and other uses such as fertilizer and gas-to liquids projects from the lake's methane resource. The methane in Lake Kivu is estimated to be sufficient to generate 700 MW of electricity over a period of 55 years. Rwanda's share of the total generation potential is about 350 MW, with the rest belonging to DRC. It has the capacity to generate 120 million to 150 million m^3 of CH_4 per annum, representing a power potential of 90 to 130 MW (MININFRA, 2014b).

The following are Rwanda's existing methane-to-power projects:

- KivuWatt, a subsidiary of Contour Global (USA), is developing a 100 MW plant;
- KP I, a 45 MW pilot plant developed by GoR, has been operating about 1.5 MW since late 2007 with a plan to scale-up capacity to 50 MW;
- REC (Rwanda Energy Company) is a subsidiary of RIG (Rwanda Investment Group) and is

undertaking a 3.6 MW plant project, and seeking new partners and investors to revive and scale up the project.

Solar

Located in East Africa at approximately two degrees below the equator and generally characterized by a Savannah climate, Rwanda's geographical location endows it with solar radiation intensity approximately equal to 5 kWh/m^2/day and peak sun hours of approximately 5 hours per day. In 2006, the GoR signed a memorandum of understanding with the German state Rhineland-Palatinate to construct, own and operate a 250 kWp (kilowatt-peak) grid connected solar plant; commissioning was completed in 2007 and it was installed in 2008 (MININFRA, 2014b). The plant was constructed on top of Mount Jali in Kigali City. Since its commissioning date, the plant has been operating successfully. More recently, an 8.5 MW solar PV power plant, GigaWatt, was connected to the grid in September 2014 (MININFRA, 2015a). This plant represents the largest solar on-grid PV installation in East Africa. To date, solar PV in Rwanda is almost exclusively used on a small scale for community centres in remote areas using solar panels to generate off-grid electricity (MININFRA, 2014b).

The GoR is also considering a plan to develop a 10 MW solar power plant at a 25 ha site in the Eastern Province in Nyagatare District, approximately 190 km from Kigali. The plant will be constructed on an Independent Power Producer (IPP) basis (MININFRA, 2014b).

7.2 Pressures and impacts

Impacts of biomass

Electricity sector emissions remain a relatively minor contribution to Rwanda's GHG emissions, although the rising trend may be a concern over the longer term. Since biomass consumption (wood-energy and agricultural residues) remains the main source of domestic and small-scale commercial energy, the demand for wood for fuel is a major driver of forest degradation, and subsequently the release of GHG emissions. Some sources estimate that cooking with traditional biomass fuels contributes approximately 18 per cent of current GHG emissions, if deforestation and forest degradation are included in the equation (UNEP, 2013).

The production, transport, and combustion of charcoal constitute a critical environmental and economic cost. Charcoal production releases methane — especially in the traditional open pit process (UNEP, 2013). There are two ways to improve the efficiency of charcoal production: one is to improve kiln design to improve temperature control and carbonization variables and the other is to capture the methane released from the charcoaling plant and use it to generate electricity (e.g., in a gas engine) (MININFRA, 2014b).

Impacts of hydro developments

Hydropower has important interactions with water-system management. While hydro is not considered to be particularly consumptive of water (apart from evaporation from the reservoirs), it does affect downstream river-flow rates. Thus, combining the use of water for hydropower with alternative uses such as irrigation creates complex coordination challenges. Typically, hydropower is scheduled to meet variations in daily electricity demand, which may not match the timing of irrigation uses. Conversely, irrigation will be needed in the dry season and more water may be required than would be needed for energy purposes. Coordinating these different types of demand may therefore lead to additional engineering requirements, such as extra storage, which could raise costs (Kumar, et al., 2011).

Likewise, watershed management can also have an impact on water availability for hydroelectric schemes. Part of the electricity supply crisis in the mid-2000s in Rwanda has been attributed to poor management of upstream wetlands and degradation of the surrounding Rugezi-Bulera-Ruhondo watershed (Hove, Parry, & Lujara, 2011).

To restore water levels for electricity production, the GoR sought to halt the degradation of the Rugezi-

Bulera-Ruhondo watershed and drainage of the wetlands by banning farming and grazing within and around the ecosystem, including the shores of Lakes Bulera and Ruhondo (Hove, Parry, & Lujara, 2011). Rwanda's Environment Policy (2003), National Land Policy (2004), Environment Law (2005) and Land Law (2005) provided the legal means to justify the decision.

Large hydropower schemes usually last a long time (typically 40 years) and to be cost-effective, should be generating electricity over their entire life span. Changes in rainfall patterns due to climate change, however, create a high level of uncertainty about whether there will be enough water since the climate will likely become more erratic with larger variations in seasonal and multi-year precipitation. Future water conservation requirements need to be considered when planning new hydro schemes (Blyth, Sperling, Nwamarah, & Uwella, 2014).

Impacts of peat development

Extraction of peat for energy uses has a number of potential environmental impacts. A review by the UN Food and Agriculture Organization (FAO) lists the following:

- Toxic metal release from peat;
- Eutrophication (release of excess nutrients) of surface waters;
- Increased run-off water (disturbance of the hydrological balance);
- Impacts on flooding and local fisheries;
- Release of organic pollutants;
- Changes of salt- and fresh-water systems;
- Changes in groundwater supply; and
- Air pollution and fires

In Rwanda, the main impacts are likely to be on water systems, including potential eutrophication and increased run-off, and on flood control, soil erosion and groundwater supplies in neighbouring areas. Thus, developing peat resources needs to carefully weigh these risks, and in particular, coordinate these activities with water management strategies.

7.3 Response

The Energy Sector Strategic Plan (ESSP) adopted in March 2015 aims to increase household access to grid electricity to 48 per cent and access to off-grid electricity to 22 per cent.

Furthermore, one of the three strategic objectives of Rwanda's GGCR strategy is to achieve energy security and a low carbon energy supply that supports the development of green industry and services and 2 of its 14 Programmes of Action (PoA) are to develop a low carbon energy grid and promote small-scale energy access in rural areas. In its Roadmap to Implementation, one of its aims for "Big Wins" is Low Carbon Development/Mitigation using geothermal energy (RoR, 2011b).

Although Rwanda's energy sector has greatly improved recently, there is room for further progress. According to the Rwanda Energy Policy (MININFRA, 2015a), the sector's aim is to create conditions to ensure access to modern, sustainable and affordable energy services that help to achieve sustainable growth for the country. There is a need to improve power generation, transmission and distribution and diversify energy sources to reduce costs and implement a very conducive legal and regulatory framework.

Financial and human resource requirements of the energy sector

Total financing requirements for the remaining four years (2014-2018) of the energy sector plan is estimated at roughly US$4 billion. This includes electricity generation and transmission, electricity access, Energy Efficiency (EE) and Demand-Side Management (DSM) and petroleum and biomass energy. The total financing requirements are split between the public (US$ 2 billion or 48 per cent), the private sector (US$ 1.5billion or 30 per cent), development partners (US$ 771 million or 19 per cent) and district contributions to the Electricity Access Roll-out Programme (EARP) (US$87 m or 2 per cent) (MININFRA, 2015b).

The total expenditure on electricity investments is estimated to be 81 per cent of the overall energy sector financing requirements. Roughly two-thirds of this is required for generation and transmission activities to deliver the 563 MW. The remaining one-third is earmarked for electricity access to reach the combined 70 per cent electricity access target (MININFRA, 2015b).

The remaining 19 per cent is mainly consumed by petroleum activities at 18 per cent, and the rest is required for biomass and EE and DSM activities. For biomass energy, resources will mainly be directed to meet the cost of the government's subsidy for the installation of biogas digesters as well as awareness and sensitisation programmes (MININFRA, 2015b).

REMA

Energy sector progress also depends on the appropriate development of human resources. Today, there is a lack of trained and skilled energy experts in the sector (AfDB, 2013). There is therefore a need to encourage and facilitate training in various disciplines necessary for the energy sector's development: local communities, stakeholders of civil society and the private sector (AfDB, 2013). Local investors in micro hydropower generation should continue to be encouraged to boost on-the-job training and is essential for spillover effects (Nkulikiyinka, 2008).

The regulatory framework for the energy sector

Rwanda has a relatively comprehensive and progressive regulatory framework and has established agencies to work cross-sectorally to develop the energy sector according to the EDPRS II and Vision 2020.

Energy Sector Strategic Plan (Energy SSP)

The government has fully recognized that the availability of a reliable power supply is not only a

Table 3: ESSP high-level target objectives

ESSP high-level target objectives
• Increase the electric power system equivalent installed capacity (domestic generation + imports) to 563 MW.
• Increase household access to grid electricity to 48 per cent and access to off-grid electricity to 22 per cent.
• Achieve savings from energy efficiency measures of 10 per cent through demand-side management measures and grid-loss reductions (from a 2013 baseline).
• Reduce the carbon intensity of the grid by 10 per cent by 2018, and 25 per cent by 2025 (from a 2013 baseline).
• Ensure 80 per cent of all households employ clean cooking energy technologies.
• Realize all EAC Regional Integration Policy priorities for the energy sector.
• Ensure the necessary infrastructure is in place to meet current petroleum strategic reserve requirements (currently 3 months supply)

Source: (MININFRA, 2015b)

Table 4: Sustainable Energy for All (SE4ALL) strategic targets

Sector	Target
Access to clean and sustainable cooking	1. To close the gap (currently about 20%) between production and consumption of biomass to make it a sustainable source of energy 2. To supply a growing and urbanising population with clean supplies of biomass for cooking, requiring: a. 100% access to much more efficient cookstoves than currently used b. Reduction if losses from charcoal by improving charcoal production and promoting alternatives such as biomass pellets and biogas c. Increasing production by improving forestry management 3. To ensure that the efficient cookstove solutions noted above address health issues by significantly reducing indoor pollution
Access to electricity	1. To achieve 100% electricity access: By 2025, all households will have at least basic levels of access (Tier 1 and above), and by 2030, all households will have at least moderate access to electricity services (Tier 2 and above). 2. Progress to higher quality and quantity of electricty over time, with >50% of the population having Tier 3-5 access by 2030
Renewables	1. Exceed the global SE4All target (26%) of renewable energy as a percentage of the primary energy supply 2. Exceed the global SE4All target (44%) of renewable electricity generation as a percentage of total electricity generation
Energy efficiency	1. At least double the efficiency of biomass energy use 2. Extend current rates of electrical efficiency improvement to 2030

Source: (SE4ALL AA, 2015)

pre-requisite for economic growth but also for social prosperity and human development. Thus, it launched an aggressive programme to increase all economic sectors' and consumer's access to electricity services (RoR, 2000). The Rwanda Energy Policy (REP) and Energy SSP were developed and approved by Cabinet in March 2015. The REP sets out the vision for the energy sector, while the SSP sets out how this vision will be implemented. The SSP defined the high level targets shown in Table 3.

Sustainable Energy for All (SE4ALL)

In addition to the government's policy package (REP and SSP), the first long-term strategic document has been developed for the energy sector under the Sustainable Energy For All framework (SE4ALL): The SE4ALL Action Agenda. It is only at the final draft stage, but sets out key high-level strategic targets for up to 2030 and defines the actions necessary to reach these targets (Table 4).

Conclusion

Presently, Rwanda imports all of its oil-based products. It is endowed with ample non-renewable and renewable energy resources, however, that together could exceed its electricity needs by 2020 and replace oil-fuelled power plants. Attaining this goal would provide domestic energy security, reduce greenhouse gas (GHG) emissions and stimulate the economy. Advancements in the energy sector represent an important milestone in attaining the economic development goals in Vision 2020 and the EDPRS II. Establishing an energy sector that produces, transmits and distributes energy reliably, sufficiently, cost-effectively, sustainably and to all Rwandans represents one of the primary strategies that will help sustain private sector and industrial growth, empower economic activities in rural areas and help to achieve the resource-efficient and low carbon targets in the GGCR strategy.

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Part II
Greening Agriculture

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Chapter 8: The State of Rwanda's Agriculture Sector

8.1 Status and trends

The importance of agriculture to the Rwandan economy and livelihoods

The agriculture sector dominates Rwanda's economy and the majority of households are engaged in some sort of crop or livestock production. The agriculture sector is therefore widely regarded as the major catalyst for growth and poverty reduction.

In 2014, agriculture's share of Gross Domestic Product (GDP) was 33 per cent (NISR, 2015a). Between 2008 and 2013, agricultural GDP grew at an average annual rate of 5.4 per cent (World Bank, 2015). Table 1 shows the trend in the various agricultural sectors' contributions to GDP in Rwandan francs from 2006 to 2013, illustrating the increase across all sub-sectors except export crops, which suffered a small decline.

Table 1: Trend in agriculture's contribution to GDP (in billions of RWF), 2006-2013

Sector	2006	2007	2008	2009	2010	2011	2012	2013
Gross Domestic Product	2,649	2,851	3,170	3,368	3,579	3,846	4,127	4,316
Agriculture	965	990	1,053	1,135	1,193	1 244	1,278	1,317
Foods crops	634	660	701	767	805	845	872	899
Export crops	86	61	79	67	76	79	71	76
Livestock	104	107	109	113	118	122	128	129
Forestry	159	165	171	175	180	185	192	197
Fisheries	12	12	13	13	14	14	14	15

Source: (RoR, 2015)

The agricultural sector employs over 70 per cent of the working population and is characterized by low productivity and low economic value (NISR, 2014a). Almost 90 per cent of households practice traditional subsistence agriculture, mainly on narrow plots of land exhausted by continuous utilization (RoR, 2013). Between EICV 2 (2005/06) and EICV 3 (2010/11)), the percentage of small farmers who rely on wage labour increased from 22 per cent to 35 per cent (NISR, 2012). Most of those whose work is related to farming are poor, live in rural areas, have low levels of education, are underemployed and work an average 26 hours a week (RoR, 2013).

The agriculture sector accounts for almost half of aggregate household income and much more for poor households, and meets about 80 per cent of national food needs. It is also one of the main foreign currency earners, accounting for about 55 per cent of export goods (Hernandez, 2013).

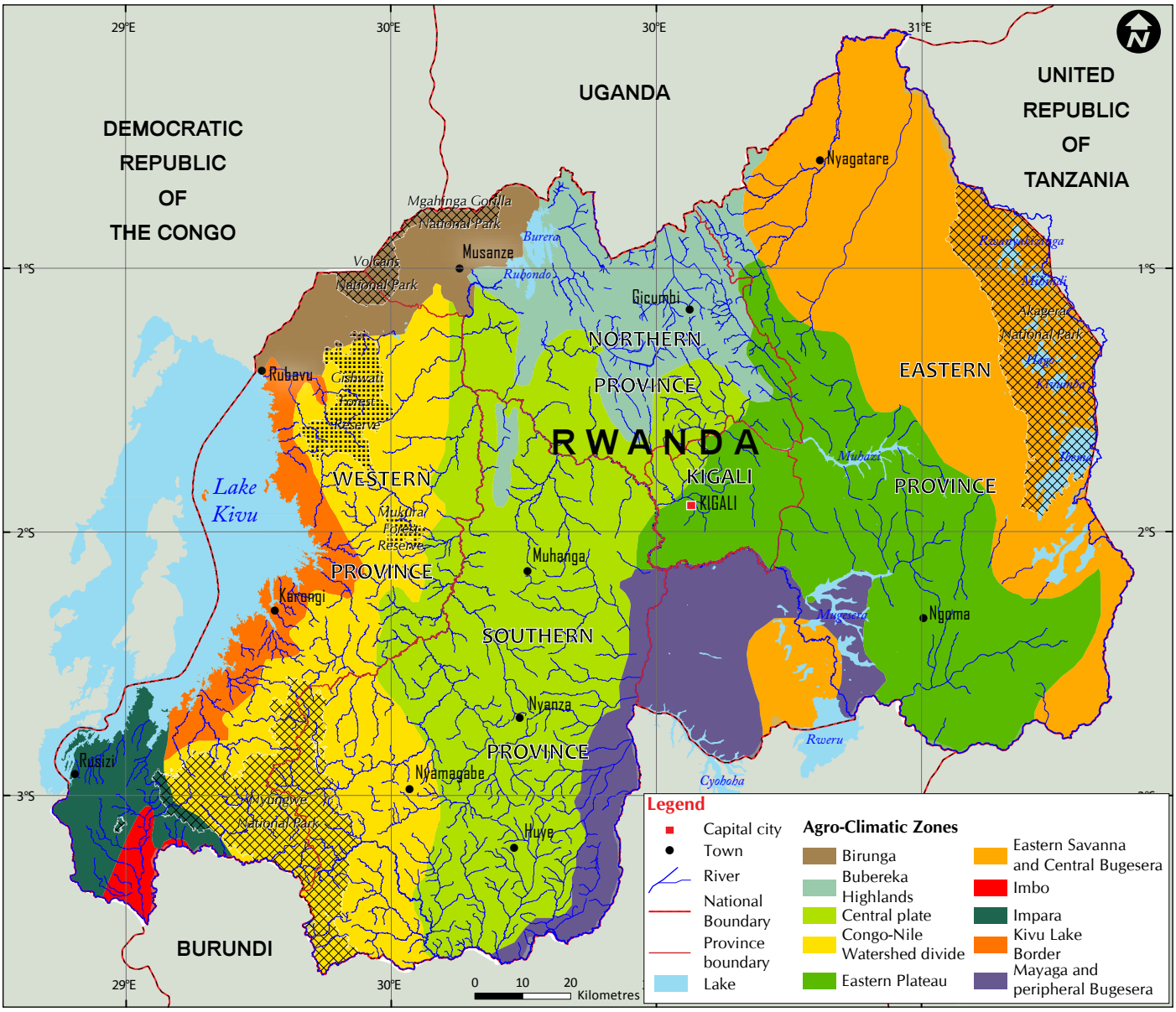
Women in the agriculture sector

As farmers, labourers and entrepreneurs, women in developing countries are a crucial resource in agriculture and the rural economy. They typically grow crops, tend animals, process and prepare food, work for wages in agricultural or other rural jobs, collect fuel and water, engage in trade and marketing, care for family members and maintain their homes. These tasks are essential to the well-being of rural households, but many are not defined as "economically active employment" in national accounts. In addition, women face more severe constraints than men in access to productive resources, which contributes to agriculture's underperformance in many countries. Rwanda's goals for agricultural development, economic growth and food security will be strengthened and accelerated by building on women's contributions and alleviating these constraints (FAO 2011).

In 2012, women represented the majority of agricultural workers: 82 per cent of women work in the sector compared to 63 per cent of men (NISR, 2014c). They especially dominate subsistence farming (RoR, 2012).

Women farmers in a coffee field.

Figure 1: Agro-climatic zones



Source: (Mutanganda et al. 2010)

Agricultural wage labourers are among the poorest in the country and tend to combine waged farm work with independent farm work (NISR, 2012). About 75 per cent of Rwandans obtain more than 30 per cent of their income from farm wage work and more women than men are in this category. Over the past decade, there has been a trend towards men moving to off-farm employment, leaving more women involved in agricultural subsistence production (RoR, 2013).

Just over two-thirds of households keep livestock; women farmers are less likely to own livestock than their male counterparts. Levels of land ownership appear to be equal among male- and female-headed households, although female heads are more likely to have rented or sharecropped land. Compared with adult women, almost twice the proportion of adult men sells small crop harvests regularly or occasionally (NISR, 2014c).

Geographical context for farming in Rwanda

Rwanda's altitude, climate and rainfall regimes are favourable for many crops, and with 12 main agricultural regions each with different conditions, the country has a diversity of areas suited for a range of different crops (REMA, 2010a) (Figure 1).

Potatoes and wheat are generally grown in highland areas (2,000-2,800m); coffee, sweet potato, banana and sorghum characteristically grow in the middle slopes (1,800-2000m); and lowland areas (<1,800m) are most suited to soya beans and rice. Banana and sorghum are culturally important crops because they are used to make local beers and provide income for smallholder farmers (Gapusi, et al., 2013).

Climate

Rwanda's climate is moderate, with an average temperature of 20°C, and rainfall is generally abundant, occurring in two rainy seasons and varying between 900 and 1,600 mm. Agriculture is still predominantly rain-fed. Rwanda also has abundant water resources distributed in a dense hydrological network.

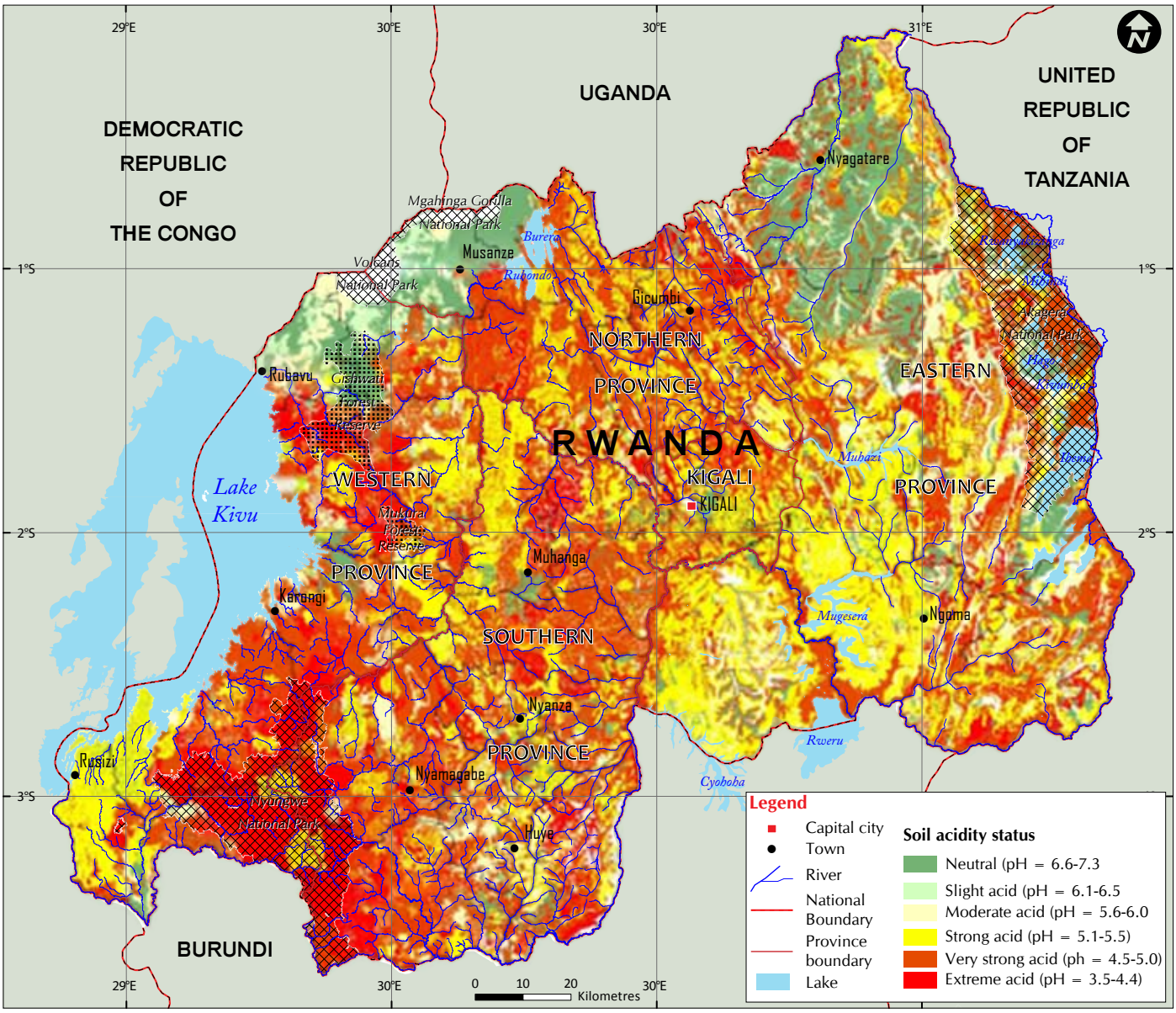
There are three agricultural seasons in Rwanda: the first begins in September of one calendar year and ends in February of the following calendar year; the second starts in March and ends in July of the same calendar year; and the third begins in August and ends in September of the same calendar year (NISR, 2014b). In Rwanda's Seasonal Agricultural Survey (SAS), they are called Seasons A, B, and C (NISR, 2014b).

Soils

Rwandan soils are naturally fragile. The rich volcanic soils in the northwest (highlands at more than 2,000 m) are generally fertile and allow cultivation of a wide range of food crops (for example, maize, potato, banana, beans, sorghum, green peas and wheat); acidic soils of Congo-Nile Crest (1,500-1,700 m) are suitable for certain other crops, such as tea, and soils in the larger river valleys and extensive wetlands are the most fertile. Most volcanic soils in naturally forested areas, such as the Volcanoes National Park and the Gishwati forests, are high in nitrogen (Nzeyimana, Hartemink, & de Graaff, 2013).

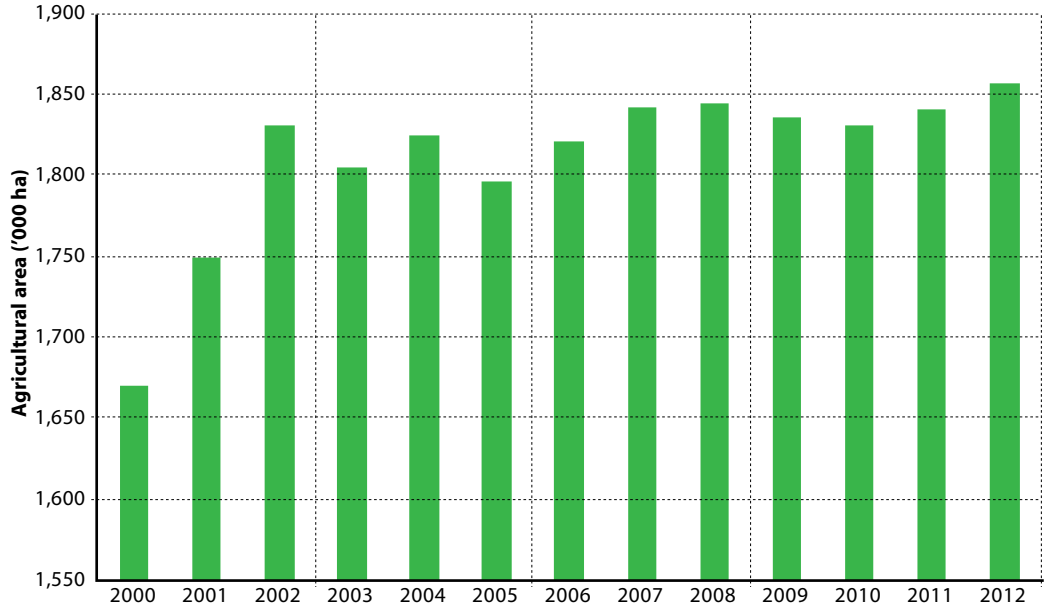
The eastern lowlands have relatively fertile soils, but because of the long dry season, crops require irrigation. In many highland areas, the deep soils are typically acidic (with a pH of less than 5.0) because nutrients have been leached away. Aluminium is very soluble in soils with low pH levels, making the soil toxic to plants, inhibiting growth and often leading to high soil phosphorus fixation. Deforestation and tillage rapidly deplete organic matter in highland soils, threatening the viability of long-term cultivation

Figure 2: Soil acidity map (percentage)



Source: (Nabahungu, 2013)

Figure 3: Trend in the land area devoted to agriculture, 2000-2012



Source: (FAOSTAT, 2015)

(REMA, 2010a); (Nzeyimana, Hartemink, & de Graaff, 2013).

It is thought that about three-quarters of Rwanda's soils are acidic, with a pH below 5.5 (Figure 2). Soils in the central and southern regions are often deficient in nitrogen (Nzeyimana, Hartemink, & de Graaff, 2013). Nitrogen deficiency causes soil erosion and quick mineralization (Nabahungu, 2013). In most soils, but particularly those resulting from volcanic deposits, phosphorus is the main limiting nutrient for crops. About 87 per cent of soils have a pH of < 5.2 and are deficient in phosphorus (Nzeyimana, Hartemink, & de Graaff, 2013).

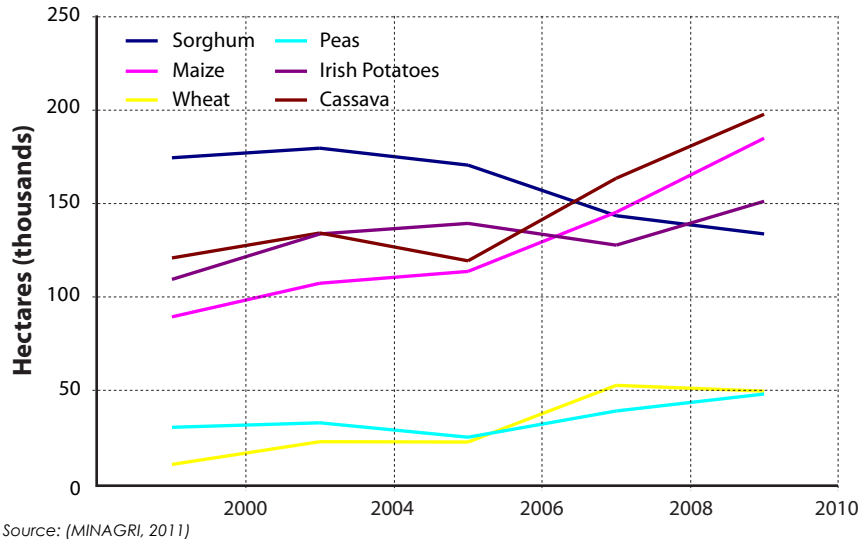
Table 2: Land use, 2013

Land use	Land area (km^2)
Intensive hillside cropland (50-100% cultivated)	15,350
Intensive marshland cropland (50-100% cultivated)	551
Extensive cropland (15-50% cultivated)	1,928
Non-cropland (0-15% cultivated)	739
Cities and towns (0-15% cultivated)	477
Water	1,302
National parks (defined by political boundaries)	2,190
Marshland, riverbed with potential for rice (0-15% cultivated)	792
Forest	1,722
Tea plantation	232

Source: (NISR, 2014b)

Terranced hills

Figure 4: Area of land devoted to staple crops, 2000-2010



Source: (MINAGRI, 2011)

Land use by agriculture

Land productivity is generally low on rainfed croplands, because of low inherent soil fertility, severe nutrient depletion, poor soil structure and inappropriate soil management practices.

With a growing population and the landscape already covered with farms, pastures and woodlots, land availability is a major constraint to increasing agricultural productivity (NISR, 2012). Figure 3 shows a very marginal increase in the total area occupied by agriculture.

In 2002, there were about 1.4 million hectares of arable land; this area has remained fairly stable, with the cultivated area increasing by only 1.4 per cent between 2001 and 2011 (Hernandez, 2013). From 2006 to 2010/11, the area of marshland used for agriculture grew from 11,000 ha to 17,363 ha (MINECOFIN, 2012). The 2013 SAS revealed that by far the largest land use (of all land uses) was intensive hillside cropland, covering 15,350 km^2 or 1.5 million hectares (Table 2) (NISR, 2014b).

As the population increases, not only does the size of landholdings fall, but also they are increasingly fragmented into small plots (USAID, 2013). One-half of the population currently holds less than 0.33 ha, which significantly restricts both land productivity and the ability of a large proportion of the rural population to escape poverty (RoR, 2013). A Rwandan household requires an average of 0.9 ha of productive land to feed a family without having to take a job off-farm (World Bank, 2014a).

Typically, subsistence farmers rotate crops, intercrop with other plants — often more than four crops may grow on the same plot at the same time — and use land in different micro-niches as strategies to cope with land scarcity and to minimize the risk of crop failure (World Bank, 2012); (REMA, 2010a); (USAID, 2013).

Food crops are grown on almost 70 per cent of cultivated land, reflecting the subsistence nature of agriculture in Rwanda. In 2012, roots and tubers represented the largest share of food crops at 53 per cent, followed by bananas at 28 per cent, fruits and vegetables (8 per cent), cereals (7 per cent), and pulses, including beans and peas, at 4 per cent (Hernandez, 2013). Figure 4 presents the trend in the area of land covered by staple crops, according to data available for different time periods, showing a significant rise in the area growing cassava, potatoes and maize since 2006.

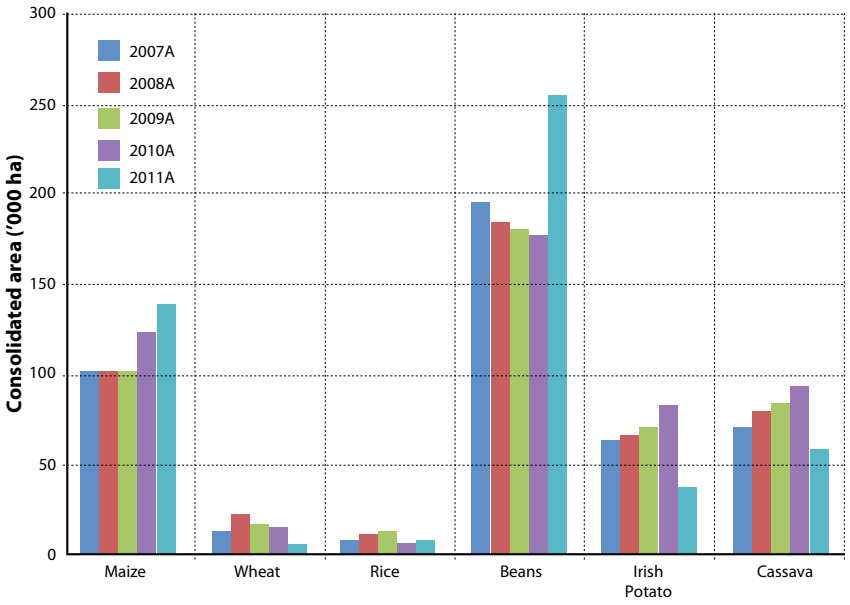
Crop intensification and land consolidation

In an effort to achieve food security, in 2007, the Government of Rwanda developed a plan to improve agricultural productivity under PSTA II through the Crop Intensification Programme (CIP). It aims to increase the access and affordability of agricultural inputs, such as lime, composts, chemical fertilizers and improved seeds, through a subsidy program. Twigire Muhinzi, a village-level farmer-to-farmer extension model introduced in 2014, is improving harvesting, post-harvest handling (cleaning, drying and packing) and storage practices; creating awareness through hands-on training to farmers; establishing appropriate storage facilities and irrigation equipment across the country; and providing access to community storage facilities to facilitate agroprocessing and marketing in rural areas (RAB, n.d.a). The land consolidation aspect of the programme focused on six priority crops: maize, wheat, rice, Irish potato, beans and cassava. Farmers synchronized crop cultivation in consolidated lands that were rearranged to form larger and more rational holdings (Kathiresan, 2012).

Before consolidation could take place, however, land tenure had to be regulated by demarcating land and identifying ownership, a process that began in 2005 and that saw large amounts of state land converted into privately owned or leased land. Between February 2010 and August 2013, 10.3 million land parcels were demarcated and adjudicated (Gillingham & Buckle, 2014). A key part of EDPRS II is to complete the process by finalizing formal property rights.

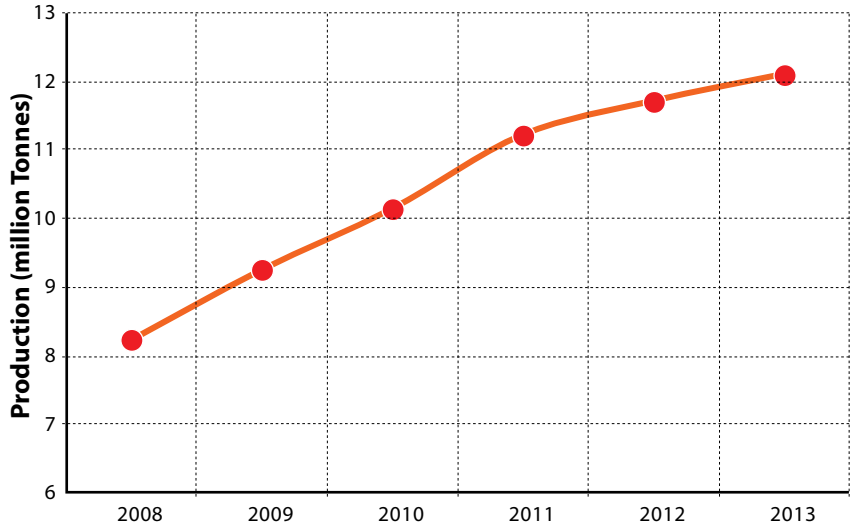
At the beginning, many farmers opposed the land consolidation programme, but its advantages soon

Figure 5: Recent trends in consolidation of land use areas under cultivation of priority crops in Season A



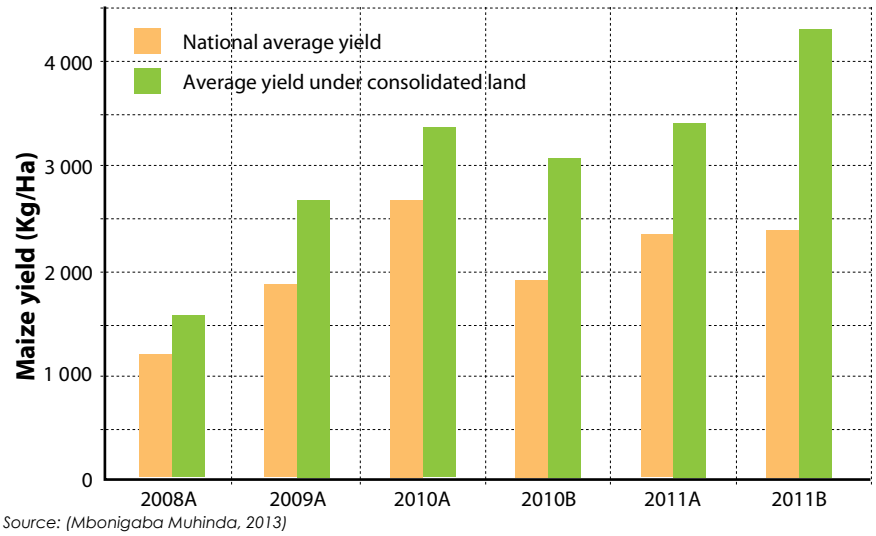
Source: (Kathiresan, 2011)

Figure 6: Trend in total annual crop production, 2008-2013



(NISR, 2014b)

Figure 7: Trend in maize yields, national average versus consolidated land, 2008-2011



Source: (Mbonigaba Muhinda, 2013)

became apparent: it reduces the volume-to-cost ratio and the logistics and transportation costs of inputs and outputs; fosters a concentrated market for farm produce; increases access to extension services; allows a more equitable sharing of land and water resources; and increases crop productivity (Kathiresan, 2011).

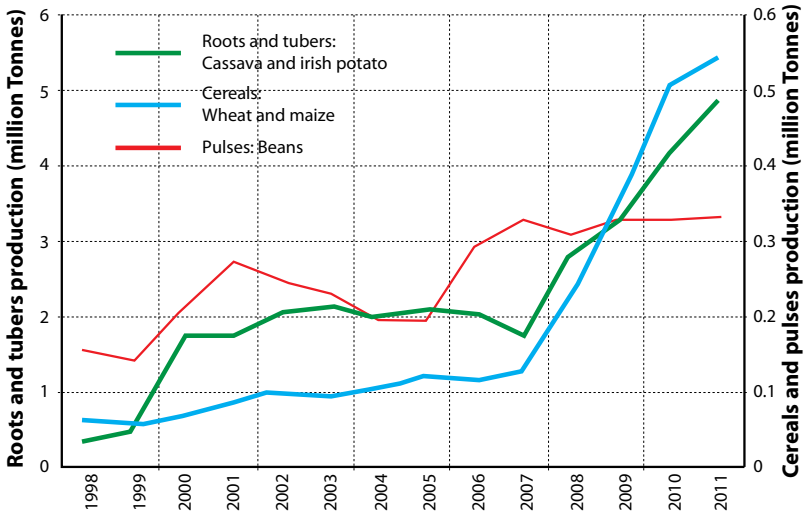
According to EICV 3 (2010/11), land consolidation affected about 27 per cent of households (NISR, 2014a). Without expanding the total area under crops, the consolidated use of land area under crops generally increased from 2007 to 2010 (Figure 5) (Kathiresan, 2011).

Agricultural productivity

Land use consolidation involves successfully rearranging land parcels to consolidate the use of farm holdings. Farmers in a given area need to grow specific food crops in a synchronized fashion that will improve productivity and environmental sustainability. It also required resettlement of family housing in an administrative area (Umudugudu) removed from the agriculturally productive lands (Kathiresan, 2011). Land consolidation, fertilizer use and efforts to prevent soil erosion led to an increase in yields of all food crops from 1998 to 2011 (MINECOFIN, 2012). Between 2001 and 2006, food crop output increased by 5.4 per cent. During the next five years, between 2006 and 2011, it almost doubled to 9.8 per cent (Hernandez, 2013). Figure 6 shows the rising trend in total crop production from 2008 to 2013.

The EDPRS II notes the significant contribution the Crop Intensification Programme had on improving productivity (RoR, 2013). To illustrate this impact, Figure 7 shows the correlation between consolidation and a trend in increasing maize yields compared to the national average yield.

Figure 8: Trend in crop production, 1998-2011



Source: (Mbonigaba Muhinda, 2013)

Production trends

The majority of farming households in Rwanda are engaged in growing a wide diversity of crops; they usually focus on at least one staple crop and the majority also produces a range of fruit and vegetables. The main food crops are bean, maize, rice, banana, Irish potato, cassava, sweet potato, sorghum, wheat and soybean and a variety of fruits and vegetables. Coffee, tea and sugar cane are the most important income earners, although pyrethrum, grown in the north, is an increasingly significant cash crop (see below). Farmers generally also grow forage and agroforestry species and some may include indigenous vegetables and medicinal plants (Gapusi, et al., 2013).

Between EICV 2 (2005/06) and EICV 3 (2010/11), the proportion of cultivating households growing maize, Irish potatoes and taro rose, accompanied by bigger harvests of these crops, while the percentage growing sweet potatoes, beer bananas and sorghum declined along with harvests, except for the amount of sorghum produced, which remained about the same (NISR, 2012).

Between 2000 and 2015, agriculture production almost doubled, with most of the increase occurring after 2007. Agricultural GDP grew at 5.4 per cent a year between 2008 and 2013, while the value of food crops rose by 6 per cent a year. The percentage increase in yields of priority crops from 2008 to 2013 were as follows: maize: 225 per cent; wheat: 129 per cent; cassava: 90 per cent; potato: 66 per cent; bananas: 62 per cent; and rice: 34 per cent (World Bank, 2015).

Figure 8 illustrates the impressive gains made by cereals, roots and tubers, beginning in 2007, with the harvests of beans increasing to a lesser degree (MINECOFIN, 2012).

Rice cultivation

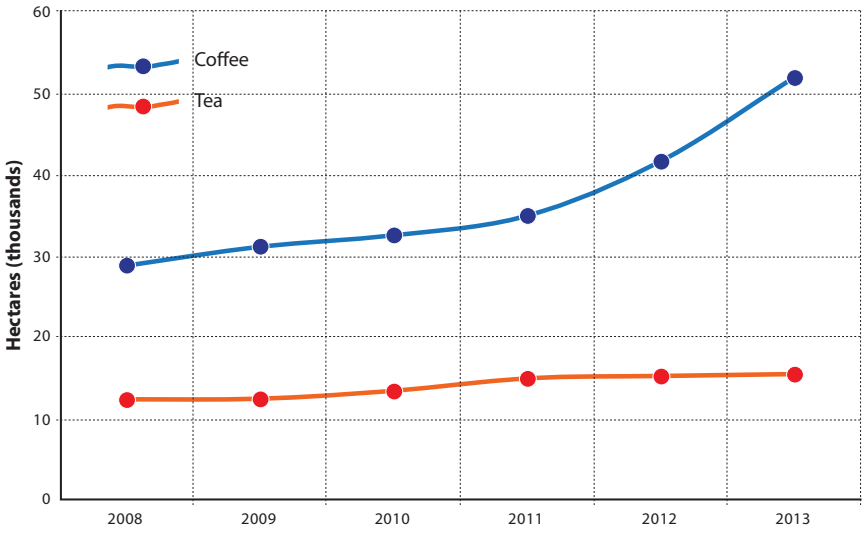
Given Rwanda's geographic conditions, rice is grown mostly in its marshlands, which are well suited to the crop. Rice is a vital food crop and income source for smallholder farmers. It is the main staple grown on developed wetlands (Harindintwali, 2012); (Ruganzu,

Rice fields in a marshland.

Shirimpumu, & Mutegi, 2015). In 2012, annual rice consumption was about 104,000 tonnes, of which some 48,000 tonnes were derived from imports. Rice yield grew from 4.4 t/ha in 2005 to 5.5 t/ha in 2012 (Ruganzu, Shirimpumu, & Mutegi, 2015).

In 2013, 70,353 people were engaged in rice cultivation. Rice farmers belong to a total of about 100 cooperatives, each of which includes the rice farmers within a specific watershed (Box1). Through Rwanda's Rural Sector Support Programme (RSSP) and the National Rice Policy (NRP), Rwanda is helping communities to develop and improve sustainable rice cultivation. The NRP's goal is that rice production becomes self-reliant and competitive; the RSSP's purpose is to convert marshlands to rice fields to increase rice cultivation and yields (Blach, Mwiza, Dusabimana, & Muzungu, 2014).

Figure 9: Land area under production of coffee and tea, 2008-2013



Source: (NISR, 2014a)

Table 3: Coffee exports, 2011-2013

2011		2012		2013	
Export (Kg)	**Export revenues (USD)**	**Export (Kg)**	**Export revenues (USD)**	**Export (Kg)**	**Export revenues (USD)**
15,596,618	74,604,393	16,989,730	60,886,260	19,969,713	55,204,349

Source: (NAEB, 2012b); (NAEB, 2013)

Cash crops

Coffee and tea are Rwanda's major export crops for the international market; hides, skins and pyrethrum are other predominant cash crops that reach mainly regional markets. The land under coffee production has been increasing since about 2011 while the area of tea crops has remained fairly stable (Figure 9) (NISR, 2012).

Rwanda continues to focus on producing and exporting tea, coffee and pyrethrum, while it promotes the expansion of emerging cash crops such as horticultural products, including a variety of fruits and vegetables; flowers (mainly fresh roses); essential oils like pyrethrum and patchouli; dairy, meat, poultry, and fish products; and stevia, a plant with sweet properties increasingly sought after to replace sugar (RDB, n.d.).

Coffee

Most of the suitable land for coffee is located on the borders of Lake Kivu and in the central part of the country. Coffee is mainly grown by smallholder farmers on plots of less than one hectare; it is intercropped with annual food crops to diversify production and ensure food security. In 2002, the GoR instituted a National Coffee Strategy to promote the cultivation and production of high-quality coffee through new higher-yielding varieties and improved cultivation and soil management practices (NAEB, 2012a). In addition, every year the National Agriculture Export Board (NAEB) trains some 10,000 coffee farmers in Farmer

Picking coffee beans.

noodlepie / Flickr / CC BY-NC 2.0

A farming cooperative threshing rice.

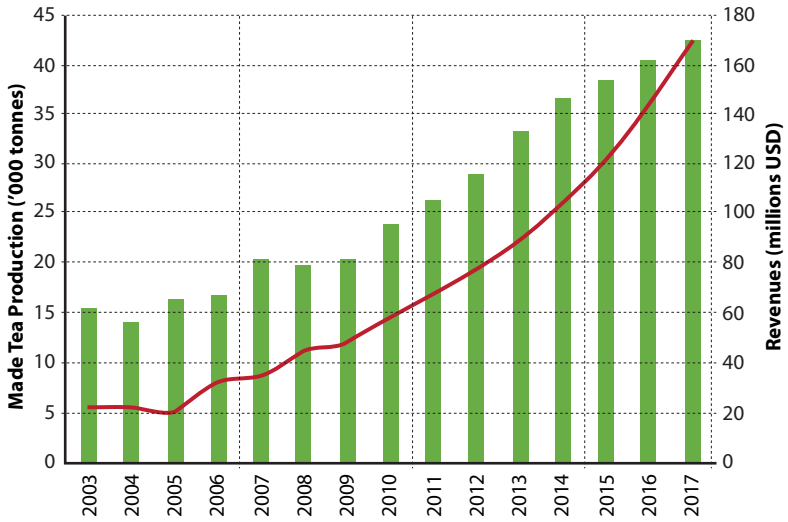
Box 1: Cooperative rice farming in the Muvumba marshland

The Muvumba marshland is in Nyagatare District in the Eastern Province. The dammed water flows into a main channel and a secondary one to irrigate about 1,750 ha of rice production. The rice fields are owned by the Muvumba Rice Growers Cooperative, which engages in best rice management practices, supported by the Ministry of Agriculture and extension services. Farmers use improved seed varieties, practice timely weeding and fertilization and ensure the irrigation system functions properly (Ruganzu, Shirimpumu, & Mutegi, 2015).

There is an approved plan to build a multipurpose Muvumba dam to collect water on a catchment area of 942.7 km^2, of which 62 per cent is located in Uganda, for domestic, irrigation, livestock and hydropower uses (RNRA, 2015).

The images, from Google Earth, show the changes that have taken place within the Muvumba Marshland. The two insets (inset 1 and inset 2) are high resolution change pairs representing the change between 2006 and 2014. In both cases, productive farms now occupy land that was previously marsh.

Figure 10: Rwanda tea sector: recent and projected trends in production and revenues, 2003-2017



Source: (RDB, 2010)

Field Schools (RoR, 2013). As a result, between 2002 and 2011, coffee production increased by 20 per cent and coffee exports by 15 per cent. In 2010, coffee production covered 2.3 per cent of total cultivated land and produced 19,320 tonnes (NAEB, 2012b) and between 2000 and 2010, the price farmers received for their coffee cherries increased from RWF 250 to RWF 1,200 per kg (Nzeyimana, Hartemink, & de Graaff, 2013). Table 3 shows the trend in coffee exports and values from 2011 to 2013.

Tea

Since its introduction to Rwanda in 1952, tea production has increased steadily. Rwanda's tea grows on hillsides at altitudes of between 1,900 and 2,500 m and on well-drained marshes between 1,550 and 1,800 m (NAEB, 2012a).

Tea is Rwanda's second-largest export earner (RDB, 2012). In 2013, tea exports were valued at US$56,243,600 (NAEB, 2013). Almost all the tea (97.3 per cent) is exported in raw form. Exports have been rising gradually, from about 20 thousand tonnes in 2008 to just over 24 thousand tonnes in 2011 (NAEB, 2012). Figure 10 shows the significant rise in tea production from 2003, with the projection to 2017 showing continued increases.

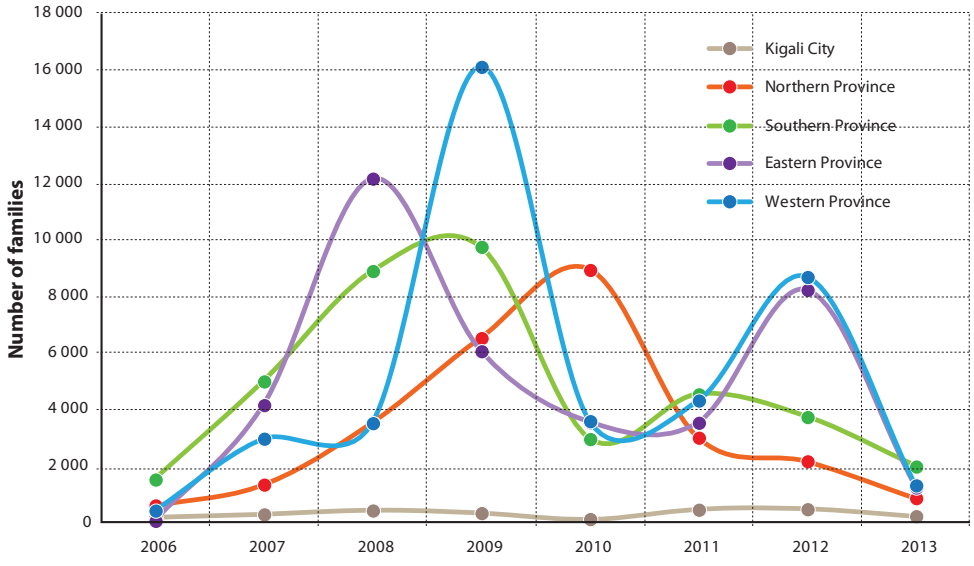
Horticulture

Rwanda's horticulture sector comprises fruits and vegetables, among which the most important are avocado, citrus fruits, mango, pineapple, passion fruit, tomato, sweet and hot peppers and eggplant (REMA, 2010a). A number of other important plant species are amarante, pumpkin, garlic, pepper, cabbage, sunflower and onion (Gapusi, et al., 2013). From 2011 to 2013, vegetable production increased by 9 per cent and fruit production by 18 per cent (NISR, 2014a). In 2013, vegetable exports were valued at US$9,250,839 (NAEB, 2013).

Livestock

Keeping livestock is an integral part of subsistence farming in Rwanda and numbers of livestock usually reflect household prosperity, particularly in the case of cattle. Since 2005, the percentage of households raising some type of livestock has been declining slightly. Between EICV 3 in 2010/11 and EICV 4 in 2013/14, it dropped from 68 per cent to 65 per cent. Goats, cattle and chickens remain the most commonly owned types, at 51 per cent, 50 per cent and 46 per cent, respectively (NISR, 2015).

Figure 11: Number of families that received cattle, 2006-2013



Source: (RAB, n.d.b)

Most livestock production takes place in the eastern and some southern parts of the country. 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 programme, or Girinka, which has a number of interrelated benefits, including increasing agricultural production, supplying manure and reducing childhood malnutrition (REMA, 2010a) (Box 2 and Figure 11).

Box 2: Girinka, the One-Cow-per-Poor-Family Programme

Rwanda's One-Cow-per-Poor-Family Programme (*Girinka*) started in 2006. Poor households, especially vulnerable ones such as those headed by women, children, the disabled and widowed, are given an inseminated heifer. The cow is kept in a stall (zero grazing) and the farmer receives multiple benefits, ranging from milk that improves nutrition, manure to boost crop production and income from the sale of surplus milk (RAB, n.d.b). Research conducted by International Fund for Agricultural Development (IFAD) from 2006 to 2013 confirmed these benefits (IFAD, 2014). In addition, Girinka has generated jobs, allowed some farmers to get bank loans and created opportunities for family members to obtain an education (RAB, n.d.b). The programme also has a multiplier effect and promotes social relations, since the first female calf is passed onto another beneficiary (RAB, n.d.b).

Denis Rugege / REMA

More than 177,200 families have benefitted from receiving a cow or other small livestock breed (MINAGRI, n.d.), such that 47 per cent of households now have at least one cow and 53 per cent have at least one goat. Milk production has also increased from 50,000 MT in 2000 to 450,000 MT in 2012 (MINAGRI, 2013a). Thus, the programme is widely supported throughout Rwanda (UNDP, 2014). The 2018 target is to reach 350,000 families (MINAGRI, n.d.). Figure 11 shows the number of families that have received cattle by Province.

Table 4: Trends in livestock and livestock products, 2008-2013

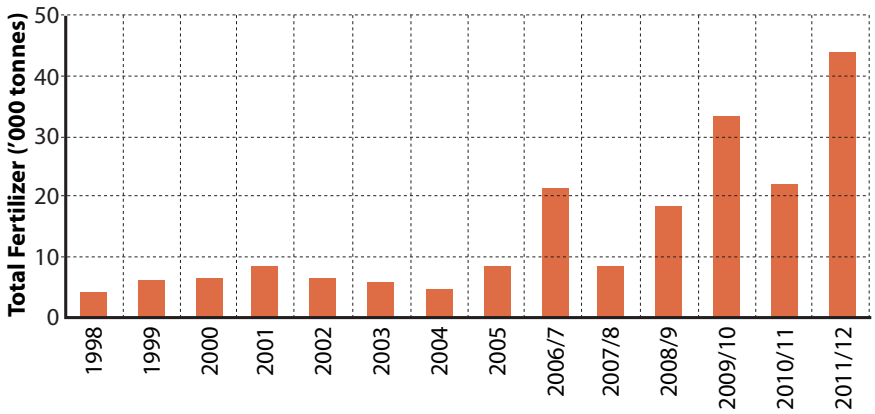
Category	2008	2009	2010	2011	2012	2013
Livestock ('000 head)						
Cattle	1,195	1,219	1,335	1,143	1,135	1,132
Sheep	718	743	799	829	807	798
Goats	2,520	2,735	2,688	2,971	2,673	2,702
Pigs	587	602	706	707	807	1,011
Rabbits	451	790	792	865	994	1,106
Poultry	2,218	3,272	3,537	4,421	4,688	4,803
Animal Products (Tonnes)						
Milk	257,480	334,727	372,619	442,337	503,130	628,266
Meat	56,900	65,863	70,928	73,633	74,519	81,087
Fish	12,594	14,104	15,007	15,526	17,566	24,550
Eggs	2,327	3,268	5,203	5,736	6,324	6,757
Honey	1,654	2,684	2,921	3,221	3,785	4,286
Hides and skin	4,496	4,098	4,072	4,017	3,814	5,207
Meat Production by Animals (Tonnes)						
Beef	24,889	25,462	27,538	28,311	29,021	29,807
Goat	13,420	14,195	15,005	15,836	16,748	16,953
Ovine	4,573	4,823	5,064	5,317	5,583	5,802
Poultry	8,443	11,970	13,718	13,846	14,384	15,727
Rabbit	1,610	1,890	2,375	2,863	3,156	3,893
Pork	3,965	4,523	7,228	7,460	7,938	8,905
Total meat production	**56,900**	**62,863**	**70,928**	**73,633**	**76,830**	**81,087**

Source: (NISR, 2014a)

Cattle-raising has increased throughout the country, especially in the Western, Northern and Eastern Provinces. Between 2006 and 2011, the percentage of households raising sheep and goats declined. During those five years, the proportion of households stabling their livestock increased from 61 per cent to 79 per cent; overall, only a very small proportion of farmers use maintained pasture (NISR, 2012).

Table 4 shows the trends in numbers of livestock from 2000 to 2013, revealing the significant increase in all livestock, especially pigs. In 2013, there were 1.13 million cattle, of which 28 per cent were improved dairy cows producing 82 per cent of Rwanda's milk. The dairy subsector contributes 15 per cent to agricultural GDP and 6 per cent to GDP (MINAGRI, 2013b).

Figure 12: Trend in fertilizer importation, 1998-2012



Source: (REMA, 2014)

8.2: Pressures and Impacts

Irrigation, chemical fertilizer and pesticide applications are pressures that can lead to impacts on soil and water quality, among other ecosystem services, and potentially impact human health. Unsustainable land-use practices related to agriculture that put pressure on the land include deforestation, expansion into fragile ecosystems, over-cultivation and overgrazing (REMA, 2010b).

Box 3: The impact of agrochemicals on the Rweru-Mugesera wetlands

The Rweru-Mugesera wetland complex is located in Eastern Province, south of Rwamagana, between Lake Rweru and Lake Mugesera. The wetlands include Lake Sake, Lake Rumira, Lake Gashanga and the Akagera River's floodplain (USAID, 2014).

Agricultural activity is mostly subsistence farming. A recent field study of agricultural practices related to fertilizer use in the wetlands found that farmers benefit significantly from higher yields when they apply mineral fertilizers. Recently, REMA commissioned a scientific research project at the site to determine the impacts of agrochemicals on the ecosystem, hypothesizing that the high sediment load transported and deposited by the Nyabarongo-Akanyaru-Akagera River system brought polluting agro-chemical runoff from the farmlands. The study confirmed that the wetlands ecosystem was highly enriched with nutrients from the inorganic fertilizers. All the lakes, rivers and swamps in the study were found to be highly eutrophic, with nitrogen, phosphorous and potassium levels above the set National Standards for natural waters (REMA, 2014).

Irrigation and chemical inputs

Rwanda's agriculture is predominantly rain-fed. Only 0.6 per cent of its permanent cropland is irrigated (World Bank, 2014b) and nationwide only around 3 per cent of all cultivated land is irrigated (NISR, 2012). Of the 590,000 ha that could potentially receive irrigation (SAFEGE, 2012), the total area under irrigation in 2012 was just over 25,590 ha, of which 2,490 ha was on hillsides, 23,000 ha was in marshlands and around 100 ha was small-scale garden plots with rainwater harvesting (MINAGRI, 2013a).

According to the 2013 SAS, in season A, only 2.1 per cent of agricultural operators practiced irrigation and only 4.1 per cent of large-scale farmers, while in Season B, 2.7 per cent of total operators had irrigation (NISR, 2014b).

Chemical fertilizer use increased starting in 2007 when the GoR, with the help of development partners and the private sector, began to import, subsidize and distribute fertilizers and improved seeds through the CIP, which focused on priority crops (REMA, 2014) (Kathiresan, 2012) (Figure 12).

The total amount of mineral fertilizers used by farmers increased from 14,000 tonnes to 44,000 tonnes between 2005/06 and 2010/11. The EDPRS target for 2012/13 was for a total of 56,000 MT (MINECOFIN, 2012). According to EICV 2, between 2005/06 and 2010/11, the percentage of crop-producing households that purchased fertilizer rose from 18 to 38 (NISR, 2014a) and between 2006 and 2012, the amount of fertilizer applied to cropland increased from 6 kg/ha to 29 kg/ha (Nabahungu, 2013).

Pesticide use in Rwanda is very low and limited to high-income crops like coffee, potatoes and some vegetables, such as tomatoes. Average pesticide use is below 1 kg/ha and consists mainly of fungicides (REMA, 2011). Farmers commonly use traditional pest control practices, which include the use of resistant varieties in food crops, intercropping and other sustainable approaches.

Chemical fertilizers and pesticides are highly soluble and if applied improperly or in excess of plant needs, they run off the land into surface and groundwater. As well, nitrogen from manure can accumulate in water sources. These inputs can pollute water and degrade ecosystem services, harming wildlife habitats and affecting human health (RNRA, 2012) (Box 3).

Over-cultivation and overgrazing

Land shortages have led to the reduction or abandonment of fallow periods in many areas of Rwanda, along with limited manure and mineral fertilizer inputs, few soil conservation practices and associated low yields. In many instances, it resulted in over-cultivation and land degradation. The impact has been a vicious cycle of erosion and reduced soil fertility and productive capacity (REMA, 2010b).

Erosion

In 2011, a Geographical Information System (GIS) modeling study estimated soil loss to erosion and found that 47 per cent and 34 per cent of the country suffers from soil erosion rates of 50 and 100 t/ha/yr, respectively. Agricultural areas in the northern and western uplands, where the terrain is steeper and annual rainfall is higher, are the most vulnerable to erosion (SAFEGE, 2012).

Agriculture and climate change

Agriculture emits the largest proportion of Rwanda's GHG emissions, small though they may be relative to most other countries. Data from 2010 reveal that the agriculture sector accounts for about 65 per cent of non-LULUCF (Land Use, Land-Use Change and Forestry) emissions, mainly due to emissions from cultivating soils (Stiebert, 2013).

In addition, Rwanda is subject to the impacts of a changing global climate that will affect the agriculture sector, especially since it relies so heavily on rain-fed farming practices. The impacts of potential changes in rainfall intensity, frequency and duration include flooding and landslides as well as drought that adversely affect agricultural output and thus food security (RoR, 2012). The GGCR strategy warns that "temperature rise could negatively affect crop yields, impacting food security and export earnings. Higher temperatures result in higher altitudes at which tea and coffee can be grown, which may significantly impact the land available for tea and coffee, and may result in land use conflict. Extreme weather already negatively impacts the economy and climate change could result in annual economic costs of just under 1 per cent GDP by 2030" (RoR, 2011).

Conclusion

Agriculture, especially rain-fed subsistence farming, continues to be the most important economic sector for the Rwandan people: it contributes 33 per cent of GDP, represents 55 per cent of the country's exports, employs 70 per cent of working people and with about 70 per cent of cultivated land covered with food crops, it provides 80 per cent of national food needs.

Over the past five years, agricultural production almost doubled and coffee production rose by 20 per cent, driven by the impacts of land consolidation, increased fertilizer use (which rose from 6 kg/ha to 29 kg/ha on cropland) and soil conservation practices, which covered 40 per cent of cultivated land in 2006 but increased to 87 per cent by 2011. The national livestock herd grew, and today, 47 per cent of farm households have at least one cow and 53 per cent have at least one goat.

The GoR recognizes that increased production can come at the expense of the environment, with impacts including land scarcity, erosion, loss of soil fertility, water pollution from agro-chemicals and greenhouse gas emissions, among others. The next chapter focuses on responses to agricultural issues in Rwanda, acknowledging the important role of farming for the Rwandan people and the country's economy and continuing to foster the sector's growth, while addressing its real and potential future impacts on ecosystems and human well-being.

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Potato growing trials at high altitude of 2200 metres

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Chapter 9: Greening Agriculture — Policies and Practices

9.1 Policies and strategies

Agriculture and Vision 2020

The future orientation of agriculture in Rwanda is guided by the country's overarching Vision 2020 and the strategies and programmes to achieve its goals. One of Vision 2020's six pillars is the "Transformation of agriculture into a productive, high value, market oriented sector, with forward linkages to other sectors" (RoR, 2000). The Vision aims to "replace subsistence

Table 1: EDPRS II priorities linked to agriculture

Thematic priority	Thematic outcome	Interventions	Lead sectors/ institutions
Priority Area 1: Integrated Approach to Land Use and Rural Settlements	1.1 Improved land rights and land administration 1.2 Enhanced rural settlements which facilitate access to basic services, farm and off-farm economic activities through integrated district land-use plans	• Securing land tenure for all land claimants through systematic Land Administration. Coordinated Land Use Planning through District Land Use Master Plans. • Layout plans of villages designed through a consultative process. • Land Use Planning is Monitored and Enforced. • Supporting the Growth, Quality and Affordability of Rural Housing.	MINIRENA/ RNRA,MININFRA, MINALOC/ TF Rural Settlements
Priority Area 2: Productivity and Sustainability of Agriculture	2.1 Increased Productivity and Sustainability of Agriculture 2.2 Increased Private and Public Advisory Services to Farmers, especially women and youth, for Agriculture Skill Development 2.3 Farming Models scaled up to link farmers and cooperatives to agroprocessing	• Irrigation Developed by Public and Private Sector. • Land Husbandry Approach promoted across Rwanda. • Farmer Field School scaled - up. • Training of GoR extension workers. • Setting - up farmer promoters and animal health works. • Promote private extension/ advisory services in fertiliser and seed to support privatisation. • Models of bulking production implemented.	MINAGRI, RDB

Source: (RoR, 2013b)

farming by a fully, commercialized agricultural sector by 2020" and "reduce the proportion of the farming population from 90 per cent in 2000 to 50 per cent by 2020" (RoR, 2012a).

The key targets to be achieved by the agricultural sector include:

- Increase the proportion of the country farmed under modern agricultural methods from 3 to 50 per cent;
- Increase fertilizer use from an average of 0.5 to 15 kg ha per year;
- Expand soil protection from 20 to 90 per cent of the country;
- Increase agricultural production from 2,385 to 2,600 kcal/day per person (This figure represents calories available from crop products. It is calculated by dividing the total available food supply for human consumption by the population. The minimum daily need is typically 2,100 kcal); and
- Achieve major increases in export earnings from crops such as tea and coffee.

Agriculture and the Economic Development and Poverty Reduction Strategy (EDPRS)

The Economic Development and Poverty Reduction Strategy (EDPRS) is the framework for achieving Vision 2020 and the Millennium Development Goals (MDGs). Thus, the Rural Development theme of the EDPRS II (2013-2018) aligns perfectly with Vision 2020 to focus on increasing agricultural productivity and ensuring sustainable poverty reduction (RoR, 2013b). Priority 2 of this thematic area is to increase irrigation and land husbandry, proximity advisory services for crops and livestock and the connections between farmers and agribusiness (RoR, 2013a). Table 1 shows the priorities and strategies in more detail.

Strategic Plan for the Transformation of Agriculture in Rwanda (PSTA 3)

Likewise, Rwanda's third Strategic Plan for the Transformation of Agriculture (PSTA 3) fully aligns with Vision 2020, refining the goals into a strategy for implementation. It is a five-year program covering the period 2013/14 to 2017/18. Its strategic objectives are also to transform Rwandan agriculture from a subsistence sector to a market-oriented, value creating sector and to grow as rapidly as possible, both in relation to production and commercialization, to increase rural incomes and reduce poverty

Agriculture in the reclaimed Kimicanga area of Kigali City. Eugene Apindi Ochieng

Box 1: Pillars and strategic programmes from PSTA 3

Under the PSTA 3, the key pillars for rapid growth in the agriculture sector are as follows:

1. Land, irrigation, inputs and infrastructure;
2. Soft skills and farmer capacity;
3. Value chains and markets; and
4. Private sector investment.

The strategic programmes are:

1: Agriculture and animal resource intensification;

2: Research, technology transfer and professionalization of farmers;

3: Value chain development and private sector investment; and

4: Institutional development and agricultural crosscutting issues (MINAGRI, 2013).

(MINAGRI, 2013). Box 1 shows the pillars and strategic programmes under PSTA 3.

More specifically, the PSTA 3 has set high-level targets, as follows:

- Increase agricultural productivity by 8.5 per cent per year;
- Decrease agriculture's share of GDP to 25 per cent; and
- Increase the number of households with good food consumption to 90 per cent.

The ultimate objective is that growth in the agriculture sector makes a significant contribution to the Vision 2020 goals to increase GDP growth to 11.5 per cent a year and to reduce poverty from 45 per cent to 20 per cent by 2020 (MINAGRI, 2013).

The Green Growth and Climate Resilience (GGCR) Strategy

As a land-locked country facing high import and export costs, the GoR recognizes that a growing economy, as required by its Vision and strategies described above, comes with the risk of increasing greenhouse gas (GHG) emissions from transport and energy use as well as from agricultural development. Given its stated goals, how shall Rwanda implement a "fully, commercialized agricultural sector" that generally involves increased mechanization and agrochemical inputs, while at the same time pursuing a Green Economy approach that requires reducing carbon emissions and preventing the deterioration of its ecosystems and their services? Using the language of the DPSIR framework, it needs to transform the agriculture sector from a Pressure on the environment to a Response to both environmental degradation and the need for economic development.

Recognizing this challenge, Rwanda has revised its vision of the future to foresee a country in which 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 by 2050 (RoR, 2011). Rwanda has taken on the challenge to grow the economy and not simply prevent environmental degradation, but actually employ green approaches, technologies and policies to both reduce environmental pressures and contribute to economic growth. It will reap the "multiple payoffs" to this approach in terms of growth, poverty reduction and positive environmental outcomes.

Rwanda is guiding the process of mainstreaming climate resilience, low carbon development and other environmental protection practices into key sectors of the economy through the adoption of the Green Growth and Climate Resilience Strategy, henceforth referred to as the GGCR strategy (RoR, 2011).

Table 2: Summary of Rwanda's key characteristics related to agriculture, their implications and the climate resilient and low carbon development pathway

Characteristics	Implications	Development path
Limited land but very fertile	Able to achieve food security	Expand crop varieties, local sales and manufactured products and exports
High population density with most people farming on hillside plots	High vulnerability and potential to create rural poor	Employ sustainable intensification of small scale farming and resource recovery and reuse Educate women and girls
High rainfall, though limited water resource management	Currently vulnerable to weather variations Able to achieve water security High occurrence of vector and water-borne diseases	Implement integrated Water Resource Management Expand irrigation infrastructure

Source: (RoR, 2011)

Table 2 summarizes the GGCR strategy's proposed development path for the agriculture sector to help green the country's economy, in response to the challenges presented by its limited but fertile land base, high population density on hillside plots and high rainfall but as yet inadequate water resources management.

In response to the development path suggested in Table 2, of the GGCR strategy's 14 Programmes of Action, four in particular are closely related to agriculture and its role in greening the economy through resource efficient, low carbon and climate resilient practices:

- Sustainable intensification of small-scale farming;
- Agricultural diversity for local and export markets;
- Integrated Water Resource Management and Planning; and
- Sustainable forestry, agroforestry and biomass.

9.2 Practices to implement the GGCR strategy's Programmes of Action

The rest of this special thematic chapter of the State of the Environment report examines how Rwanda might meet the agricultural goals and targets in its GGCR strategy; it focuses primarily on agriculture practices related to the four programmes listed above. It describes a number of key farming practices that Rwanda is pursuing or might consider implementing to lower carbon emissions, increase resilience to the impacts of climate change and use resources more efficiently. It organizes the practices under the following guidelines related to the GGCR's Programmes of Actions:

- Build, restore and enhance soil fertility
- Apply agro-ecological approaches
- Reduce and prevent soil erosion
- Manage irrigation sustainably
- Protect plants from pests
- Integrate climate resilience
- Add value through niche products
- Reduce post harvest losses
- Increase access to markets

Progress in implementing these practices will enable the country's agricultural sector to develop in ways that provide economic stability while lowering fossil fuel use, and by so doing, also mitigate GHG emissions, foster adaptation to the impacts of a changing climate and protect and enhance the ecosystem goods and services that make economic growth and poverty reduction possible.

Build, restore and enhance soil fertility

Rwanda's GGCR strategy suggests implementing an integrated approach to soil fertility management that employs practices that recover and reuse resources and by also applying fertilizer-enriched compost. This improves soil structure and water retention, thus helping to reduce the demand for inorganic fertilizers, dependence on oil and GHG emissions. An integrated approach also increases farm profitability because of reduced input costs for farmers, which in turn reduces vulnerability to external shocks (RoR, 2011).

Integrated Soil Fertility Management (ISFM)

Conventional agriculture rapidly depletes soil organic matter (SOM) while repeated cultivation degrades soil structure, lowering crop yields and increasing production costs (UNEP, 2011a). Instead, many

sustainable agricultural systems engage in Integrated Soil Fertility Management (ISFM), which combines natural soil amendments, such as organic matter, phosphate and lime, with smaller inputs of inorganic fertilizers (Cantore, 2011).

Presently, inorganic fertilizer applications in Rwanda do not comprehensively address specific soil nutrient deficiencies. To remedy this, the GoR recently conducted research to determine soil nutrient levels throughout the country as a basis for recommending proper doses of both organic and inorganic fertilizer inputs for specific crops and areas. It established four soil fertility management zones, took samples and compared nutrient status to crop requirements. Fertile soils were deemed to require — in order of importance — manure and fertilizers; medium fertility soils require manure, fertilizer and lime inputs; and infertile soils need lime, manure and fertilizers. Rice, potatoes and wheat were evaluated and found to benefit from small micronutrients (SMN), nitrogen (N) and Phosphorus (P) additions. In the future, research will continue to look at crop and site-specific fertilizer blends and extension services for farmers will include demonstrating secondary and micronutrient fertilizers to comprehensively address soil nutrient deficiencies and promoting ISFM, emphasizing organic and inorganic fertilizers and agroforestry (RoR, 2015).

The GGCR strategy promotes the use of organic waste as fertilizer. Recycling organic waste to make compost is a critical climate change adaptation and mitigation strategy. Compost improves soil fertility and structure, which increases soil water retention and nutrient levels, while diverting food and other waste from waste dumps and landfill sites reduces methane emissions (RoR, 2011).

One Acre Fund provides training in making compost in Rwanda.

Evariste Bagambiki / One Acre Fund

Other sustainable soil fertility strategies include growing nitrogen-fixing fodder and green manure crops, such as pea, ferns and clover or rice straw and integrating them back into the soil; the no-tillage approach where new seeds are planted into crop residue; and fertilizing with waste biomass or biochar, which is charcoal used as a soil amendment, especially for acidic soils (UNEP, 2011a). Farming systems that make better use of manures, compost, legumes, crop residues or agroforestry to maintain soil nutrient levels will have less need for inorganic fertilizer (FAO, 2012).

Box 2 documents the results of some pilot projects in Rwanda that prove how these types of low carbon, sustainable land management practices both increase productivity and protect ecosystem services such as soil fertility.

Box 2: Pilot Actions through Innovative Models

The International Fund for Agricultural Development (IFAD) initiated pilot projects in Rwanda to overcome soil fertility constraints, protect watersheds, improve livestock and increase rice production. The "Pilot Actions through Innovative Models'' projects involve intensifying research and extension services and engaging in the following practices:

- Sustainable and productive land management systems and soil conservation measures based on the introduction of systematic hedging;
- Management of biomass and anti-erosion measures including plantation of grass and shrubs;
- Agroforestry on steep slopes and terraces;
- Integration of improved animal husbandry practices into the agricultural production system; and
- Development of marshlands for rice cultivation.

Results have been a general increase in crop production and an average 35 per cent increase in staple food availability. The project has reached about 95,000 households, formed or strengthened 145 community groups, established progressive terracing over 14,600 ha, developed about 100 rainwater harvesting ponds and supported poor rural households in restocking livestock. Projects were conducted in Bugesera, Gakenke, Kirehe, Ngorero, Nyamagabe and Nyanza Districts.

Source: (IFAD, 2013; IFAD, 2015)

Box 3: Agroecology

Agroecology is the application of ecological concepts and principles to the design and management of sustainable agro-ecosystems. It has three facets:

1. A scientific discipline involving the holistic study of agro-ecosystems, including human and environmental elements;
2. A set of principles and practices to enhance the resilience and ecological, socioeconomic and cultural sustainability of farming systems; and
3. A movement seeking a new way of considering agriculture and its relationships with society.

Source: (Silici, 2014)

Apply agro-ecological approaches

Agroecology (Box 3) is a sustainable farming approach that is increasingly regarded as a valid scientific discipline as well as a social movement. There is growing evidence of its multiple benefits, including building resilience to climate change and increasing farm productivity (Silici, 2014).

The following is a list of its benefits compared to conventional high-external input farming:

- "A multi-functional approach to farming, capable of meeting environmental, economic and social needs;
- Greater environmental sustainability and resilience, especially in marginal areas subject to environmental degradation and extreme climatic events, and higher agrobiodiversity;
- The ability to support farmers' food sovereignty, reducing their dependence on costly and sometimes difficult-to-access chemical inputs;
- Higher overall productivity (at farm rather than crop level) achieved through a diverse range of agricultural products and environmental services, which reduce risks of crop failure in the long term" (Silici, 2014).

Mixed farming

Mixed farming incorporates many agroecological practices. It refers to a household farming system that integrates crops and livestock, with animal inputs such as manure or draft power contributing to crop production and crop inputs such as residues or forage being used in livestock production (Williams, Hiernaux, & Fernández-Rivera, 2000).

Mixed farming has been shown to be one of the least environmentally damaging ways to raise animals for human consumption and one that provides most opportunities for poor rural farmers in developing countries to benefit from livestock (Steinfeld, 1997). Managed well, the integration of livestock with crop farming is likely the most feasible avenue for intensifying livestock production in more humid and subhumid regions since it can support higher rural populations than extensive grazing systems alone (Mearns, 1997).

Box 4: Land husbandry, Water harvesting and Hillside irrigation Project (LWH)

Often, population pressures among subsistence farmers in Rwanda force people to cultivate slopes that are vulnerable to soil erosion while the lack of irrigation keeps productivity low. To address these challenges, the government initiated the Land husbandry, Water harvesting and Hillside irrigation Project (LWH) Project in 2008 at sites in Karongi, Rutsiro, Nyanza and Gatsibo. It aims to increase productivity and commercialization of hillside agriculture using a holistic and comprehensive watershed approach, adaptable to local conditions. It targets highly economical horticultural crops such as coffee, tea, mangoes, avocado, cooking banana and pineapple grown in areas that are conducive to their production. It introduces appropriate and modern land conservation and irrigation techniques and technologies on both rain-fed and irrigated areas. Small farmer groups are trained in post-harvest handling, marketing, business planning, compost making, tree nursery maintenance and savings. The project includes extensive community sensitization and participation so that people are involved in their own transformation.

The groups formed cooperatives linked to financial institutions and are enjoying financial services in the agriculture value chain. The project now benefits over 22,689 families (more than 100,000 people). More than 22,000 community members are employed in constructing terraces, making compost and planting trees.

Source: (MINAGRI, 2010)

As envisaged in the GGCR strategy's Programmes of Action, Rwanda is mainstreaming agroecology in the agriculture intensification programme and other natural resource-based livelihood programmes. Actions focus particularly on the Land husbandry, Water harvesting and Hillside irrigation Project (LWH) (Box 4); Integrated Water Resource Management (IWRM), especially irrigated rice production; and the One-Cow-per-Poor-Family Program or Girinka programme (RoR, 2011). By integrating livestock into household farming, the latter enhances livestock productivity by improving breeds and farm management, including the use of farmyard manure for soil improvement (RoR, 2009).

Table 3: On-farm erosion controls

Agronomic or Biological Measures	Soil Management Strategies	Mechanical or Physical Methods
Mulching	**Conservation Tillage**	**Terracing**
Crop Management	*Minimum tillage*	**Contour Bunds**
Cover Crops	*Improved fallows*	**Infiltration Galleries**
Improved Fallows	*No-till*	**Waterways**
Intercropping	**Contour Tillage**	**Gully Controls**
Planting Pattern/Time	**Strip farming**	*Stabilisation structures*
Crop rotation		*Stone check dam*
Agroforestry		*Gabion baskets*
		Reno Mattresses
		Stone lining

Source: (REMA, 2010c)

Reduce and prevent soil erosion

Rwandan farmers have a long history of controlling erosion on their sloping fields. In 2011, 87 per cent of cultivated land was protected from erosion. Agricultural intensification and increased irrigation and mechanization will require vigilance in applying these practices to continue avoiding erosion and building stable soil structures that also retain fertility. Table 3 categorizes the various practices available, from biological to mechanical soil-management strategies. One of these is minimum or no tillage, a practice to increase soil fertility and retain soil moisture that also prevents soil erosion, with the potential to reduce it by 50-98 per cent (FarmingFirst, n.d.). Terracing is commonly used in Rwanda's hilly farming areas. The average cost to establish one hectare of radical terraces in Rwanda (including manpower and basic tools such as picks, shovels, etc.) is $1,000. The cost for any additional unit (ha) of radical terracing costs the same as the initial unit (RoR, 2012b). Box 5 illustrates the benefits of terracing.

Agroforestry

Agroforestry reduces soil erosion, increases resilience to heavy rains, sequesters carbon, increases shade, creates micro-climates and recycles nutrients that help improve agricultural production (RoR, 2011). For example, in terms of increasing harvests, research has shown that yields of millet and sorghum may increase by 50 to 100 per cent when planted directly under Acacia albida (RoR, 2012b). Agroforestry also provides wood for communities while avoiding deforestation (See chapter 2). Different tree species are planted according to the need: fuel; construction materials; livestock fodder; stakes; and food, such as fruit and nuts.

One way to mainstream agroforestry into Rwanda's farming systems is to promote the use of bushes

Box 5: Terraced farms in Cyungo

In exchange for food for themselves and their families, a World Food Programme supported 4,000 people working for over a year to build terraces on 240 ha of fertile hills in the Cyungo sector in the Rulindo District of Northern Province (Smerdon, 2010).

A radical terrace is a levelled section of a cultivated hill, often formed into multiple terraces giving a stepped appearance (REMA, 2010b). After a terrace has been dug, a riser is shaped, upon which grasses, shrubs or trees are planted. The vegetation, such as napier grass, provides forage and crops grown on the terrace improve farmers' livelihoods, while the land is protected from erosion and water infiltration into the soil is enhanced (Kagabo, 2014).

Today, Cyungo grows enough food on the terraces to feed the inhabitants and sell some extra produce for income. Farmers alternate growing wheat for sale and Irish potatoes for consumption. They also grow cattle fodder between the terraces and reap the benefits of milk for the community as well as manure to use as fertilizer on the terraces. Only a quarter of the land was planted with crops before terracing began in 2007 and 2008, but by 2010, some 95 per cent of the land was producing wheat, potatoes and peas.

Source: (Smerdon, 2010)

Box 6: Climbing beans on live stakes has multiple benefits

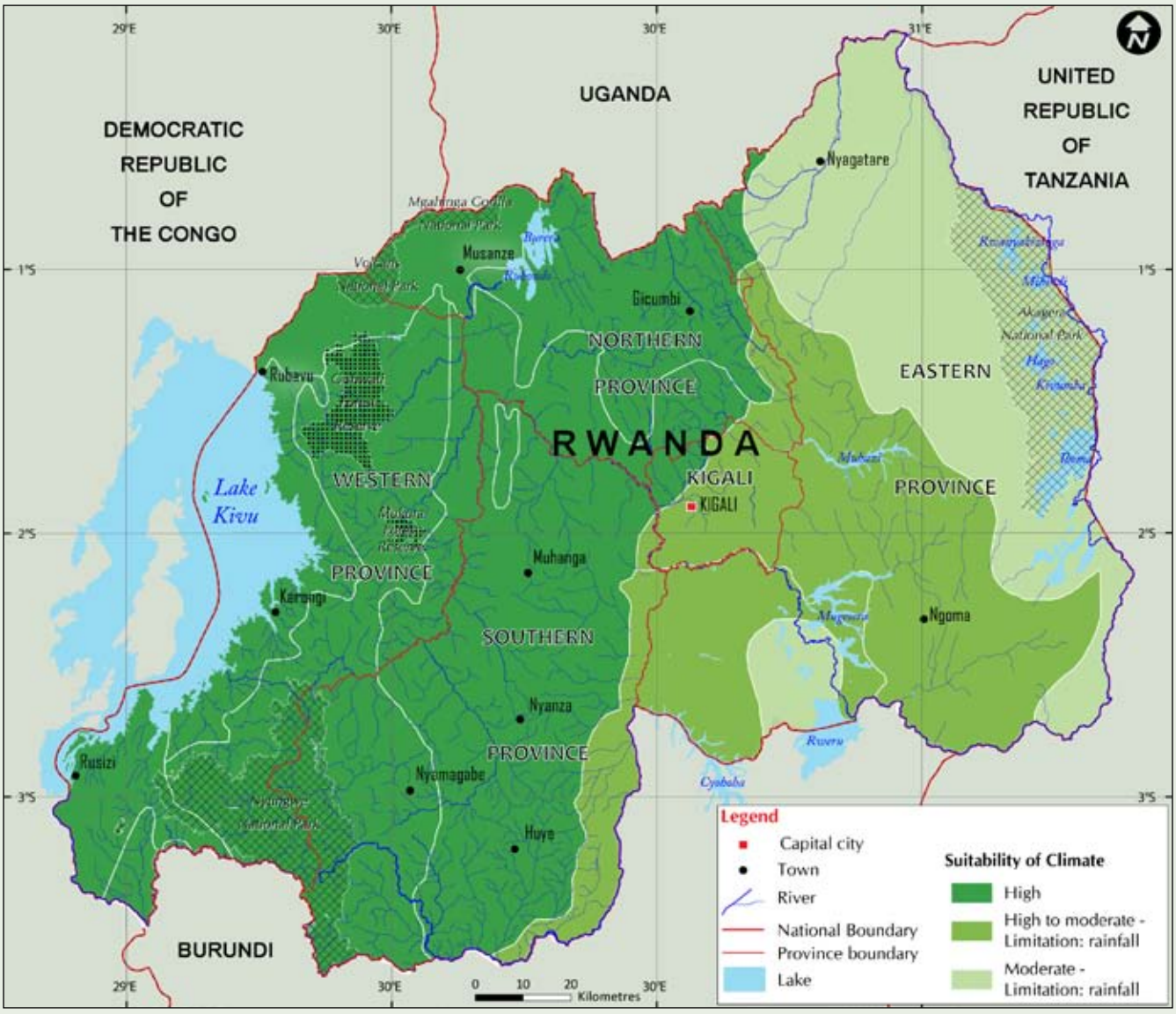
Rwandans have the highest per capita bean consumption in the world, eating them an average of five days a week, at an estimated 164 grams a day. In the average household, they provide 32 per cent of calories and as much as 65 per cent of protein intake. As well, almost all rural households grow beans, which supply 79–88 per cent of their needs, with the rest being purchased (Oparinde, et al., 2015). The quality and quantity of beans produced for subsistence has been in decline, however, resulting in increased malnutrition, especially among children and the elderly (ASARECA, 2014). Fortunately, Rwanda remains an ideal place for growing beans (Figure 1) and there are a number of projects that are introducing better bean varieties and innovative practices to encourage better harvests as well as protect and improve soils and their fertility to sustain bean production.

There are three types of beans: bush beans, semi-climbing beans and climbing beans. According to the International Center for Tropical Agriculture (CIAT), climbing beans produce three times the harvest of bush beans. In addition, climbing beans are the best nitrogen fixers, an added benefit in improving soil fertility (Eliud, 2015). Studies in Rwanda show that without using improved agricultural practices or inputs, climbing beans yield a maximum of 800 kg/ha on good soils, but when suitable technologies are applied (use of inputs, staking properly) the yield on consolidated land at the farm level reaches 3,000 kg/ha (AGRA-SHP, 2014).

Farmers, however, have continued to grow poorly performing mixed bush bean varieties. This is because climbing beans require vertical support (staking) as they grow. Woody sticks, which are commonly used for staking, are costly and scarce because households usually burn them as fuel. A farmer may need as many as 50,000 stakes per hectare, the gathering of which contributes to deforestation (ASARECA, 2014).

Studies by the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA)

Figure 1: Climatic suitability for growing beans



have shown that using cord strung between sticks uses far fewer stakes, reducing the number needed to about 10,000 per ha (ASARECA, 2014).

An even greener solution is to use "living stakes". In lieu of sticks, farmers are encouraged to plant special shrubs or trees such as nitrogen fixing agroforestry species (*Lecaena, Calliandra, Gliricidia, Alinus*), and forestry types like Eucalyptus and Grivelleaon for the stakes on well-terraced tops and hillsides. The use of such "living stakes" provides a source of more durable wood sticks while simultaneously providing protective vegetation cover that prevents wind and water erosion, stabilizes the terraces and replenishes soil nitrogen. In addition, pruning and leafy residues from the bushes provide nutrition for livestock, which in turn produce milk and manure, while old stakes are used as cooking fuel (Steven, 2015).

Because of its cultural, ecological and nutritional importance, a number of plant breeding programmes in Rwanda focus on improving bean quality and production to increase food security and reduce its environmental impact. "The adoption and improvement of climbing beans has become one of the most successful agricultural innovations in recent times" (Steven, 2015). The Rwanda Agriculture Board (RAB) and CIAT are working to develop new varieties of beans that are adaptable to the country's varying climates and as well as new types that take less time to cook, thus saving use of fuelwood and curtailing deforestation (Eliud, 2015).

Although the bean-breeding programme has succeeded in releasing high yielding varieties that are resistant or tolerant to major biotic and abiotic constraints that normally restrict yields, their adoption has been stymied by the farmers' difficulty in accessing improved seed varieties as well as the scarcity of staking materials. Currently, less than 3 per cent of farmers plant improved seed annually. In addition, the climbing beans perform best with applications of phosphorus-containing fertilizers, which farmers lack (AGRA-SHP, 2014).

Neil Palmer/Ciat

The CIAT-RAB project is now working to increase the availability of suitable varieties of climbing beans for both high and low altitude zones in northern and eastern Rwanda; improve seed production and distribution systems by creating links with private and public seed providers; improve fertilizer adoption by strengthening contacts with agro dealers; provide training and demonstration of best-bet agronomic practices for bean production, especially in ways that boost soil fertility; and promote types of agroforestry legumes to be used to stake climbing beans but that also enhance soil fertility by fixing nitrogen and controlling erosion (AGRA-SHP, 2014).

and trees as "living stakes" in the country's bean production. The case study in Box 6 shows how growing improved bean varieties using live stakes has the potential to increase production, contribute to food security, prevent soil erosion and enhance soil fertility.

Manage irrigation sustainably

Intensifying agricultural production will increase the need for secure water resources (SSEE, 2011). Rwanda's abundant rainfall and water resources in its rivers, lakes and groundwater make irrigation expansion feasible (RDB, n.d.a). The EDPRS II goals include expanding irrigation to increase productivity and enhance food security. Its target is to bring 100,000 ha under irrigation of which 65,000 ha will be in marshland and 35,000 ha will be hillside irrigation (RoR, 2013b).

Water supplies for the agriculture sector are vulnerable to the impacts of climate change, however, since even small variations in rainfall patterns can have significant impacts on crops and livestock. Irrigation removes some of the uncertainty about when to plant a crop; reduces the vulnerability to climate change; enables farmers to diversify their crops; allows them to plant in otherwise dry areas and in dry seasons, often enabling multiple cropping; and it creates more efficient water use systems (RoR, 2011); (RoR, 2013b).

Box 7: Sustainable irrigation in Ndego, Kayonza District

Most people in Ndego, in the District of Kayonza in the Eastern Province, rely on rain-fed subsistence agriculture. The area is endowed with many lakes and the soil is fertile, but rainfall is scarce. Faced with frequent droughts, many people have abandoned the area in search of greener and more reliable arable land elsewhere. The Africa Adaptation Programme (AAP) has developed an irrigation scheme in Ndego to overcome the lack of adequate rain by exploiting lake water for irrigation using 57 solar pumps. Solar radiation generates kinetic energy (electricity), which drives two pumps installed in Lake Rwakirezi. Pipes direct the pumped water to irrigation channels and sprinklers installed over 5 ha of arable land.

To assess the impact, an experiment compared the results of the same maize variety sowed on irrigated and non-irrigated land, and found the former produced superior results. One pioneering entrepreneurial farmer risked planting beans and maize during the normally dry season of July and August and achieved excellent harvests, prompting her to invest in planting tomatoes with her earnings. She now provides employment to other Ndgeo residents, helping keep jobs in the area, and has become a role model for residents and authorities. The scheme is simple, low carbon and climate resilient making it a model that could be replicated and expanded into other areas of Rwanda.

Solar park of 57 solar panels

Source: (AAP/REMA, 2014)

Developing Rwanda's irrigation potential for agriculture, however, presents technical, financial and managerial challenges (RoR, 2013b). Since the agriculture sector is already the greatest water user, it will need to manage demand by using more resource efficient techniques such as drip irrigation and treadle pumps and cultivating more drought-resistant and less water demanding crop varieties (SSEE, 2011). In small irrigation schemes, solar energy can be used to pump water to avoid the use of expensive and GHG emitting fossil fuels (Box 7).

While they have significant positive effects on production, irrigation schemes can have important environmental impacts, ranging from causing soil salinization, alkalization, acidification or water logging to depleting groundwater resources; human well-being can also be affected, such as water loss or degradation for downstream users and heightening the risk of water-borne disease. Table 4 suggests some management strategies and practices that could mitigate the negative environmental and socioeconomic impacts of irrigation schemes in Rwanda.

Drip irrigation is especially recommended since it can provide as much as 90 per cent water-use efficiency compared to surface irrigation at 60 per cent efficiency and sprinkler systems at 75 per cent. Drip irrigation systems deliver water directly to the plant's roots, which minimizes runoff and evaporation, and it includes rain shut-off devices to minimize over-watering after significant rainfall. The slow delivery and enhanced seepage promotes healthy plant life, which

Table 4: Problems related to irrigation and appropriate mitigation measures

Problem	Mitigation measures
Degradation of irrigated lands:	
Salinization	Provide drainage including disposal of water to evaporation ponds if quality of river flow adversely affected by drainage water.
Alkalization	Maintain channels to prevent seepage, and reduce inefficiencies resulting from siltation and weeds. Allow for access to channels for maintenance in design.
Water logging	Provide water for leaching as a specific operation.
Soil acidification	Set-up or adjust irrigation management infrastructure to ensure sufficient income to maintain both the irrigation and drainage systems.
	Analyse soils and monitor changes so that potential problems can be managed.
Reduced socio-economic conditions:	
Increased incidence of water related disease	Educate about causes of disease.
Increased inequity	Improve health facilities.
Weaker community infrastructure	Allow sufficient time and money for extensive public participation to ensure that plans are optimal, that all sections of affected society are considered and that local institutions are in place to sustain irrigated agriculture, particularly in respect of land and water rights.
	Consider markets, financial services and agricultural extension in conjunction with proposed irrigation and drainage changes.
	Ensure that agricultural intensification does not preclude other economic or subsistence activity, such as household vegetables, fodder or growing trees for firewood.
	Provide short-term support and/or skills for an alternative livelihood if irrigation removes existing livelihood.
Poor water quality:	
Reduction in irrigation water quality	Define and enforce return water quality levels (including monitoring).
	Control industrial development.
Water quality problems for downstream users caused by irrigation return flow	Designate land for saline water disposal; build separate disposal channels.
	Educate for pesticide or sewage contamination dangers.
	Monitor irrigation water quality.
Groundwater depletion:	
Dry drinking & irrigation wells	Monitor ground water levels.
Reduced base flow/wetlands	
Ecological degradation:	
Reduced biodiversity in project area	Operate dams to suit downstream requirements and encourage wildlife around reservoirs.
Damage to downstream ecosystems due to reduced water quantity and quality	Designate land (in law and supported by protection institutions) for flood plains; wetlands; watersheds; drainage water disposal; river corridors.

Source: (REMA, 2010b)

also benefits wildlife habitat. Another advantage is that it consumes less energy and thus emits fewer CO_2 emissions; since less water is used, there are savings from less pumping and treating irrigation water. In Rwanda, about 80 per cent of the entire farming community could benefit from drip irrigation technologies. The cost is widely variable, ranging from US$800 to US$2,500 per hectare depending on the specific type of system (RoR, 2012b).

Rainwater harvesting, which captures and stores rainfall from roofs, constructed catchment surfaces and streets, is another low cost, low carbon and climate resilient practice that can be used for agricultural irrigation. An IFAD-supported project in Kirehe District provides irrigation infrastructure that allows farmers to grow crops throughout the year (Pichón & Ntukanyagwe, 2014) (Box 8).

Box 8: Simple irrigation technologies improve production in Kirehe District

IFDC / Foter / CC-BY-NC-SA

A project supported by the International Fund for Agricultural Development (IFAD) in Kirehe District provides irrigation infrastructure so farmers can grow crops throughout the year. It set up valley dams and reclaimed marshlands and stored the water in reservoirs to irrigate rice and vegetable plots. Farmers close to tarmac roads dug simple irrigation ponds and lined them with plastic to retain water that runs off the roads. They use hand-operated pumps to irrigate their gardens and they can now farm in the dry season. They keep the water trenches clean to avoid silting. The project's dams irrigate more than 1,500 ha and benefit over 5,000 households.

Farmers can now grow rice for household consumption and for local markets. Before the project, the community grew few vegetables, but since the irrigation project, they now grow cabbages, tomatoes, eggplants, onions, tree tomatoes, passion fruits and pawpaws. A 2013 mid-term impact assessment of the project showed a 50 per cent improvement in household food security and nutrition and a 22 per cent improvement in housing across the 18 watersheds.

Source: (Pichón & Ntukanyagwe, 2014)

Protect plants from pests

Although pesticide use is very low in Rwanda, changing climatic conditions could favour certain crop and livestock pests. Also, with crop intensification and improved seed varieties, farmers may be tempted to abandon crop rotation, adopt monocroping or grow the same crop continuously over several seasons, creating conditions susceptible to pest and disease outbreaks (Kathiresan, 2011). It is important to establish sustainable pest management plans to ensure food safety, human and animal safety and protect the environment (REMA, 2012). Integrated Pest Management (IPM) is a sustainable practice that helps maintain or increase agricultural productivity without over-reliance on synthetic chemical pesticides (SP-IPM, n.d.) (Box 9).

Box 9: Integrated Pest Management (IPM)

A commonly accepted definition of Integrated Pest Management is "an approach to enhancing crop and livestock production, based on an understanding of ecological principles, that empowers farmers to promote the health of crops and animals within a well-balanced agro-ecosystem, making full use of available technologies, especially host resistance, biological control and cultural practices. Chemical pesticides are used only when the above measures fail to keep pests below acceptable levels, and when assessment of associated risks and benefits (considering effects on human and environmental health, as well as profitability) indicates that the benefits of their use outweigh the costs. All interventions are need-based and are applied in ways that minimize undesirable side-effects".

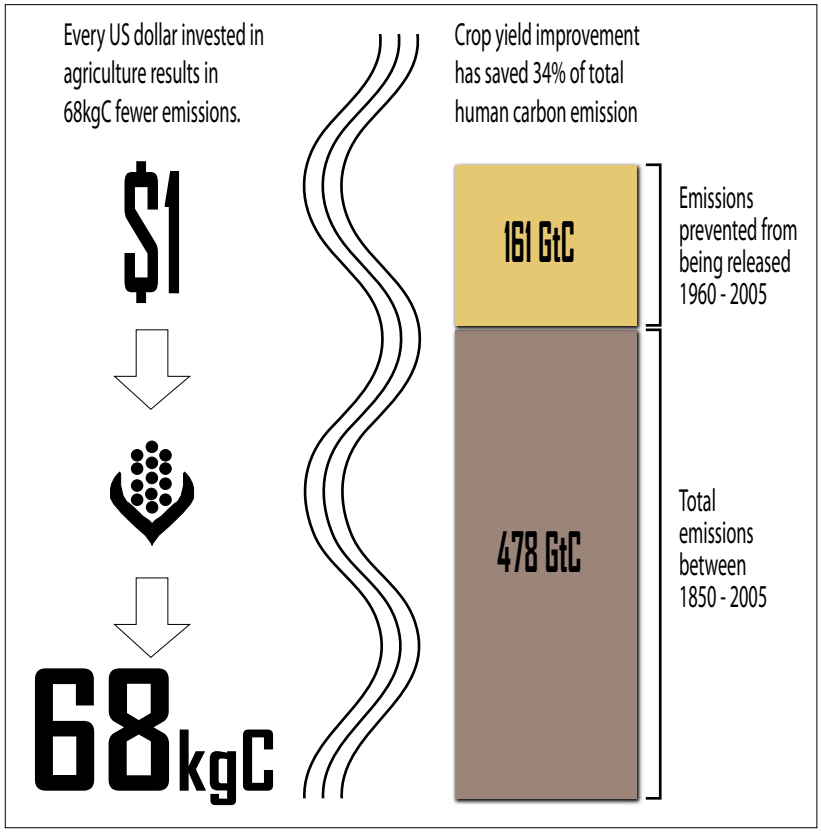
Source: (SP-IPM, n.d.)

The main features of IPM involve the use of non-chemical methods of pest control:

- Biological controls: use of the natural enemies of crop pests, often called beneficials, which include parasites, predators and insect pathogens;
- Cultural control and crop or livestock management: tissue culture, disease-free seed, trap crops, cross-protection, cultivation techniques, refuge management, mulching, field sanitation, crop rotations, grazing rotations and intercropping;
- Strategic control: variety selection, planting location, timing of planting and timing of harvest; and
- Genetically based controls: insect- and disease-resistant root stock and varieties, developed through classical and modern molecular breeding (SP-IPM, n.d.).

The GGCR strategy aims to mainstream "Push-Pull" strategies associated with IPM, which refers to growing plants that repel pests and employing techniques

Figure 2: Agriculture's potential to mitigate climate change



Source: (FarmingFirst, n.d.)

that trap them. IPM also promotes the practice of producing multiple crops and fodder varieties, which helps to control plant parasites and pathogens such as stemborers and striga weed. Napier grass and desmodium legume grown alongside maize, sorghum, millets and rain-fed rice fix nitrogen in soils to enhance fertility and increase yields, provide a continuous supply of cattle fodder that improves milk yields and reduces methane emissions compared to other fodder regimes and also helps to manage pests due to the increased diversity of species in the field (RoR, 2011).

Integrate climate resilience

Agriculture and climate change mitigation

Greening agriculture involves implementing low carbon practices — paying attention to how to decrease GHGs emissions while still allowing economic development. Farming First, a global coalition for sustainable agricultural development suggests that "growth from agriculture is at least twice as effective in reducing poverty than growth from any other sector, and it has one of the highest potentials to mitigate carbon emissions" (FarmingFirst, n.d.)(Figure 2).

The United Nations Environment Programme (2011a) confirms that, globally, "agriculture has the potential to significantly reduce its GHG emissions, and possibly to function as a net carbon sink within the next 50 years". Rwanda's Green Growth strategy and its programmes of action fully support practices such as agroforestry and no-till farming that promise to both reduce agriculture's emissions and store more carbon in soils and perennial vegetation. Such practices also contribute to climate-change adaptation.

Greening mechanization

In its aim to increase the intensification of small-scale farming, Rwanda's Crop Intensification Programme (CIP) pools land to grow the same crops on a bigger area of neighbouring parcels, which allows for more mechanization if the terrain is not too steep (RNRA, 2013). The goal is for 25 per cent of farm operations to become mechanized by 2017, meaning one in every 4 Rwandan farmers will either own and/or hire farm machinery (RDB, n.d.a). It is possible that enabling the communal ownership of, and access to farm machinery will help to reduce costs and encourage farm holders to adopt mechanization (Kathiresan, 2011).

Most farm machinery requires modern fuels or electric power to operate. It is thus important that farm management strategies include developing and using non-conventional energy sources such as biodiesel fuels and biogas power generation in mechanized

Woman working in an eggplant field REMA

farming systems (UNEP, 2011a). In addition, promoting on-farm resource efficiency will reduce the need for machinery that uses fossil fuels. For example, no-till systems require less fuel for tractors and more efficient use of water in irrigation systems reduces fuel use for pumping water (FAO, 2012). There are already examples of farmers using solar energy to pump water for irrigation that could be expanded (Box 7). Studies have shown that pumping water for irrigation using solar energy is relatively cheaper compared to the price of buying fuel or electricity to pump water (RoR, 2012b).

Transitioning to green mechanization requires the following:

- Use of more energy efficient cultivating machines that incorporate plant residues into the soil to increase fertility;
- Zero-tillage and minimal-tillage direct seeders for optimum planting uniformity and minimal topsoil disturbance;
- Precision application systems for more efficient use of agri-chemicals;
- Drip and sparkling irrigation; and
- Harvest and postharvest operations that include village-level processing of farm products and by-products that are central to the "green" mechanization of farms (UNEP, 2011a).

Improving infrastructure and processing practices in existing tea processing facilities is an example of how to mitigate GHG emissions and use natural resources more efficiently. Tea factories are one of the highest users of bulk firewood, which can lead to deforestation

Box 10: Greening tea production

The Kitabi tea factory, located in the Nyamagabe District of the Southern Province, produces black tea that is grown on its own plantation and on a village Cooperative and smallholder parcels of land. It also manages its own forest for wood fuel. It has the capacity to produce 2,400 tonnes of black tea, an output that is expected to increase to 4,800 tonnes by 2019. Guided by the Resource Efficient and Cleaner Production Centre (RRECPC), the company took on a project to green its value chain and realized significant financial savings at the same time (RRECPC, 2014).

It began an awareness campaign to encourage workers to report and fix leakages along its conveyer belt during tea processing and purchased new, more-resource efficient and less wasteful machinery. It also designed and implemented more efficient ventilation, lighting and energy systems in the factory. Steam leaks were fixed, which lowered energy use and costs and water wastage was reduced by 32 per cent. A simple energy saving change was to construct a shed to keep the fuelwood dry, which reduced wood consumption by 15 per cent and also saved money in the long run.

In the beginning, the project gathered baseline data about energy use, costs, and the ratio of tea leaves to finished product before the renovations and then projected the energy, water and financial savings that would be possible over a period of time.

Kitabe Tea Factory Colleen Taugher / Flickr / CC BY 2.0

Once the changes were made and the factory had been operating for a period of time, these data were compared with the actual savings. In total, it realized an estimated US$28,657 at an investment cost of only US$9,020. Because of these achievements, it obtained an ISO award for Food Safety Management Systems and a Rainforest Alliance certification for environmental, social and economic sustainability. It is now exploring the use of solar energy for lighting and the potential to install a mini hydro power plant to save energy in the long term (Kitabi Tea Factory RECP Team, 2014).

The Mata Tea Company has also taken advantage of the Resource Efficient and Cleaner Production approach and realized the following gains: reduced firewood use by almost 16 per cent, and the amount of wood to produce one tonne of tea from 3.8 to 3.2 tonnes; decline in deforestation; a reduction in GHG emissions of about 1,290 tCO_2 eq/year; savings of US$17,901 over four years; and a gain of US$91,834 in 2014 from improvements in the ratio of green leaf to "made" tea (RRECPC 2015).

Box 11: Climate change adaptation and mitigation practices

Climate change mitigation practices

- Conservation agriculture;
- Soil compaction management;
- Improved farming systems with several crop rotations;
- Crop diversification;
- Promotion of legumes in crop rotations;
- Cover cropping;
- Mulch cropping;
- Restoration of cultivated peaty soils and degraded lands;
- Integrated nutrient management;
- Soil management practices that reduce fertilizer use (e.g. urea deep placement);
- Growing nutrient-use efficient crop varieties;
- Integrated crop and livestock systems;
- Dedicated energy crops to replace fossil fuel use;
- Emission control and reduction (combustion engines, animal waste);
- Improved rice cultivation techniques;
- Water management/conservation, irrigation, water table management; and
- Agroforestry

Climate change adaptation practices

- Conservation agriculture;
- Ecosystem-based approaches;
- Alterations in cropping patterns and rotations;
- Crop diversification;
- Using high quality seeds and planting materials of adapted varieties;
- Cover cropping;
- Mulch cropping;
- Integrated pest management;
- Integrated weed management;
- Integrated nutrient and soil management;
- Ecosystem management;
- Water and irrigation management;
- Landscape-level pollination management;
- Organic agriculture; and
- Managing land fragmentation (for example, riparian areas, forest land within agricultural landscapes).

Source: (FAO, 2013)

and carbon emissions to the atmosphere (RoR, 2012b). Box 10 illustrates the climate, environmental and financial savings possible by introducing best practices for resource efficiency and cleaner production.

Agriculture and climate change adaptation

In Rwanda, higher temperatures due to climate change are likely to negatively affect crop yields and favour plant pests and diseases, while changes in rainfall patterns will impact flooding and drought trends. For farming to become more climate resilient, it needs to adopt "climate-smart" practices (World Bank, 2015). Climate-smart agriculture (CSA) contributes to the achievement of sustainable development goals by jointly addressing food security and climate challenges. The three pillars of climate-smart agriculture are as follows:

1. Sustainably increase agricultural productivity and incomes;
2. Adapt and build resilience to climate change; and
3. Reduce and/or remove greenhouse gases emissions, where possible (FAO, 2013).

Climate-smart agriculture requires adopting agricultural production systems that are more productive, use inputs more efficiently, have less variability and greater stability in their outputs and are more resilient to risks, shocks and long-term climate variability (FAO, 2013). Box 11 provides examples of approaches and practices for sustainable farming that on the one hand contribute to climate change mitigation and on the other, to adaptation. Note that many practices address both.

Crop diversification and agrobiodiversity

To become more self-sufficient, the GGCR strategy states that Rwanda will expand crop varieties for import substitution and climate resilience. Diversifying crop and livestock varieties to support the sustainable intensification of small scale farming will both increase potential products for local markets and exports and increase resilience to climate change impacts. Relying on a small number of varieties of food products puts food security in jeopardy should hazardous

Box 12: What is agrobiodiversity?

Agrobiodiversity is "the variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries. It comprises the diversity of genetic resources (varieties, breeds) and species used for food, fodder, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators), and those in the wider environment that support agro-ecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agro-ecosystems".

Source: (FAO, 2005)

weather, a pest invasion or other calamity destroy production. During or after such disasters, farmers are often forced to consume their seed stocks and/or livestock. They may thus lose varieties that are adapted to local conditions (Gapusi, et al., 2013). Maintaining a diversity of crop, livestock and fish varieties (agrobiodiversity) and their wild relatives is of long term interest for adapting to changing climatic conditions (CBD, 2014) (Box 12).

In Rwanda, farmers are custodians of about 47 per cent of the conservation of plant genetic resources for food and agriculture (Gapusi, et al., 2013). Rwanda's Fifth National Report to the Convention on Biological Diversity warns that the country's agrobiodiversity is potentially threatened by "underutilization and disappearance of landraces and local breeds due to crop intensification policy that favours high yield varieties and races" (RoR, 2014).

The GGCR strategy aims to address this by expanding crop varieties to make Rwanda more self-sufficient by meeting its own demand for foodstuffs that are currently imported from regional and international markets. Examples include introducing vanilla seeds, apricot saplings and macadamia plants in Rwanda's north-central region. Other potential products include Russian comfrey, a high-yielding fodder crop, as well as indigenous African vegetables that are in high demand and are particularly suited to small-scale farms, as they require low external inputs and are resistant to local pest and climatic conditions (RoR, 2011).

To conserve seeds for local heritage and encourage experimentation to find climate-resilient varieties and new products for local and international markets, the Rwanda Agriculture Board (RAB) has established a National Gene bank to conserve and use plant genetic resources for food and agriculture (PGRFA). Field and experimental sites as well as herbariums, an arboretum and botanical gardens also collect and store food and fodder seed. As well, a national program is being instituted to improve plant taxonomy, farm and natural habitat management and public awareness of the importance of PGRFA. These efforts will provide breeders with better access to a larger variety of genetic diversity so they can identify and foster climate adaptation traits, such as tolerance to drought, pests and diseases. Research to improve the productivity of rice varieties, for example, has focused on adaptation to low temperatures and moisture stress, and new varieties of drought-tolerant climbing beans are being sought (Box 6). Already, new bean, maize, rice, sorghum, Irish potato and cassava varieties have been developed that have contributed to food security (Gapusi, et al., 2013). In addition, to ensure seeds are kept viable to sow in following seasons, the GoR has procured hundreds of cocoons of 50 and 150 metric tonnes capacity for villages to store maize, pulses and sorghum (Gapusi, et al., 2013).

Urban farming and kitchen or home gardens

Urban farming, kitchen gardens and community or cooperative gardening also conserve and improve the genetic diversity of plants and animals and provide resilience against climatic and economic shocks (Landon-Lane, 2011). They can also improve local environmental conditions by providing green spaces, shade and beauty and retaining water in soils, among other ecosystem services like organic waste disposal.

Growing a diversity of edible plants in multiple layers also allows households to harvest a large quantity of food from a small space and is common where competition for land is high. Such gardens are highly productive and may use ten or more different food species in the various layers: root crops, leaf vegetables, climbing vines, low trees and bushes and emerging canopy trees (Landon-Lane, 2011). Multi-layered gardens mimic nature and have many ecological advantages that make these systems sustainable: the roots of the diverse plants use different parts of the soil profile so do not compete for the same nutrients; in occupying different vertical niches, shade-loving species can grow under taller vegetation that needs more light; incorporating plants that fix nitrogen enhances soil fertility; and the multiplicity of plant types confuses pests but attracts pollinators.

Box 13: The Chagga home garden: a multilayered agroforestry system

The Chagga home garden is an example drawn from northern Tanzania. This Upland Agro-forestry System is a multi-layered structure similar to a tropical montane forest. Typically it consists of four vegetation layers. The top layer of sparsely spaced trees provides shade, medicine, fodder, fruits, firewood and timber. More than 15 banana varieties may grow under the canopy. Coffee shrubs thrive under the bananas and many varieties of vegetables, including vines, grown closest to the ground. This multilayered system also maximizes the use of limited land by combining crops with livestock; crop residues and fodder provide animal feed and livestock manure and litter provide renewable sources of organic matter and plant nutrients. The systems maintain soil health and a high degree of organic recycling, resulting in higher soil fertility than in other systems. It is "agronomically productive, economically sustainable and efficient, and environmentally safe".

Source: (GIAHS, n.d.)

Falling leaves create a layer of mulch that keeps the soil moist and adds hummus while incorporating edible ground-cover plants prevents weed growth. The Chagga garden described in Box 13 is an example of such a system.

Rwanda's GGCR strategy promotes mainstreaming kitchen gardens in urban areas and the Kigali Conceptual Master Plan envisions the city set amid greenbelts and zones reserved for urban agriculture, open spaces and community gardens.

Reduce post-harvest losses

Post-harvest activities refer to the many stages in the chain of activities that take grain, pulses, vegetable and fruit crops from the field to the consumer, including primary handling (drying, threshing, shelling, winnowing, sorting); aggregation and transport; storage and speculation; marketing; and processing. In Rwanda, significant produce losses can occur during this post harvest period. The main relevant activities are associated with pre-harvest field drying and ensuring moisture related quality issues (including moulds and microtoxins) are addressed during handling, subsequent storage and processing (MINAGRI, 2011).

The National Post-Harvest Staple Crop Strategy is meant to help to strengthen harvesting, post-harvest handling, trade, storage and marketing of staple crops and reduce post-harvest losses; support private sector investments; improve efficiency and decrease marketing costs along the staple crop value chain; and improve producers' access to, and linkages with markets (MINAGRI, 2011).

Drying and storage facilities have been established across the country, where products from rural farming areas are temporarily stored and then transported to fill the modern grain storage facilities in Kigali's Special Economic zone in Gasabo District. Proper storage of agricultural produce allows post-harvesting treatments to add value to them, by processing and transforming perishable food by canning, drying, or otherwise treating it for long-term shelf life. For example, the Tuzamurane Cooperative in the rural community of Kirehe is specializing in storing, sorting and drying pineapple to extend its shelf life. The product can last for more than six months, which facilitates its transportation. The cooperative also has a market for raw pineapple, selling the fruit to Inyange Industries, which takes 25 tonnes every week. It also has a market in France, selling 500 kg of dried pineapple at $14 per kilo (Sezerano, 2015).

Increase access to markets

In the short and medium terms, strategies to transition to Vision 2020's goals need to gradually develop association-based farming, rural food markets, storage facilities and improved roads and transport to support off-farm livelihood activities and prevent a negative effect on household nutrition and food choices (RNRA, 2013).

With increased agricultural production, Rwanda will have the primary resources to allow it to upscale trade, marketing, postharvest storage, processing and food packaging activities in rural areas that also open up new non-farm jobs and improve market access for agricultural produce (Hernandez, 2013); (UNEP, 2011a).

Improving domestic agricultural markets is important to develop value chains that allow smallholders to participate (FAO, 2012). The Rwanda Grains and Cereals Corporation, a consortium of government and private sector entities, is addressing the issue of poor markets and fluctuating prices by providing constant markets for farmers' produce across the country (EA Agribusiness).

Box 14: Use ICT to improve agricultural revenues

ESoko is a platform used to collect and distribute agricultural market price information using Short Message Service (SMS), and in the near future, through the web via IVR (voice). The service currently provides information on all major agricultural commodities (staple crops, vegetables and fruits) sold in 50 markets throughout the country (Swanson, Mutimba, & Remington, 2011). Implemented by the eRwanda Project and the Ministry of Agriculture, it plans to distribute 3,500 mobile phones to farmers through cooperatives and at least one cooperative in every district will benefit from the project. Operating since 2005, MPAIS (Marketplace for Agricultural Information and Services) is a demand driven information and service platform that uses SMS to provide information to farmers and extension workers.

Sources: (Hellström, 2009); (Hellström, 2010); (Hellström, 2011)

One of the major opportunities to expand markets, especially in rural areas in Rwanda, is to improve its road network, which will reduce wasteful crop losses and enhance opportunities to commercialize farm products. Although Rwanda's road network is one of Africa's densest, roads vary in quality, with poor road conditions contributing to food product losses during transit to market. Most roads are also susceptible to the impacts of severe weather events, which risk increasing in frequency and intensity with the changing climate. Building and maintaining the roads for sustainability and resilience to more extreme weather will reduce Rwanda's vulnerability and promote economic development through access to agricultural produce, particularly in rural areas (RoR, 2011).

Farmers in rural areas often lack access to information about grain and produce pricing that would help them market their goods. Rwanda is experimenting with using Information and Communication Technologies (ICT) to improve their access to agricultural market information through the eSoko project (Box 14).

Expand niche markets for Rwanda's agricultural products

As a land-locked country, Rwanda suffers from high transport costs that affect the marketing of its goods. To survive in export markets, it needs to produce high quality niche products and market them in new ways, taking advantage of high labour availability, especially innovative youth and skills already developed among farmers and in the processing sectors (REMA, 2010a).

A recent policy brief studying Rwanda's export sector noted that in the short term, Rwanda is most likely to develop mainly agriculture products for export. Examples include oils and grain seeds, fruits and nuts, spices, vegetable fats, vegetable textile fibres and traditional edible vegetables. In the medium term, it should promote processed agricultural products, including foods and drinks such as cereals, sweets, honey, milk, juices and essences extracted from coffee or tea, for example (Gathani, Stoelinga, & Savini, 2015).

Coffee

Vision 2020 promotes the large and systematic expansion of extension services and capacity building in the coffee sector, modelled on successful approaches tested domestically (RoR, 2012a). To encourage export markets, the EDPRS II (2013–2018) aims to intensify capacity building and research to boost coffee production. The National Agriculture Export Board (NAEB) is already training 10,000 coffee farmers every year through the Farmer Field School approach (FFS). It also targets building capacity at coffee washing stations and continues to support cooperatives (RoR, 2013b).

Tea

Vision 2020 promotes investments in a major tea expansion programme, increasing the area under production by 18,000 ha by 2018 (RoR, 2012a). The Rwanda Development Board (RDB) suggests Rwanda take advantage of the strong growth in global demand for specialty teas, which requires 60 million kilograms of tea be added to global supply each year (RDB, 2012). Rwanda has ideal environmental and climatic conditions to grow naturally high quality tea at competitive prices and is gradually improving its infrastructure with support from government, donors and the private sector (RDB, 2010).

Honey

Another example of a niche market is Rwanda's honey production, which increased from 38 tonnes in 2005 to 321 tonnes in 2010 (RDB, 2015). MINAGRI is committed to boosting beekeeping in the country because it complements farming systems by helping pollination, provides supplementary income to rural households, is simple and relatively easy to start, enhances

biodiversity by pollination and requires few inputs in land, labour and capital. It is therefore an ideal activity for resource-poor farmers and one that easily integrates with other programmes and projects, such as community based natural resource management and projects to increase food production through cross pollination of food and cash crops by bee colonies (SNV Rwanda, 2009).

Pyrethrum

Rwanda's pyrethrum industry brings in over US$15 million a year in revenues. The main product is an organic insecticide effective against a wide range of pests made by refining the plant's beautiful white flower. Rwanda now competes with the few countries able to reliably grow pyrethrum, including Kenya, which supplies over 70 per cent of the world's pyrethrum, and Tanzania and Australia. The pyrethrum crop in Rwanda covers about 3,200 ha of land and involves some 30,000 farmers, providing them with a new source of dependable income. It is mainly grown in Musanze, Nyabihu, Rubavu and Burera Districts in the Northern Province. Rwanda's pyrethrum may soon be used to manufacture organic insecticides for crops and animals for both local use and export to eastern and western African countries (EA Agribusiness).

Pyrethrum is already used locally to protect passion fruit from pests and disease. Instead of using costly and potentially contaminating chemical pesticides, some farmers make and use their own natural mixture of pyrethrum, Aloe vera, garlic, *Crotalaria Juncea, Ricinus communis*, common nettle, *Ocotea usambarensis*, Jimson weed and *Iboza riparia* as well as tobacco leaves (Sezerano, 2015).

Stevia

Stevia is a small perennial shrub that has been used for centuries as a natural herbal sweetener that has no calories and is over 10–300 times sweeter than table sugar. A white crystalline compound (stevioside) is derived from the plant for use as an additive in food and beverages and for medicinal uses such as to lower blood sugar. (Goyal, Samsher, & Goyal, 2010). Globally, the value of stevia as an additive totalled US$110 million in 2013. Driven by rising consumer concerns over the health impacts of sugar, the Stevia market is growing rapidly. By 2017, its value is forecast to increase to US$275 million (Mintel, 2014).

SteviaLife, a Canadian company, is now growing premium stevia leaf in Rwanda (EA Agribusiness). The country has ideal soil and climate conditions for the stevia plant and can achieve naturally high yields (RDB, n.d.b.). At the end of 2011, Rwanda was producing 1.3 tonnes of stevia per hectare. Three pilot projects in Ngoma Sector, Rulindo District, Northern Province covering 42 hectares and employing 250 people were obtaining 2 tonnes per hectare every three months, and in 2014, 100 tonnes of stevia were exported to China (Ntirenganya, 2015).

Niche export of organic and fair trade foods

The GGCR strategy aims to create additional market opportunities by developing niche export crops under organic and fairtrade branding, such as tea, coffee and sugar. Such initiatives have numerous "green" benefits including increasing adaptive capacity and reducing GHG emissions by using processing technologies to reduce energy and biomass use (RoR, 2011).

In 2015, researchers from Washington State University hypothesized that the potential for organic agriculture to expand will likely be determined by whether it is economically competitive with conventional agriculture. Their meta-analysis of 44 scientific studies covering 55 crops grown on five continents found that in spite of lower yields, organic agriculture was significantly more profitable than conventional agriculture. They also concluded that given its environmental benefits, organic agriculture could contribute a larger share in sustainably feeding the world (Crowder & Reganold, 2015).

Organic agricultural export products from East Africa generally cater to high-end markets in Europe and the United States, which offer price premiums for certified organic goods. Such niche exports can bring small farmers who traditionally grow crops without chemical inputs into global supply chains, allowing them to develop their businesses and improve their livelihoods (CBTF, 2010).

The Rwanda Standards Board (RSB) and the National Agricultural Export Development Board (NAEB) have dedicated, government supported organic units to develop commercial organic production. Non-Government Organizations that promote sustainable agriculture also foster the sector's progress and the GAKO Organic Farming Training Centre is active in training farmers in organic practices (CBTF, 2010). Established in 2007, the Rwanda Organic Agricultural Movement (ROAM) is a National Umbrella

Organization uniting producers, farmers' organizations, processors, export and import companies, institutions and organizations involved in or supporting organic production, processing, marketing and export; ROAM has about 30,000 members (ROAM, 2015). In 2010, there were three companies in Rwanda involved in organic production; they export organic hot chillies, geranium oil and fresh fruits certified by ECOCERT, a certification body for sustainable development (CBTF, 2010).

Conclusion

In sum, Rwanda's GGCR strategy has recommended appropriate actions within the agricultural sector to help foster Rwanda's transition to a green economy. The country is also already implementing many of the best practices in sustainable agriculture that support the strategy's Programmes of Action, as illustrated throughout this chapter. As Rwanda transitions to a more efficient and productive agricultural sector, fewer people will work the land and more jobs and revenues will derive from post-harvesting activities and the export of niche agricultural products. The GoR is committed to accomplishing this by constraining carbon emissions and resource use that would normally ensue from adopting more conventional agricultural approaches that rely heavily on agrochemicals and mechanization, and ensuring that the agricultural sector incorporates climate resilience practices. These practices need to be upscaled and expanded from pilot projects and exemplary case studies to become the new business-as-usual. When a critical mass of farmers and off-farm agricultural workers are employed in resource efficient, low carbon and climate resilient practices, Rwanda will no doubt realize its aim to reduce poverty to at least 20 per cent. This shift would also improve the ecosystem goods and services that are the very foundations of economic development.

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Chapter 10: Greening Agriculture — Successes, Outlook and Proposals

This final chapter of the report summarizes the progress Rwanda has made in creating a more productive and sustainable agricultural sector, looks into the future at the costs of further greening agriculture and proposes some ways that might support and strengthen the transition to a fully modern agricultural sector that is economically and environmentally sustainable.

Table 1: Vision 2020 targets related to agricultural goals

Indicator	2000	2010	2020
Agricultural GDP growth (%)	9	8	8.5
Agriculture as a percentage of GDP	45	47	25
Agricultural workers as a percentage of the total population	90	75	50
Land under "modernized" agriculture (%)	3	20	40
Fertilizer application (kg/ha/year)	0.5	8	45
Percentage of banks' portfolio in the agriculture sector	1	15	20
Soil erosion protection (% of total land)	20	80	90

Source: (MINAGRI, 2013)

Successes

Agricultural transformation in Rwanda over the past decade has been profound. Chapter 8 details the successes achieved in Rwanda's agriculture sector and Table 1 summarizes its progress towards achieving agricultural goals expressed in Vision 2020.

Further achievements include the expansion of the surface area under irrigation, which culminated at 24,131 ha, above the set target of 24,000 ha. In addition, 4.2 million land titles were issued between 2006 and 2012 from a baseline figure of 8,000; this represents more than a 500 per cent increase. Livestock in intensive systems grew from 16 to 60 per cent against a set target of 55 per cent. And the use of mineral fertilizer increased from 14,000 million tonnes to 46,000 million tonnes between 2006 and 2012 (RoR, 2013). In addition, 23,683 ha of marshlands were developed for agricultural purposes (Mbonigaba Muhinda, 2013).

Interventions to move agriculture from a subsistence economy to a market economy were largely responsible for the fall in extreme rural poverty from 35.8 per cent to 24.1 per cent over the five years between EICV 2 (2005/06) and EICV 3 (2010/11) (MINAGRI, 2013).

Given this success and the continued importance of farming to Rwandan livelihoods and the economy, the GoR aims for the agriculture sector to continue to make the principal contribution to increasing GDP growth and reducing poverty. Chapter 9 explains how it might accomplish this without jeopardizing the resilience of the ecosystem goods and services that underpin development and underscores the related goals in the GGCR strategy.

The question now is "How is Rwanda doing in terms of greening agriculture?" It is still too early to tell how the many different and complementary agricultural practices highlighted in Chapter 9 are together and cumulatively greening the country's agriculture sector by making it more sustainable economically, environmentally and socially. To date, there have been no comprehensive assessments of the level of adoption and performance of green agricultural approaches and the degree to which they contribute to improving national economic performance. It

Table 2: Adoption of integrated soil conservation practices

Issues	Technology	Target area	Current adoption	Constraints
Stop erosion on hillsides, creating multiple benefits	Bench terraces	Areas with 25-40% slope	Mainly driven by public investment and where there has been a long and consistent demonstration period	Too little investment in social capital to establish and maintain erosion controls
Stop erosion on gentle slopes and where bench terraces are not possible, creating multiple benefits	Trenches, bunding with hedge rows	Areas where bench terraces are not recommended and where erosion occurs	The adoption is high but the compliance to technical recommendation highly fluctuates	No clear tree nurseries and fodder seed support where bench terrancing occurs (compared to crop seed systems, for example)
Reduce tillage to retain soil moisture and enhance soil fertility	Conservation agriculture	Crop intensification areas	Still low due to recent introduction	Need to demonstrate method for different crops and crop intensification strategies, including farming that integrates livestock

Source: (Nabahungu, 2013)

is thus important for Rwanda to systematically and periodically measure its progress in greening agriculture for a green economy to determine its success in helping to achieve the GGCR strategy's targets.

1.1 Measuring success

Such measurement requires the use of a set of indicators. Indicators and composite indices are "signs" that point out, or stand for, something; they illustrate and communicate complex data and trends in a simplified form and can be qualitative or quantitative. The latter are usually based on physical, chemical, biological or economic data (UNEP, 2006); (UNEP, 2012).

Table 2 illustrates the use of qualitative indicators when data are lacking. The example is the adoption rate of some soil erosion practices being implemented by farmers in Rwanda.

Rwanda is already preparing sets of potential indicators for the agriculture sector. The GGCR strategy suggests a number of key, mostly qualitative, indicators to measure progress in its Programmes of Action. Table 3 illustrates those related to sustainable agriculture.

In addition, the Rwanda Environment Management Authority (REMA) has proposed a number of specific mostly quantitative indicators to measure how the agriculture sector is becoming more productive as well

Table 3: Progress indicators for greening agriculture in the GGCR Programmes of Action

Programme 1: Sustainable Intensification of Agriculture	
Key Indicators	
Action 1: Mainstreaming of agroecology	Percentage of farms taking up agroecology technologies
Action 2: Resource recovery and reuse	Volume of waste reduction/compost production
Action 3: Fertilizer enriched compost	Percentage of farms applying fertilizer enriched compost
Action 4: Mainstreaming of "push-pull" strategies	Percentage of farms taking up "push-pull" strategies
Programme 2: Agricultural Diversity in Local and Export Markets	
Key Indicators	
Action 1: Expansion of crop varieties	Percentage of farms adopting crops
Action 2: Expansion of local markets	Number of markets constructed/national product flows
Action 3: Expansion of manufactured products	Percentage of districts with product manufacturing capacity
Action 4: Expansion of exports	Percentage of agricultural production of "niche" export products
Programme 3: Integrated Water Resource Management (IWRM)	
Key Indicators	
Action 1: Establish a national IWRM framework	Framework in place
Action 2: Community water management	Community level framework implemented
Action 3: Understanding the water balance	District and catchment water balances in place
Action 4: Water security	Percentage water efficiency achieved
Programme 4: Integrated Approach to Land Use Planning and Sustainable Land Use Management	
Key Indicators	
Action 1: Integrated planning and land use management	Operational Inter-Ministerial Council and National Water Authority
Action 2: Rwanda Spatial Data Infrastructure	Organizational structure populated
GIS/ICT innovation: central and local government	Completed water balance at national and district levels

Source: (RoR, 2011)

as increasingly resource efficient, low carbon and climate resilient (Table 4).

While good indicator sets or aggregated indices exist on paper, and there are some examples of efforts to qualitatively assess progress in greening agriculture, reliable and robust time-series data sets are needed to monitor progress towards goals, targets and objectives. Data are often lacking to populate indicators, however, especially in developing countries and regions; this is generally the case in Rwanda (UNEP, 2012). Reliable time-series data are still lacking to inform many of the indicators listed in Tables 3 and 4. Accurate and timely statistics are needed to monitor progress in achieving the agricultural goals and targets in the GGCR strategy as well as those in national and international programmes and policies, including the EDPRS II and Vision 2020.

It is noteworthy, however, that the National Institute of Statistics of Rwanda (NISR) in collaboration with the Ministry of Agriculture and Animal Resources (MINAGRI) is already collecting relevant data and is using a multiple frame sampling technique. The Seasonal Agriculture Survey (SAS) was designed and implemented from November 2012 onwards (NISR, 2014).

Table 4: REMA's proposed indicators for agriculture

Issue: Productivity needs to be increased to meet food security requirements while reducing any environmental stresses	
Issue identification indicators	**Most recent value (year)**
Productivity (tonnes/ha)	Average yields for key food security crops of 0.75 (2010)
High use of inorganic fertilizer by large scale farmers (%)	44% of large scale operations use inorganic fertilizer, and 20% of all farms (2013)
Cultivated land under irrigation (% of total cultivable land)	Less than 1.5% (2012)
Policy formulation indicator(s)	
Policy objectives	Intervention options
Increase productivity of crops by 2017 (in tonnes/ha): maize: 4; wheat: 3.5; rice: 7; irish potato: 30; cassava: 30; and beans: 3	Investments in mechanized farms and improved seeds (US$)
Access to organic fertilizers to all farms by 2017/18	Government investment in fertilizer procurement and distribution (US$)
Cultivated land under irrigation	Annual public investment on irrigation (US$)
Policy assessment indicator(s)	
Increase in productivity of crops (%)	
Improvements to efficiency of water usage in irrigation systems	
Improvements to food security	
Green jobs created by additional investments	
Annual rate of clearing of forest areas attributable to need for agricultural land (%)	

Source: (REMA, 2015a)

Recommendation:

- Set up an environmental measuring and monitoring programme to track bio-geo-chemical data to populate suites of appropriate agricultural and water indicators, as well as qualitative measures to track progress in achieving GGCR strategy targets (as in Tables 3 and 4), with the understanding that "what gets measured gets managed". The agricultural surveys programme should ensure that data collection instruments include "measures" of indicators for GGCRS Programmes of Action 1, 2, 3 and 4 shown in Table 3 and elaborated in the green growth costing report for the agricultural sector as shown in Table 4.

Outlook

In addition to providing knowledge about historical trends in agriculture's performance towards greening the economy, relevant data can be used to forecast the potential to achieve success in the future. Exercises to envision desired futures are useful in prompting the implementation of the necessary steps to achieve them.

There are numerous qualitative and quantitative approaches to assessing the outlook for the future. The Foresight Process/Delphi technique is a popular method that uses expert judgment, but there are also a variety of new developments, projections and forecasting analyses based on modeling, analytical techniques and statistical indicator models.

Scenario building is a popular exercise used in the business and financial sectors to systematically and creatively assess and describe long-term outcomes. Its goal is to imagine future states and anticipate future developments in the environment and society, to

identify strategies to respond to these developments and to evaluate the robustness of those strategies (RoR, 2009).

In the field of environmental sustainability, after the Brundtland Report and the 1992 Rio World Conference on Environment and Development, a wave of global scenarios was launched in the context of the sustainability challenge. Some were model-based and focused on one issue such as climate change, but broader efforts were also undertaken, such as the updated work of Meadows *et al.* (Meadows, Meadows, & Randers, 1992) and new integrated studies on such themes as climate change, water scarcity, public health and land use (Swart, 2004). The most well-know of these are the Emission Scenarios prepared by the Intergovernmental Panel on Climate Change (IPCC) and referred to as IPCC SRES as well as the scenarios developed by the World Water Vision, UNEP's Global Environment Outlook (GEO) report series and the Millennium Ecosystem Assessment (MEA), among others.

Rwanda's scenarios for the future of agriculture

In late-2013, the Government of Rwanda (GoR) commissioned technical assistance to conduct an exercise in scenario building. The purpose was to estimate the medium-term investment needed to implement green growth priorities in agriculture, including through improved water resource management to optimize the impact of irrigation on agriculture (Kaindaneh & Ntabana, 2014).

The costs of implementing the agriculture and natural resources scenario

The "greenness" of the agriculture and natural resource sector was assessed against four criteria,

Table 5: Agriculture and natural resources: three scenario outcomes by sub-sector

Sub-sector	BAU Scenario 2030 (1)	Medium Green Scenario (2)	High Green Scenario (4)
Research & extension	• Conventional agriculture	• Agro ecology • 30 Innovation centers	• Conservation agriculture • 30 Innovation centers
Land and water husbandry	• 252,370 ha. Progressive terraces • 58,485 ha. Bench terraces	• 69,666 ha. Progressive terraces • 60,864 ha. Bench terraces • 247,330 ha. Rehab of progressive terraces • 100,000,000 Agro forestry trees	• - • 562,160 ha. Rehabilitation of progressive terraces • 150,000,000 Agro forestry trees
Irrigation	• 28,795 ha. Hill side irrigation • 2,575 ha. Small scale irrigation • 42,500 ha. Marshland irrigation • 20,000 ha. Rehabilitation of existing schemes	• 50,000 ha. Hill side irrigation • 20,000 ha. Small scale irrigation • 30,000 ha. Marshland irrigation • 20,000 ha. Rehabilitation of existing schemes	• 50,000 ha. Hill side irrigation • 20,000ha. Small scale irrigation • No marshland irrigation • 30,000 ha. Rehabilitation of existing schemes • 15 Drip irrigation centers
Soil fertility	• Continuous Increase of the use of inorganic fertilizers	• 1 Production of organic fertilizers Units • 7 Construction Soil testing laboratories • 4 Rehabilitation of existing laboratories • 1 Fertilizer blending plant	• 30 Production of organic fertilizers Units • 6 Construction of pilot comlizers • 30 Fertilizer Granules machines • 6 Fertilizer blending plant
Conservation agriculture			• 245,160 ha. On bench terraces • 554,840 ha. Land under traditional farming • 6,000 Conservation agriculture Machinery • Strengthened research & extension
Value addition and post harvest	• 35 units storage infrastructure • 7 units post harvest equipment • 700 drying floors • 2 cold storage	• 2 cold storage	• 60 units post harvest equipment • 200 Community agro-processing
Market development	• 7,000 km feeder roads		• 3 Organic certification center • New Fair trade markets

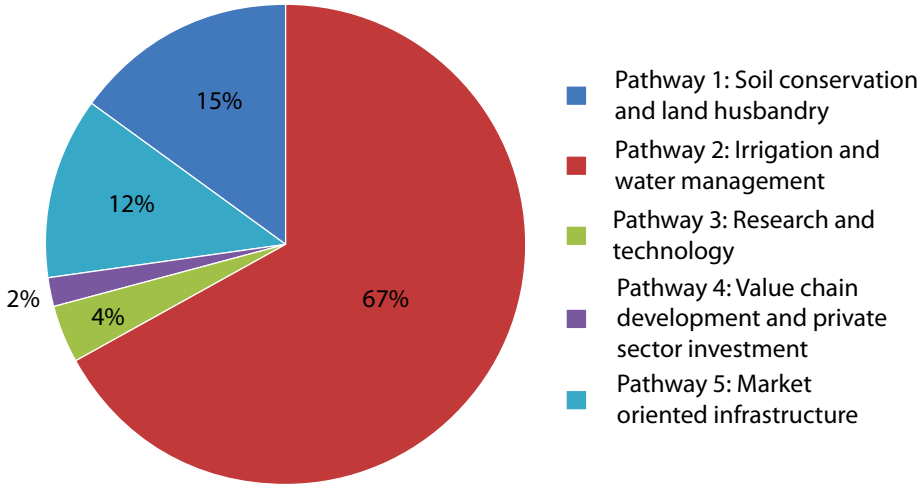
Source: (REMA, 2015b)

Table 6: Cost of investments in agriculture and natural resources, BAU

PATHWAYS	Total		
	RWF	USD	Per cent Total
Pathway 1: Soil Conservation and Land Husbandry	92,909,610,120.0	136,031,640.0	15
Pathway 2: Irrigation and Water Management	419,450,004,550.0	614,128,850.0	67
Pathway 3: Research and Technology	24,418,564,092.0	35,751,924.0	4
Pathway 4: Value Chain Development and Private Sector Investment	15,486,695,794.0	22,674,518.0	2
Pathway 5: Market Oriented Infrastructure	74,434,007,974.0	108,980,978.0	12
Total BASELINE COSTS	626,698,882,530.0	917,567,910.0	100
Physical Contingences	1,849,874,901.6	2,708,455.2	-
Price Contingences	-	-	-
TOTAL PROJECT COSTS	**628,548,757,431.6**	**920,276,365.2**	**100**

Source: (GoR, 2015)

Figure 1: Proportions of pathway costs out of total project cost, BAU scenario



Source: (GoR, 2015)

namely: 1) efficiency in the use of natural resources; 2) resilience to climate change; 3) low carbon emissions; and 4) social, economic and environmental benefits. Important decisions illustrated by these criteria include the degree of terracing, the degree of irrigation in hillside versus marshland areas, different methods that can be employed to maintain or improve soil fertility, precision application of inorganic fertilizers, the extent to which conservation agricultural methods can be developed and the exploration of markets that offer premiums to sustainably produced products (REMA, 2015b).

Three scenarios were envisioned for the future of agricultural and natural resources, depending on the degree to which these criteria were implemented: Business as Usual (BAU), a medium green growth scenario and a high green growth scenario (Table 5, previous page).

The Business As Usual (BAU) Scenario

The scenario exercise largely draws on the content of the Strategic Plan for the Transformation of Agriculture, Phase III (PSTA III) and the Agriculture Sector Investment Plan (ASIP) 2009-2012 to estimate the costs of a "Business As Usual" (BAU) baseline, in which environmental issues are only partly addressed (REMA, 2015a). The BAU scenario is organized around five individual pathways: Soil and Land Husbandry, Irrigation and Water Management, Research and Technology, Value Chain Development and Private Sector Investment and Market Oriented Infrastructure, each with their associated costs of implementation (Table 6 and Figure 1). The baseline cost was estimated at US$920 million over the period 2015-2030, of which the irrigation and water management component is projected to be around US$614 million, representing 67 per cent of the total costs (AfDB, 2015).

Although the BAU scenario includes some green activities in terms of land and water management, it is not enough to mitigate negative climate change and

Workers terrancing a hillside

Table 7: Costing of investments in agriculture and natural resources, high green growth

Pathway	Total		
	RWF	USD	Per cent Total Base Costs
Pathway 1: Greening Land and Water Husbandry	505,219,519.81	1,680,133,115.7	76
Pathway 2: Mainstreaming Green Agro-Ecology Practices into Crop Intensification Program (CIP)	363,208,560,390.4	505,219,519.8	23
Pathway 3: Strengthening the National Post Harvest and Value Addition Capacity	19,892,237,894.6	27,669,906.4	1
Total Baseline Costs	1,590,969,271.90	2,213,022,542.0	100
Physical Contingencies	1,993,472,100.0	2,772,900.0	-
Price Contingencies	-	-	-
TOTAL PROJECT COSTS	**1,592,962,744.00**	**2 215 795 442.0**	**100**

Source: (GoR 2015)

other environmental, social and economic impacts (Stratus Consulting Inc., 2015). The BAU scenario could lead to water scarcity, nutrient depletion, increased subsidies for inorganic fertilizers, increased production costs to the farmer, increased greenhouse gas (GHG) emissions, soil acidification and the pollution of waterways (REMA, 2015b). There is a need to counter the risks and to mitigate future agricultural uncertainties by sustainably intensifying small-scale agriculture and introducing climate smart farming within the ongoing Crop Intensification Programme (CIP).

The higher green growth scenarios

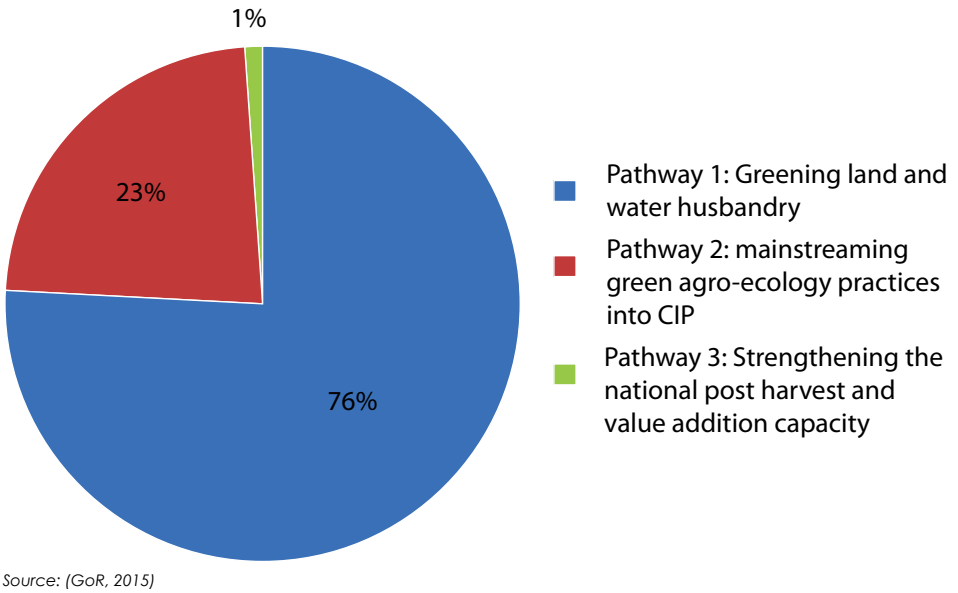
The high green growth scenario includes three pathways to reach increased production targets while minimizing impacts:

1. Scale up land and water husbandry practices under the CIP to reach 100 per cent coverage in land conservation; increase hillside and small-scale irrigation while minimizing the expansion of irrigation in marshlands; and rehabilitate existing irrigation schemes to improve water use efficiency and productivity. The scenario improves the efficiency of land and water husbandry investments planned in the BAU, reduces soil erosion and preserves the marshlands with their ecosystems and biodiversity services.
2. Mainstream agroecology practices into the ongoing CIP with a focus on soil fertility management and improve soil quality and research oriented to agroecology practices. This will improve soil quality and fertility, improve the efficiency of inorganic fertilizers through integrated soil nutrient management and reduce soil acidification and waterway pollution.
3. Strengthen the National Post Harvest and Value Addition Capacity by supporting private entrepreneurs in adding value and reducing post-harvest losses and in exploring new niche markets for sustainably produced products. This will help create new jobs, foster import substitution and improve farmers' incomes (REMA, 2015b).

The implementation cost of each pathway under the high green growth scenario is summarized in Table 7 and Figure 2.

The costs of the two scenarios with relatively greater green attributes were projected against the baseline BAU. Between 2015 and 2030, the medium green growth scenario requires an investment of US$1.5 billion and envisions the introduction of conservation agriculture to reduce the costs of land husbandry and water management. Over the same period, the high green growth scenario requires an investment of US$2.2 billion. It allots greater investment in best practices in land husbandry and water management consisting of enhanced terrace construction and

Figure 2: Proportions of various pathways costs out of total costs, high green growth



Source: (GoR, 2015)

maintenance, improved irrigation construction and maintenance, increased agroforestry activities (tree planting) and soil quality studies. Green Land and Water Husbandry accounts for 76 per cent of the total base cost of implementing the scenario. (REMA, 2015a).

Both the medium and high green growth scenarios involve a significant investment in resources (US$1.5 billion and US$2.2 billion, respectively, compared to the BAU investment of US$920 million). The return on investment is important, however, since it brings improved agricultural productivity (including through

Table 8: Water sector scenarios by subsector

Sub-sector	BAU Scenario 2020 (1)	Medium Green Scenario (2)	High Green Scenario (4)
Urban	• 100% coverage at 100 lpcd • Centralized, piped distribution systems with increased private connections and standpipes • Limited RWH • No water reuse • Collection and treatment of 50% of wastewater flows	• 100% coverage at 100 lpcd • Water supply: o 5% RWH o 28% water reuse o 10% water conservation o 57% surface and groundwater • Decentralized systems with increased private connections and standpipes • Collection and treatment of 100% of wastewater flows	• 100% coverage at 100 lpcd • Water supply: o 5% RWH o 28% water reuse o 10% water conservation o 57% surface and groundwater • Decentralized systems with increased private connections and standpipes • Collection and treatment of 100% of wastewater flows
Rural	• 100% coverage at 45 lpcd • Single-use reservoirs and distribution systems • 50% of supply provided through piped distribution systems	• 100% coverage at 80 lpcd • 50% of reservoirs are multi-use • 88% of supply provided through piped distribution systems • Increased standpipes/connections • Community-based systems paired with small-scale RWH for irrigation	• 100% coverage at 100 lpcd • 50% of reservoirs are multi-use • 88% of supply provided through piped distribution systems • Increased standpipes/connections • Community-based systems paired with smallscale RWH for irrigation
Industry	• Industrial supply at 15 lpcd • Collection and treatment of 50% of wastewater flows • Supply includes 25% recycled water	• Industrial supply at 15 lpcd • Collection and treatment of 100% of wastewater flows • Supply includes 50% recycled water	• Water conservation for 10% savings • Collection and treatment of 100% of wastewater flows • Supply includes 50% recycled water
Agriculture (in IWRM)	• 85,100-ha increase in irrigated area, including 49,000-ha marshland and 33,100-ha hillside • Limited small-scale irrigation through RWH (3,000 ha) • No conservation agriculture or water-use efficiency measures	• 135,800-ha increase in irrigated area, including 34,600-ha marshland and 81,200-ha hillside • Increased small-scale irrigation through RWH (20,000 ha) • Conservation agriculture reduces demand by 15%	• 101,250-ha increase in irrigated area • No marshland irrigation • Ecosystem services payments offset reduction in marshland irrigation • Increased small-scale irrigation through RWH (20,000 ha) • Conservation agriculture reduces demand by 15%
IWRM governance framework	• Adequately staff national IWRM department • Operationalize public-private partnerships • Develop sustainable financing mechanisms • Manage/put in place international treaties and agreements • Limited capacity building/ training	In addition to BAU activities: • Establish nine catchment-basin committees and operate catchment plans • Focus on increased coordination and capacity building/training • Value national wetlands and develop a conservation plan • Establish RWH and water conservation measures and promote them to institutions and households • Implement adaptive management	In addition to BAU activities: • Establish nine catchment-basin committees and operate catchment plans • Focus on increased coordination and capacity building/training • Value national wetlands and develop a conservation plan • Establish RWH and water conservation measures and promote them to institutions and households • Implement adaptive management
Ensure equitable allocation and use of water resources	• Assess and monitor water resources to identify spatial and temporal occurrence and distribution • Develop water resources information system and clearinghouse • Formulate guidelines for water resources allocation • Develop and implement permit system for water abstractions and wastewater discharges	In addition to BAU activities: • Map all critical catchments and establish their ecological functioning to inform environmental water demand and rehabilitation plans • Conduct EIAs for all new water supply and sanitation projects	In addition to BAU activities: • Map all critical catchments and establish their ecological functioning to inform environmental water demand and rehabilitation plans • Conduct EIAs for all new water supply and sanitation projects • Assess climate change vulnerability and adaptation options related to water resources for key sectors • Extreme weather early warning system • Safety plans for waterways and infrastructure

Source: (REMA, 2015b)

reduced vulnerability to climatic shocks) and reduces the detrimental environmental impacts of agricultural activities, such that the two higher cost scenarios contribute substantially more to green growth and the achievement of the GGCR strategy's targets (REMA, 2015a).

Recommendations:

- Introduce green technologies, especially conservation agriculture in the CIP, maintaining the current growth levels of the sector;
- Scale up land and water husbandry practices under the CIP to reach 100 per cent coverage in land conservation;
- Mainstream agroecology practices into the ongoing CIP with a focus on soil fertility management;
- Expand new technologies to more land areas currently under conventional agriculture, as farmers adopt the new technologies and productivity increases;
- Strengthen the National Post Harvest and Value Addition Capacity by supporting private entrepreneurs in adding value and reducing postharvest losses.
- Explore new niche markets for sustainably produced and organic products; the Government's efforts in securing markets for new products and services, such as organic products and fair trade, which result from green agricultural practices, should be a critical part of the inclusive growth paradigm.

The costs of implementing the water sector scenario

A thorough analysis of the future of the agricultural sector cannot be conducted without taking into account green strategies envisioned in the water sector, since implementing green agricultural practices requires the sustainable collection and management of water resources, for irrigation in particular, and protecting irrigation water sources from contamination.

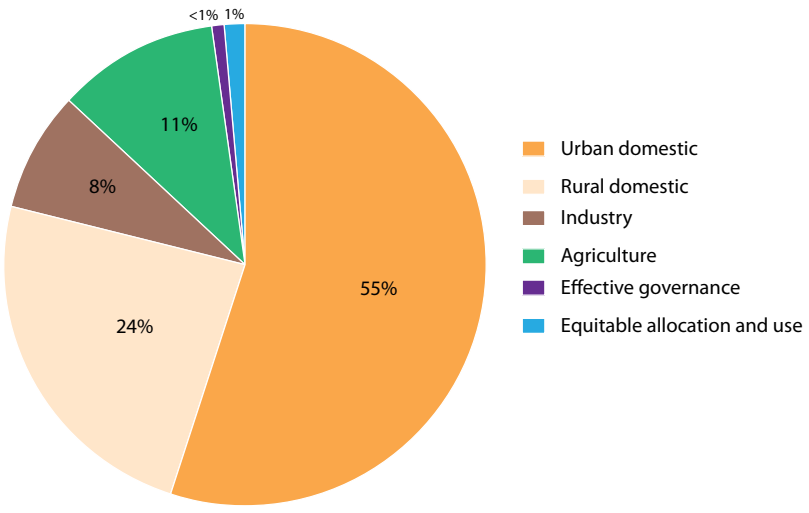
In the water sector, the GoR strategy to sustainably harvest, manage and distribute water resources to meet all demands is implemented through Integrated Water Resources Management (IWRM). The scenario building exercise also envisions three high-level IWRM targets and scenarios: the Business as Usual (BAU) scenario, which assumes conventional approaches to meet Rwanda's water resources management goals through to 2040, and two "green-growth" scenarios, which incorporate alternative strategies more in line with the GGCR strategy (Stratus Consulting Inc., 2015). The scenarios include hard infrastructure projects, but also focus on the "soft capital" necessary to implement IWRM (e.g., capacity building, establishing a water permitting system and decentralizing and managing water resources at the District level). The pathway for meeting multiple future water demands differs considerably across the three scenarios. The BAU scenario as well as both green growth scenarios focus on four primary water-demand subsectors: urban domestic use, rural domestic use, agriculture and industry. Table 8 describes the three scenarios by subsector. Urban and industrial water use and treatment are relevant to the agriculture sector given that runoff from these subsectors often finds its way into marshlands where crops are grown and other water bodies and groundwater whose waters may be used for irrigation.

The capital cost expenditures in agriculture to meet high-level water targets in a BAU scenario would be 11 per cent of the total, as illustrated in Figure 3.

The Business As Usual (BAU) scenario

The BAU scenario includes an 85,100 ha increase in irrigated area, including 33,150 ha of hillside irrigation and 49,000 ha of marshland irrigation. Only a small amount of resources will be devoted to increasing small-scale irrigation through rainwater harvesting (RWH). Thus, the BAU scenario will do little to improve the situation of Rwanda's poorest rural

Figure 3: Capital cost expenditures associated with meeting high-level targets, BAU scenario



Source: (Stratus Consulting Inc., 2015)

residents. In addition, without practices to reduce the environmental impacts of irrigation through conservation agriculture, the expansion of irrigation onto steep hillsides and marshlands will further degrade ecosystems services (Stratus Consulting Inc., 2015).

Irrigation on steep hillsides will increase erosion, which will place infrastructure at risk and increase the likelihood and severity of flooding. It will also require significant amounts of energy for pumping. Furthermore, the aggressive conversion of marshlands will reduce the effectiveness of important ecosystem services, including water filtration, flood protection and groundwater replenishment, thereby increasing the need for built infrastructure (Stratus Consulting Inc., 2015). Moreover, marshlands provide productive functions that help to sustain local livelihoods and they are important reservoirs of biodiversity (REMA, 2011). Rwanda's wetlands however, already face enormous pressures from agriculture, human settlements and urbanization. Indeed, recent inventories have reported that only 41 per cent of wetlands remain in a natural state (MINIRENA, 2011). The Ministry of Natural Resources posits, "Rwanda's main challenge in this regard relates to establishing a balance between protecting wetlands to sustain socioeconomic and ecological benefits, and continuing reclamation for agriculture" (MINIRENA, 2011).

Green growth scenarios

The medium green growth scenario incorporates a more integrated, decentralized approach to water resource governance, as well as a more comprehensive programme for ensuring equitable allocation of supplies. To meet future demands, this scenario relies on a mix of alternative and conventional water-resource management options, including decentralized infrastructure for water supply and wastewater collection, water reuse, increased RWH, demand management activities and Multiple-Use Services (MUS) systems for rural and agricultural water supply (Stratus Consulting Inc., 2015). In this scenario, expenditures associated with water for agriculture represent 18 per cent of the total (Figure 4).

Compared to the BAU scenario, the medium green growth scenario could result in significant financial, social and environmental benefits. It would increase climate resilience and water supply reliability by diversifying water supply sources. Rather than relying solely on traditional surface water and groundwater sources, the medium green growth scenario incorporates additional RWH, demand-management strategies (i.e., water conservation) and grey water and wastewater recycling (Stratus Consulting Inc., 2015).

With regards to the agricultural sector, an assumption is made that an increase in the amount of irrigated hectares under the medium green growth scenario proves consistent with the agriculture and natural resources costing assessment (above). The objective of expanding the irrigated area is to improve food security and enhance livelihoods for rural residents. Although marshland irrigation is decreased relative to the BAU scenario, the conversion of 34,600 ha of marshland will have adverse environmental and social effects (Stratus Consulting Inc., 2015).

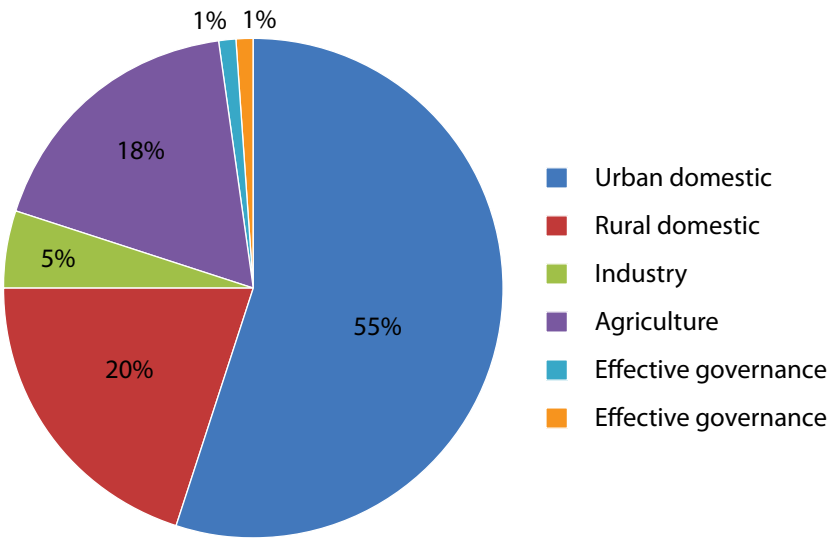
The high green growth scenario is very similar to the medium growth one, with levels of small-scale irrigation through RWH and hillside irrigation by surface water, groundwater and reservoirs remaining the same. The high green growth scenario eliminates all marshland irrigation, however, and introduces Payments for Ecosystem Services (PES) to compensate for related livelihood losses. It also increases crop intensification programmes, further offsetting food production losses. Reducing marshland irrigation will help sustain Rwanda's wetland resources and their significant ecosystem goods and services (Stratus Consulting Inc., 2015).

Conclusion

The additional cost estimates for the high green growth scenario in the agriculture and water sectors, a summary of the impacts and interventions to address them are provided in Table 9.

The Rwanda Environment Management Authority (REMA) provides a high-level integrated overview of

Figure 4: Capital cost expenditures associated with meeting high-level targets, medium green growth



Source: (Stratus Consulting Inc., 2015)

the results of these costing exercises concluding that the BAU scenario incurs environmental degradation and adverse social impacts and practices that could limit Rwanda's long-term growth potential. Such negative impacts for the agriculture and water sectors include soil erosion, soil and water quality degradation and lack of water supply diversification leading to reductions in long-term supply and climate vulnerability (REMA, 2015b).

By contrast, the greener growth scenarios lead to higher levels of services. In the water sector, the green growth scenario involves 100 per cent of wastewater collection and treatment (compared to 50 per cent under BAU) and provides a higher level of supply to residents in rural areas. In the agriculture sector, the green growth scenario leads to reduced levels of soil erosion and improved soil quality, increased water use efficiency and reduced vulnerability to climate change.

Recommendations:

- Reduce irrigation in marshlands;
- Rehabilitate and optimize existing irrigation schemes to improve water use efficiency and productivity;
- Emphasize rainwater harvesting, re-use and conservation;
- Increase small-scale decentralized irrigation systems;
- Increase to 100 per cent the collection and treatment of urban and industrial wastewater;
- Create multi-use water infrastructure and increase piped water distribution to support productive water use in rural areas.

Table 9: Overview of scenarios and costs

Sector	Development Objectives	Negative environmental and social impacts of BAU scenarios	Key interventions under green scenarios to address impacts	Additional cost of 'High Green' Scenario USD (2015-2030)
Agriculture	Maintain food security, and meet nutrition demands for a growing population.	Development of marshland areas leads to ecosystem destruction and compromises future water availability. Low water productivity reduces climate resilience. Increased use of agro chemicals raises costs, pollution of waterways and soil acidification. Mechanisation increases soil erosion.	Scaling up best practices in land and water husbandry; mainstreaming green agro-ecology practices into the crop intensification programme; and strengthening the National Post Harvest and Value Addition Capacity.	Capital: $0.6 bn O&M: <$0.1 bn Total: $0.7 bn
Water	Meet multiple increasing demands, including 100 per cent coverage for rural and urban households (HH). Establish national IWRM governance framework and ensure equitable allocation & use.	Under BAU, 100 per cent access is met through traditional infrastructure, less focus on efficiency or re-use, leading to greater water consumption and reduced climate resilience. Only 50 per cent of wastewater is collected & treated leading to degradation of urban waterways. Unequal distribution of water resources in rural areas with supply capacity supporting only basic domestic uses. Traditional, centralized governance is assumed, with little integration across sectors.	Greater emphasis on rainwater harvesting, re-use and conservation. Increase in small-scale decentralised systems and reduction in marshland irrigation increases climate resiliency and supply reliability. 100 per cent of wastewater collection & treatment in urban and industrial areas. Multi-use water infrastructure and increased piped distribution increases per capita use in rural areas to support productive uses. Focus on integration across sectors, and decentralized governance to facilitate effective local solutions. Increased funding for monitoring and permitting system to ensure equitable allocation and use.	Capital: $1.0 bn O&M: $1.8 bn Total: $2.8 bn

Source: (REMA, 2015b)

Note: O&M refers to Operations and Management. Costs are presented as "in addition to" or (for negative values) lower than the estimated costs of the Business As Usual (BAU) scenario, cumulative through 2030 (REMA, 2015b)

For Rwanda to proceed with the investments required to achieve these green pathways, sources of finance will be needed that are able to bear the larger capital requirements at reasonable cost, taking into account the additional technical risks. This might require internal budget reallocation as well as for international financial institutions to play a role in supporting these investments (REMA, 2015b).

It is also important to note that the above scenarios not only provide costing of various pathways the GoR can explore in attaining the goals of green agriculture, but also present clear guidance on which pathway to put in place by presenting the long term benefits. Any decision to be taken at the policy level for any pathway requires close and harmonious coordination between government and private sector entities in charge of agricultural and natural resources as well water sectors. A lack of synergetic coordination between government institutions may result in fragmentation of outcomes and a spike in the cost of implementation in each sector (REMA, 2015b).

Transitioning to green agriculture: requirements and proposals

This section of the chapter suggests several requirements or criteria for Rwanda to transition to green or sustainable agriculture and proposes a number of ways in which it might reform policies and strategies to create a sustainable agricultural sector that supports green growth. Greening the economy with agriculture is inevitably an iterative process (FAO, 2012). It requires a managed transition away from "business as usual" and an effort to "leap-frog" over some of the stages in industrial agriculture toward lower carbon and resource efficient technologies. This will take time. However no time should be lost in transitioning from trade-offs, such as accepting increased pollution because of the production benefits of chemical fertilizers, to synergies, such as more efficient and resilient food and agriculture systems that both feed a growing population while reducing its environmental footprint and enhancing ecosystem services (FAO, 2012).

Green agriculture will require financing

An efficient transition will require human and resource investments by public, private and civil sectors of society to ensure food security and social equity during the transition period. As is evident in the scenarios described above, transitioning to green agriculture will require substantial financial investment. In this regard, the GoR has developed an institutional framework that will help harness the necessary funding to execute the scenarios for the best low carbon development strategy, including in the agriculture sector. For example, the National Fund for Climate and Environment (FONERWA) was launched to facilitate access to international climate finance, especially Fast Start Finance for adaptation and mitigation in Least Developed Countries (LDCs) and the new Green Climate Fund (RoR, 2011). Also, the GGCR strategy developed a Climate Finance Toolkit to enable government ministries to source and access finance for climate resilience and low carbon development activities from numerous funds. In addition to these external sources, the GoR is securing domestic revenues and leveraging private capital for low carbon and adaptation activities. The Clean Development Mechanism and voluntary carbon markets offer a potential source of revenue for public and private mitigation initiatives (RoR, 2011).

The PSTA III notes that public and donor financing will not be enough to adequately boost the commercialization of the agricultural sector and suggests that it is important to develop innovative new agricultural financial products, and leverage private investment (MINAGRI, 2013).

Attracting investments

In the coming years, Rwanda needs to attract billions of US dollars in investment to implement its GGCR strategy and its agricultural goals. The outcome document of the *Third International Conference on Financing for Development* in Addis Ababa, in July of 2015 focused on "A global framework for financing development post-2015". It stipulates potential opportunities for additional domestic public resources, supplemented by international assistance as appropriate to realizing sustainable development and achieving the global Sustainable Development Goals. The Conference recognized that funding from all sources, including public and private, bilateral and multilateral, as well as alternative sources of finance, would need to be stepped up for investments in many areas including for low carbon and climate resilient development (FAO, 2015).

The Green Climate Fund, the largest dedicated climate fund, is starting its activities in supporting developing country parties to the UNFCCC Convention with the aim for a 50:50 balance between climate change mitigation and adaptation over time on a grant equivalent basis and it aims for a floor of 50 per cent of the adaptation allocation for particularly vulnerable countries, including least developed countries, small island developing States and African countries (UN, 2015).

The transition to green agriculture will require policy reforms

UNEP's report on *Investing in Natural Capital* (2011) suggests the need for a package of investments and policy reforms aimed at greening agriculture that will offer opportunities to diversify economies; reduce poverty through increased yields; create new green jobs, especially in rural areas; ensure food security on a sustainable basis; and significantly reduce the environmental and economic costs of agriculture. Through its GGCR strategy, Rwanda has already put in place policy reforms to transition to green agriculture. It is also involved in helping to reform international policies to remove environmentally harmful subsidies that artificially lower the costs of some agricultural inputs and lead to their inefficient and excessive use (UNEP, 2011). There is a need to recognize the inherent uncertainty in such policy approaches as there is not enough rigorous research and evidence gathered through the implementation processes, except limited data from case studies, the results of which are not easy to scale up. Future outcomes will depend a lot on attracting investments, technological knowhow and skill development in various sectors.

Recommendations:

- Tap into new green financing mechanisms to fill the gap of additional costs that greening will require;
- Introduce the strict monitoring of policy reform implementation through rigorous and time-scaled data collection and analysis.

In its report on *Policy Instruments to Support Green Growth in Agriculture*, the OECD suggests that policies need to be carefully designed and monitored for coherence. Policies within different sectors can either be synergetic or conflicting. In the latter case, they work against each other such that neither one can be achieved (OECD, 2013). The document provides a useful green growth toolkit for food and agriculture (Table 10). The following discussion explores some of the proposed policies that are relevant to Rwanda.

Environmental regulations and standards: certification of sustainable agricultural products

Certification and eco-labeling of products based on organic and ecological production processes

Resource effiencicency at the Kitabi Tea Processing Facility

can add substantially to marketing premiums from environmental and health conscious consumers. It is particularly important to support international efforts to "harmonize" the various sustainable and organic certification protocols and standards. Today's fragmented certification procedures impose high transaction and reporting costs on farmers, limiting their ability to access international markets (FAO, 2013).

A number of Rwanda enterprises and cooperatives are already recognized by the Rainforest Alliance, which provides certification for environmental, social and economic sustainability and there are organic food producing companies that are certified under ECOCERT (Rainforest Alliance, 2012); (Kitabi Tea Factory RECP Team, 2014); (CBTF, 2010). These provide models for other upcoming agri-businesses to follow. There is more room for Rwanda to increase its policy and regulatory support of certification schemes to increase the country's profile, credibility and sales in organic and other green goods and production processes, which are increasing in demand. For example, Rwanda is entering the field of stevia production and could benefit from support in this growing niche market related to healthy food choices (Mintel, 2014).

In addition to certifying niche goods related to sustainable agricultural products, Rwanda could improve the capacity to develop and implement food safety standards that can ensure compliance with international requirements, which can increase prospects for small farmers.

Recommendations:

- Increase the policy and regulatory support of organic certification schemes;
- Improve compliance with international food safety standards.

Support measures: Result-based incentive structures

It is critical to motivate farmers and regularly inform decision makers in a timely manner. In order to motivate farmers, the GoR could formulate and implement schemes in which farmers are provided

Table 10: Green growth policies for food and agriculture

Toolkit	Policy Instruments
Environmental regulations and standards	• Enact and enforce controls on excessive use of agrochemicals and fertilizers in production • Strengthen rules and standards for water, soil quality, and land management • Improve enforcement of environmental regulations and standards and certification from the farm-gate to the retail sector
Support measures	• Decouple farm support from commodity production levels and prices • Remunerate provision of environmental public goods (such as biodiversity, carbon sequestration, and fl ood and drought control) beyond reference level and closely targeted to environmental outcomes • Target environmental outcomes where feasible, otherwise target production practices favourable to the environment • Target public investments in green technologies
Economic instruments	• Price inputs to reflect scarcity value of natural resources • Impose charges/taxes on use of environmentally-damaging inputs • Implement trading schemes for water rights and carbon emissions
Trade measures	• Lower tariff and non-tariff barriers on food and agriculture products bearing in mind the potential impact on environmental concerns such as biodiversity and sustainable resource use • Eliminate export subsidies and restrictions on agricultural products • Support well-functioning input and output markets
Research and development	• Increase public research on sustainable food and agricultural systems • Promote private agricultural R&D through grants and tax credits • Undertake public/private partnerships for green agricultural research Information, education, training and advice • Increase public awareness of more sustainable consumption patterns such as via ecolabelling and certifi cation • Incorporate sustainable approaches in training, education and advice programmes throughout the entire food chain

Source (OECD, 2013)

Locoally grown products

with incentives to deliver an environmental result or outcome. An example is to provide financial compensation for farmers who increase the number of indigenous species around their farms (EU, 2015). This is an example of Payment for Ecosystem Services (PES). Smallholder farmers using green practices such as no-till and conservation approaches, can provide valuable services, such as carbon sequestration; water flow, infiltration and purification; and biodiversity protection. Examples of clients of such services include countries or utilities wishing to offset their carbon emissions; hydropower facilities that rely on dependable water flows; and ecotourism ventures that need high levels of biodiversity. Thus, subsistence farms can use PES policies to generate income and alleviate rural poverty by providing valuable public goods while helping to protect ecosystems (Andrew & Masozera, 2010).

Recommendation:

- Introduce Payment for Ecological Services (PES) to compensate farmers for livelihood losses they may experience with green growth strategies (such as the reduction of irrigation in marshlands) or for their contribution to ecosystem services (such as carbon sequestration; water flow, infiltration and purification; and biodiversity protection).

Result-based mechanisms such as PES can allow farmers the flexibility to choose what management is required to achieve the desired result. Compensation is only made when the result is achieved, making the link between the incentive and the achievement of well-defined environmental results on the ground. The flexibility allows farmers to use their knowledge and experience to manage the land to benefit both the environment and their farming operations. Results-based schemes often enhance farmers' awareness of the importance of protecting agricultural ecosystem services (EU, 2015).

Trade measures: reform trade subsidies and aid for trade

Supporting increased access by high-income countries to green agricultural exports originating in developing countries and reforming trade distorting production and export subsidies is another way to reform relevant policies (FAO, 2012). Such reforms would allow smallholder farmers, cooperatives and local food processing enterprises greater participation in food-production value chains (UNEP, 2011).

Aid for Trade can also play a major role in helping finance green agriculture. The 2015 Addis Ababa Conference on financing for development pledged to focus Aid for Trade on developing countries, in particular least developed countries, including through

the Enhanced Integrated Framework for Trade-Related Technical Assistance to Least Developed Countries (EIF, 2014).

Research and development: Technology transfer, research and capacity building

Vision 2020 recognizes the need for an exit strategy from reliance on agriculture into secondary and tertiary sectors. It advocates identifying and moving towards Rwanda's comparative advantage (RoR, 2000). Already, there is a high rate of underemployment in the agriculture sector and as farming practices intensify and productivity increases, it will likely require increasingly less labour. Given that less than 20 per cent of Rwandans of working age will have secondary education by 2020, it is crucial to create jobs in informal businesses in the non-farm or agricultural processing sectors (Hernandez, 2013).

Recommendation:

- Develop a robust and vibrant private sector to provide jobs for youth in rural areas. This will reduce the motivation for urban migration, while at the same time reducing the pressure on land and water use.

Rwanda might also use policies to encourage technology transfer mechanisms and Intellectual Property Rights (IPR) regimes in agri-technology, which should be more affordable and available to Rwanda. As well, policies might be strengthened to support, invest in and develop research strategies to meet the challenge of diversity in farming systems and agro-ecological and socioeconomic conditions. This would help to maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national level (UNDESA, 2014).

Recommendations:

- Review and reform agricultural policies to accommodate green technologies in the production system;
- Improve soil quality research oriented to agroecology practices;
- Invest more in research and extension to acquire and disseminate new technologies.

To develop and upgrade the skills of the growing workforce, it is important that relevant institutions introduce policies to strengthen Public Private Partnership (PPP) through skill training programmes in agribusiness, food processing and other unorganized sectors. It requires viable business models and funding in terms of grants, loans and incentive structures for income and employment. It also requires curriculum development, faculty and their training, standards and quality assurance, technology platforms, placement mechanisms and so on. The Government might play an enabling role in some of these support services, most importantly and in the near-term, setting up standards and accreditation systems in partnership with industry associations (NSDC, 2013).

Green agriculture needs to be profitable

"No business is sustainable unless it is also profitable" (UNEP, 2011). Thus, green agriculture needs to be productive. There are numerous examples of higher agricultural productivity and profitability in developing countries that implement greener farming practices. Jules Pretty (2006) studied farmers in 57 poor countries who had adopted a total of 286 "best practice" initiatives, such as integrated pest and nutrient management, conservation tillage, agroforestry, aquaculture, water harvesting and livestock integration. The results showed an average increase in yield of nearly 80 per cent. UNEP also reports there is evidence that green farming practices, especially on small farms, can increase yields by between 54 and 179 per cent (UNEP, 2011).

In addition to productivity, green agriculture can be profitable because a greater share of total farming expenses goes towards local labour and fertilizer sources, creating a local multiplier effect. Generally, green farming practices need more labour inputs than conventional farming, which helps to create jobs in rural areas and generates a higher return on labour inputs (UNEP, 2011); (UNEP, 2015).

The PSTA III deems that although Rwanda's target to grow the agricultural sector by 8.5 per cent a year over the next five years is ambitious, it is achievable. The GoR should support and foster the further development of the key drivers of this growth as outlined in the PSTA III:

- Expand CIP to further increase the productivity of staple crops;
- Expand the livestock sector, particularly small stock and fisheries;
- Invest in mechanization, processing and post-harvest facilities to modernize production;
- Target extension at producers to develop a skill-based sector;

- Conduct research that responds to farmers' needs and identifies optimal crop varieties;
- Aggregate smallholder production to provide sufficient quantities for markets;
- Improve the quality of traditional export crops to generate higher premiums;
- Increase the production of emerging export crops, including horticulture;
- Develop value chains to strengthen supply and develop market demand;
- Encourage entrepreneurship through agricultural financing and insurance to reduce risk;
- Attract investment through soft and hard market infrastructure;
- Build institutional capacity across the sector; and
- Facilitate a participatory approach, including women and youth, for inclusive growth (MINAGRI, 2013).

Recommendations:

- Support and foster the further development of the key drivers of growth as outlined in the PSTA III.
- Mainstream the high green growth scenarios into MINAGRI's programmes and projects.

Greening agriculture needs to be environmentally beneficial

For agriculture to be "green", it understandably needs to have significant environmental benefits. As shown in Chapter 9, green agricultural practices restore and maintain soil fertility; reduce soil erosion and inorganic agrochemical pollution; increase water-use efficiency; decrease deforestation, biodiversity loss and other land use impacts; and significantly reduce agricultural GHG emissions, among other benefits. Research suggests that in addition to sequestering carbon, such environmentally favourable practices have the potential to reduce deforestation and freshwater use by 55 per cent and 35 per cent, respectively (UNEP, 2011).

According to the PSTA III, the greenness of agriculture will be ensured by continued investment in land husbandry, irrigation and inputs and fostering environmental sustainability and climate change adaptation for the sector's long-term prosperity. Indeed, in its fourth strategic programme, the PSTA III includes a line of action that systematically proposes a number of interventions to mainstream environmental sustainability into all agricultural practice; it is important that the GoR adhere to this approach (MINAGRI, 2013).

Conclusion: balancing production and protection

Resource efficient, low carbon and climate resilient agriculture is a priority for Rwanda, reflected in the EDPRS II, PSTA III and the GGCR strategy. The aim is to introduce and implement green farming practices and innovation for sustainable agricultural pathways with the twin goals of productivity and ecosystem protection.

Rwanda is already eminently equipped with the policies, strategies, action plans and financial instruments to further upscale and expand green agricultural practices that will both increase food production and protect and sustain the ecosystem services that underpin economic development. This chapter has suggested some ways in which it might strengthen and elaborate on these existing tools. The balance between production and protection will be a delicate one, especially given the country's growing population, its landlocked situation and the changing global climate, among other drivers of environmental change. **It is essential that Rwanda, especially through MINAGRI, moves beyond business as usual and invests in high green growth in its agriculture sector as a major contribution to achieving Vision 2020 and the GGCR strategy.**

In the lead up to the 2015 United Nations Climate Change Conference held in Paris, France in December 2015, Rwanda submitted its Intended Nationally Determined Contribution (INDC), outlining the post-2020 climate actions it intends to take under a new international climate agreement. In accord with its agricultural goals in the Green Growth strategy, it made the following commitments, to be achieved by 2030:

- All households involved in agricultural production will be implementing agroecology for sustainable food production and composting their organic waste;
- There will be countrywide wastewater irrigation and a shift from using inorganic fertilizers to fertilizer enriched compost;
- Rwanda will promote sustainable pest management;
- Where relevant, radical and progressive terrasses will be constructed on all land needing protection;

- An intensive agroforestry programme will be developed and implemented on all the country's arable land;
- Operational irrigation infrastructure will be installed on 11 per cent of total land with irrigation potential, up from 4 per cent in 2012;
- Group-based organizations involved in agriculture production and running agro processing will make up 90 per cent of the total number of operating, group-based organizations, up from 10 per cent in 2014;
- The installed capacity of agro processing installations will reach 1,200,000 MT, up from 400,000 MT in 2014;
- All farmers will have access to post-harvest treatment and food-crop storage and their post harvest losses will be reduced to at least 1 per cent (RoR, 2015b).

These are quite ambitious goals and targets that will require not only significant financial and technical resources, but also the strengthening of institutional infrastructure to implement them as well as a comprehensive risk mitigation strategy to ensure people's food security needs are met.

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Rwanda has made enormous strides in economic growth over the past decade, with a doubling of GDP between 2001 and 2014 and rapid economic growth averaging at 8 per cent. Poverty declined from 59 per cent to 39 per cent, lifting a million people out of poverty and reducing inequality.

This progress is largely due to the success in raising agricultural productivity, which almost doubled between 2000 and 2015. About a third of Rwanda's economy still depends on agriculture and this sector is making significant progress in transitioning from a subsistence activity towards a market-based sector.

Thus, agriculture will continue to be an engine of economic growth and poverty reduction. It must do this by continuing to increase productivity and livelihoods while simultaneously protecting the ecosystems that make growth possible. It will be a challenge to do both and it will take time to make the transition.

The special focus of this State of the Environment and Outlook Report for 2015 is on Rwanda's experience in greening agriculture with resource efficient, low carbon and climate resilient practices and the opportunities for the agriculture sector to further contribute to greening Rwanda's economy.