ISSD Africa

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Climate-resilient seed systems & access and benefit-sharing in Rwanda

Thematic Working Group 3
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**In memoriam*

We dedicate this report to our co-author Jean Gapusi, who sadly passed away in September 2016. Over the course of his career, Jean took on many roles in the area of agricultural biodiversity, including project officer for the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), senior research fellow at the Tree Seed Centre, curator of the Rwanda National Gene Bank, head of station for the Rwanda Agriculture Board; and researcher at the Institute of Science and Technological Research. He was the Rwanda national focal point for the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), and for access and benefit-sharing issues under the Convention on Biological Diversity (CBD). We are greatly indebted to Jean Gapusi for his important work on plant genetic resources management and conservation, and his invaluable contributions to this study. May he rest in peace.

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EXECUTIVE SUMMARY

This study is part of the Integrated Seed Sector Development (ISSD) programme's action learning theme on matching global commitments with national realities. The theme used case studies to reflect upon climate resilience and access and benefit-sharing (ABS) mechanisms, specifically with respect to the national policy and legal environment for ABS, and the practical issues involved in the access to and exchange of plant genetic resources for food and agriculture (PGRFA) through the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) or the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from the Utilization of Genetic Resources of the Convention on Biological Diversity (Nagoya Protocol/CBD). The objective of the study was to analyse how climate change has affected agricultural productivity in Rwanda, and the strategies that have been put in place to facilitate access to PGRFA required for climate change adaptation. PGRFA exchanges between different stakeholders in and out of the country were studied using secondary data from various institutions, such as the Rwanda National Genebank (RNGB), CGIAR centres, ITPGRFA Secretariat, breeding programmes, regional research projects, breeders' networks and farming communities. A key informant survey, consisting of 52 respondents from various research and breeding programmes, was also used to augment the data obtained from secondary sources. In addition, climate and crop suitability modelling was used to identify collections of PGRFA that could potentially be suitable for climate challenges at present and in the future.

Findings show that CGIAR centres continue to play a critical role in the exchange of genetic resources for crop improvement and technology transfer in Rwanda. Apart from crop improvement, breeders' networks and regional projects have also enhanced knowledge and information dissemination among breeders and other stakeholders. Although most of the materials exchanged for crop improvement are from *ex situ* collections, famers have contributed, through informal seed systems, to the maintenance of *in situ* genetic resources by identification, conservation and sometimes even the restoration of varieties with useful traits for climate change adaptation. The RNGB's main function is the conservation of genetic resources; however, the genebank needs to be strengthened to perform other critical functions, such as characterization of PGRFA and information management. The Rwandan government is in the process of implementing the ITPGRFA and the Nagoya Protocol in a mutually supportive manner by involving a task force that consists of the focal person for the ITPGRFA and Nagoya Protocol, and the relevant stakeholders from the Ministry of Agriculture and Animal Resources (MINAGRI).

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ACRONYMS

ABS	Access and benefit sharing
AfricaRice	Africa Rice Center
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
IPCC	Intergovernmental Panel on Climate Change
ISAR	Rwanda Agricultural Research Institute
ISSD	Integrated Seed Sector Development
ITK	Indigenous traditional knowledge
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
MINAGRI	Ministry of Agriculture and Animal Resources, Rwanda
MLS	Multilateral system of access and benefit sharing of the ITPGRFA
NAEB	National Agricultural Export Development Board
NEPAD	New Partnership for Africa's Development
NIRDA	National Industrial Research and Development Agency
NISR	National Institute of Statistics of Rwanda
NUR	National University of Rwanda
OFSP	Orange-fleshed sweet potato
PABRA	Pan-African Bean Research Alliance
PAT	Participatory advanced trials
PGRFA	Plant genetic resources for food and agriculture
PIC	Prior informed consent
PPD	Postharvest physiological deterioration
RAB	Rwanda Agriculture Board
REMA	Rwanda Environment Management Agency
RNGB	Rwanda National Genebank
SASHA	Sweetpotato Action for Security and Health in Africa
SMTA	Standard Material Transfer Agreement
SOH	Seeds of Hope
VCO	Voice of Community Organization
UR	University of Rwanda

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1. INTRODUCTION

The whole world is experiencing climate change with greater weather extremes, changes in rainfall distribution, and increasing droughts and floods. These phenomena have a negative impact on the environment and on people's lives and livelihoods (GEF, 2010), especially in Africa. In Rwanda, historical famines that occurred in 1916, 1999, 2000, 2005 and 2006 affected agricultural productivity and food security (Government of Rwanda/European Commission, 2006; Downing, 2009). Before the genocide against the Tutsi of 1994, Rwanda had a reliable network of more than 150 weather observation stations, including five synoptic (main) stations, and six agro-meteorological stations, with the remaining stations dedicated to capturing rainfall and temperature variables only. The only reliable weather station left is located at Kigali International Airport. An analysis of historical temperatures at Kigali indicates that minimum temperatures have been rising faster than maximum temperatures, but with a general overall rise in temperature, particularly since 1992. All of the climate model scenarios show future increases in mean annual temperature. Climate change models predict increases in temperature of between 1.5 to 3 degrees Celsius (ºC) by the 2050s (Downing, 2009). The data, based on downscaled data for Kigali's airport weather station, reports an increase in average maximum monthly temperatures of around 1.5 to 2.7 ºC (for a business-as-usual, no mitigation scenario) by the 2050s (2046 - 2065), with the greatest increase in temperature occurring in the period July to September. The trends in monthly average minimum temperatures project a rise of 1.7 to 2.8ºC for the same period, with the greatest temperature increase occurring in the period June to August (REMA, 2011).

Changes in precipitation are less certain. Although the intensity, frequency and spatial distribution of precipitation are unknown, all the climate model scenarios show that average rainfall regimes will change, ranging from positive to negative anomalies across the models (REMA, 2011). Most of the projections suggest that average annual rainfall will increase, particularly in some seasons, indicating a potential flood risk. However, some models show reductions in rainfall in certain months. A shift in the timing of seasons is being reported in certain regions and this is already having a significant impact on agriculture (Downing 2009).

Agriculture is the backbone and main driver of economic development in Rwanda, contributing to more than 36.7% of GDP, employing more than 80% of its population (MINAGRI, 2010; REMA, 2011) and supplying 90% of the nation's food and nutritional needs (Byamukama et al., 2011). Rwanda's agriculture sector is the sector that is most vulnerable to climatic change. The impacts of climate change are mostly due to erratic rainfall and increasing episodes of extreme drought and flood. Consequently, agricultural production in Rwanda is characterized by low productivity; increased incidences of pests and disease, loss of crop genetic diversity and ultimately food insecurity and poverty. Ensuring the sector's resilience against existing and future climatic change is a national concern for long-term development. Strategies for adaptation to climate change have included the use of genetic resources and seeds that possess useful traits, such as drought and flood resistance. These useful traits can be obtained from collections of plant genetic resources for food and agriculture (PGRFA) in different genebanks (national or international) or through breeding and crop improvement. All these options require access and benefit-sharing (ABS) mechanisms through which materials can be exchanged.

The pilot project of Integrated Seed Sector Development in Africa (ISSD Africa) aims to work on complex challenges that are of strategic importance to support the development of a market-oriented, pluralistic, vibrant and dynamic seed sector in Africa. This study looks at how climate change affects agriculture and ultimately the PGRFA needs of Rwanda. It also analyses the trends in access to and exchange of PGRFA for climate change adaptation, the stakeholders involved, and the policy issues for ABS in Rwanda.

2. METHODOLOGY

Secondary data obtained from the Rwanda National Genebank (RNGB), the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) and the database of Genesys,[1] were analysed to show trends in flows of PGRFA in and out of the country, and within the country. Regarding primary data on germplasm exchange, a survey instrument (Appendix 1) was sent to key informants from agricultural and agriculture-related institutions in Rwanda, namely the Rwanda Agriculture Board (RAB); the University of Rwanda (UR); the Ministry of Agriculture and Animal Resources (MINAGRI); the Rwanda Environment Management Authority (REMA); farmers' cooperatives, including Imboneramuhinzi Cooperative, Imbaraga Cooperative, Ubumwe Cooperative and Amakiriro Cooperative; Voice of Community Organization (VCO); the National Agricultural Export Development Board (NAEB); and the National Industrial Research and Development Agency (NIRDA). It aimed to collect information from stakeholders in various institutions that are related to the conservation, use and management of PGRFA, and institutions that deal with climate change mitigation, adaptation and policy. The questionnaire sought to understand the impacts of climate change on agriculture, crop diversity and breeding with respect to climate change and the varieties released and currently in use. Stakeholders were asked to provide information regarding exchanges of PGRFA, terms and conditions of exchange, and best practices or lessons learned from such exchanges within and out of the country. The survey yielded 52 respondents.

The study also draws upon an analysis of two communities in Rwanda that were selected to demonstrate how climate change drives interdependence, and to identify present and future PGRFA needs for the communities. Two reference sites were chosen, namely Bugesera and Rubaya in Gicumbi district; both communities produce beans as a major food crop but with different agro-ecologies. The research strategy involved a step-by-step methodology linking various participatory approaches, in combination with GIS and crop suitability modelling, to select suitable varieties of beans for climate change adaptation. The identification of potentially suitable accessions was carried out by matching similar climates using bioclimatic variables relevant for bean growth i.e. temperature and precipitation. A total of 19 bioclimatic variables were extracted using the BIOCLIM algorithm at a resolution of 2.5 arc minutes[2] with the programme DIVA-GIS. Most of these variables were associated with the different precipitation and temperature regimes characteristic of the diverse habitats of beans. Locality (GIS) data from accession specimens were used to extract the variables using ArcGIS 10. The accessions were then clustered according to three variables that are relevant for bean growth (average annual temperature, annual precipitation, and agro-ecological zone); we calculated the average annual temperature and annual precipitation variables using the formulas $((tmin1+tmax1)/2+(tmin2+tmax2)/2+(tmin_n+tmax_n)/2)/12$, and $(prec1+prec2+prec_n)$ respectively.

[1] Genesys is a global portal to information on plant genetic resources for food and agriculture; available at www.genesys-pgr.org, last accessed 12 December 2016.
[2] An arc minute is a unit of angular measurement equal to one sixtieth (1⁄60) of one degree.

The first set of 20 varieties of beans were identified at the RNGB; they comprised a mix of varieties collected from various places in Rwanda, plus five improved varieties. These varieties were tested by farmers in Bugesera and Rubaya. A second tranche of 20 potentially adapted varieties that were originally collected in Ethiopia, Congo, Tanzania, Kenya and Rwanda were identified in the Genesys database. Those materials were listed as being held in the genebank of the International Centre for Tropical Agriculture (CIAT) in Colombia, and thus available under the Standard Material Transfer Agreement (SMTA) pursuant to CIAT's Article 15 agreement with the Governing Body of the ITPGRFA. The samples were requested from CIAT but only eleven out of the 20 requests were sent from CIAT because the rest were no longer available in their collection.

An analysis of the policy and regulatory environment for ABS and climate change was conducted in order to provide insights into the facilitative or inhibitive aspects of ABS regulations on access to and exchange of genetic materials required for climate change adaptation.

3. RESULTS AND DISCUSSION

3.1 Demographics of the respondents

There were 52 respondents to the survey: 84.6% were male and 15.4% were female, distributed across seven districts; 25% of respondents were members of cooperatives in Gicumbi district. RAB was the institution that was most represented, with 38.5% of respondents; it has a mission of developing agriculture and animal husbandry through reforms, and using modern methods in crop and animal production, research, agricultural extension, education and training of farmers in new technologies. Considering climate change challenges, the RAB's mission is to increase the productivity of crops, livestock, and natural resources by applying scientific knowledge in the generation and dissemination of appropriate technologies to sustainably enhance the quantity, quality and profitability of agricultural products for improved livelihoods.

3.2 Climate change in Rwanda and related effects

3.2.1 Trends in climate change and disasters in Rwanda

According to a report by REMA , past climate trends indicate that the mean annual temperature gradually increased from 1971 to 2007, from an average of 19.8 ºC in 1971 to 20.7 ºC in 2007, showing an increase of 0.9 ºC in 27 years (REMA, 2010). The report further notes that the number of warm days (with temperatures exceeding 30 ºC) increased, from five days in the 1970s to 26 days in the 2010s, while the number of rainy days decreased from 150 in the 1970s to 125 in 2010s. Recently, these changes have been coupled with the shifting and shortening of growing seasons, rainfall variability and increased incidences of droughts and floods (REMA, 2010). The details in REMA's report were further corroborated in interviews with key stakeholders who felt that there have been recent and significant changes in the following climate-related aspects: (i) irregularity of rainfall, encompassing changes in quantity of rain water or variability in rainfall (46%); (ii) drought length and unexpected drought (41.7%); (iii) disasters (29.3%); (iv) changes/increase in temperature (12.2%); (v) outbreaks of pests and increase in incidence of disease (10.4%); and (vi) unpredictable agricultural season (10%).

Temperature and precipitation changes, and other related climate variability, have led to a shortening of the growing seasons and a shifting of planting dates, with heavy and erratic rainfall causing floods, soil erosion, landslides, and river flow changes. As a result, there has been a reduction in agricultural yields or in the areas suitable for agricultural production, and a proliferation of pests and diseases, impacting on food security and livelihoods (Gishinge, 2014). Finally, climate change has also resulted in a loss of genetic resources.

Findings from the current studies by Ngoga, Mutabazi and Thomas (2013) have confirmed that climate change impacts on livelihoods and nutrition; soil and water; cropping season; plant genetic resources; animal genetic resources; and agricultural production. The three main impacts of climate change on livelihoods in Rwanda are hunger/migration, chronic poverty and malnutrition. Land dryness is considered to be the main impact of climate change on soil. In case of long periods of drought, farmers sustain their crops by referring mainly to wetland cultivation and irrigation techniques, and constructing water tanks. In relation to cropping season, climate change has mainly resulted in a shift in the planting dates and a shorter growing season.

Climate projections show increases in temperature and precipitation. Median projections of temperature indicate a rise of around 1 ºC by the 2020s, 1.5 - 2 ºC by the 2050s and 2 – 3 ºC by the 2050s. Median projections for precipitation show an increase of up to 7% by the 2080s (Conway, 2002). Changes in precipitation are less predictable than temperature. Although the intensity, frequency and spatial distribution of precipitation are unknown, all the climate model scenarios show that average rainfall regimes will increase, indicating a risk of flooding (Msaki, Tambi and Bangali, 2015). The projected changes will result in greater prevalence of disease and risks related to extreme weather events, such as drought and floods. The Rwandan economy relies on rain-fed agriculture. Climate change and its variability affect the agricultural sector, which is itself vulnerable. Loss in crop and livestock productivity; loss of agro-biodiversity; pest and disease incidence; land degradation; and loss of soil fertility due to soil erosion, increasing soil carbon decomposition and diminution of water resources, are alarming drivers of food insecurity, poverty and household vulnerability.

3.2.2 Climate change impacts on agriculture in Rwanda

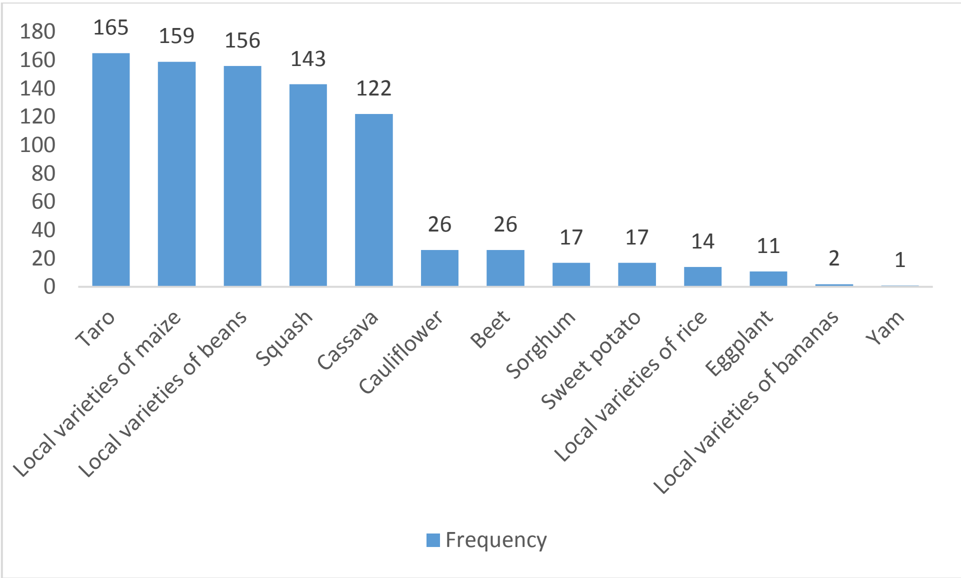
Recent studies show that bananas, beans, maize, cassava, rice, and horticultural crops are the main crops and improved varieties being cultivated in Rwanda to ensure food security, as well as to improve farmers' capacity to cope with climate change impacts (Ngoga, Mutabazi and Thomas, 2013; Gishinge, 2014).

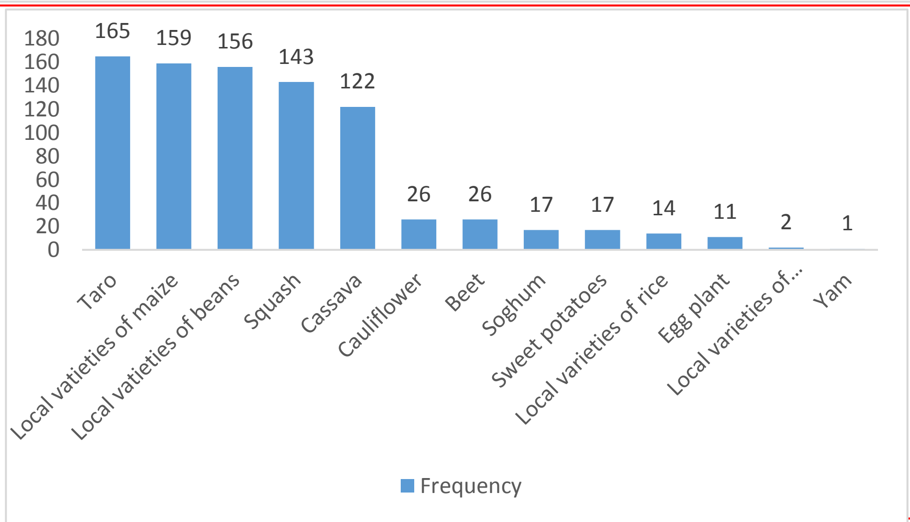
Important impacts on the sector, as emphasized by the survey respondents, are as follow: (i) food and nutrition insecurity (50%), i.e. cited by more than 50% of respondents); (ii) poverty (45.8%); (iii) decreased agricultural production (40.5%); (iv) new outbreaks of pests and diseases (more than 24%); (v) insufficient quantity of seed (18.9%); increase in flooding events (15.7%); decrease in water for irrigation (12.5%); shifting seasons i.e early starting dry season (10.8%); scarcity of livestock fodder (6%); and lack of information and insurance for farmers (5.9%).

On the issue of climate change impacting on plant genetic resources, Ngoga, Mutabazi and Thomas (2013) point out that sorghum, millet, groundnut and pigeon pea are being abandoned due to climate change mainly because they are longer maturing and do not perform well under current climate conditions where seasons have become shorter.

The main reasons such crops are being neglected are (i) low productivity of the crop or variety, which is the central cause; (ii) late maturity of the crop or variety; (iii) scarcity of arable land; (iv) low pest resistance of the crop or variety; and (vi) an agricultural intensification policy that tends to promote other crops such as maize and beans, which are considered as key food security crops. All these contribute to the neglect and underutilization of these crops, therefore contributing to the reduction and loss of species' diversity in general and agro-biodiversity in particular.

Figure 1. Underutilized and neglected crops in Rwanda





Source: Gishinge (2014)

The above-mentioned study by Gishinge demonstrates that agricultural production has been mainly impacted by climate change, lack of soil fertility and land shortage, lack of fertilizers and lack of improved seed. Major causes of low crop production are drought, followed by scarcity of arable land, insufficient agricultural inputs and flooding (Gishinge, 2014). Changing climatic conditions have resulted in a significant decrease in agricultural productivity. Consequently, food insecurity and malnutrition are on the rise throughout the country, especially in the southern part of the country, which has been experiencing long dry spells and prolonged drought.

The effects of future climate change on some of the crops that are significant for food and livelihood security are summarized in Table 1. According to findings from several studies (Schlenker and Lobell, 2010; Adhikari Nejadhashemi and Woznicki, 2015), climate change in Africa will lead to a reduction in yields of cereal crops such as maize, rice, sorghum and wheat, mainly due to a projected increase in temperature (1 - 2 ºC) and variable precipitation, coupled with flood risk, water and temperature stress, and the shortening of growing seasons. In Rwanda, all the different IPPC emissions scenarios projected[3] indicate a reduction in yields for maize, beans and coffee. Coffee would be more affected by these changes, specifically because of its sensitivity to temperature increases. Although a decrease in the yield of sorghum and millets is projected, the area suitable for sorghum and millet production would increase, suggesting that these two crops will in future be important for resilience and adaptation. Disease prevalence would also increase in all the crops resulting in lower productivity.

Table 1. Effects of climate change on major crops in the 2050s (1 - 1.5 ºC increase)

Crop	**Effects**	
	Description	*Details (quantity or type)*
Maize	Reduction in yield	- 6 – 20 %
	Reduction in suitable areas	-10 – 15 %
	Diseases	Aflatoxins, Maize Lethal Necrosis
Beans	Reduction in yield	-17%
	Reduction in suitable areas	10 – 20 %
	Diseases	Fusarium wilt
Coffee	Reduction in yield	-40%
	Reduction in suitable areas	-40 – 50 %
	Diseases	Wilt, leaf rust
Sorghum	Reduction in yield	10 – 15 %
	Reduction in suitable areas	10%

[3] The IPPC emissions scenarios – B1, A1B and B2 – are scenarios that characterize alternative developments of energy technologies: A1FI (fossil fuel intensive), A1B (balanced), and A1T (predominantly non-fossil fuel). The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with a continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines (IPCC, 2000).

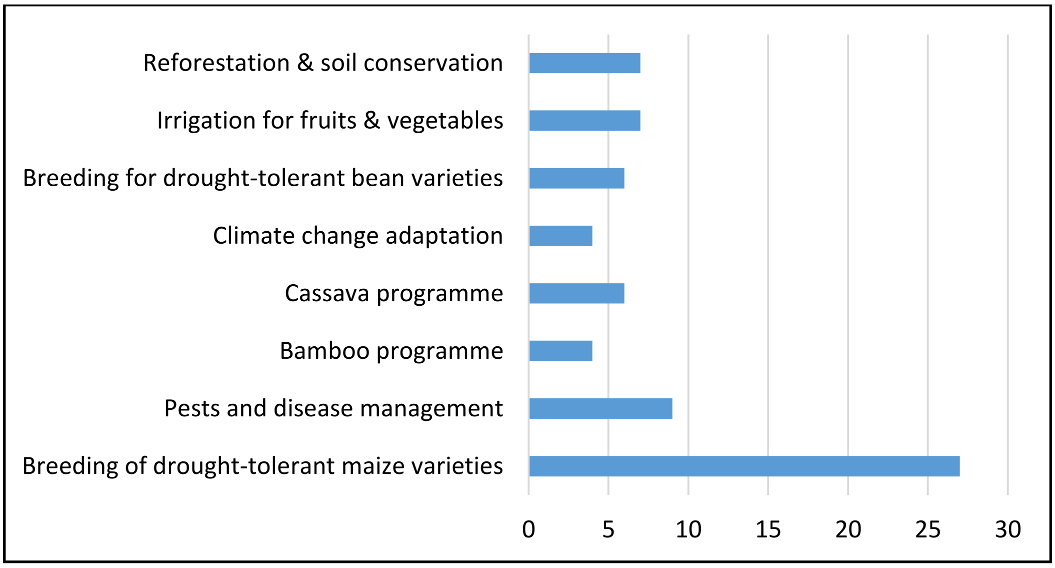
	Diseases	Fungal diseases, Striga
Millets	Reduction in yield	10 – 15 %
	Reduction in suitable areas	20 – 30 %
	Diseases	Fungal diseases

Source: Schlenker and Lobell (2010); Adhikari, Nejadhashemi and Woznicki *(2015)*

3.3 Strategies and programmes for climate change adaptation in Rwanda

The aforementioned survey demonstrated that the Rwandan government is pursuing several strategies for climate change adaptation, such as breeding drought-tolerant varieties of maize, integrated pest and disease management, and irrigation schemes for vegetable and fruit production in particular (Figures 2 and 3 below).

Figure 2. Strategies and programmes for climate change adaptation in Rwanda



Source: Survey (2016)

Other adaptive measures for challenges related to climate change, as detailed in a study by Gishinge (2014), include the following:

- *Cultivation of high-yielding crops or varieties*. Farmers need to increase crop production in order to have sufficient food for consumption, sell part of the production to have cash, and store food for potential future drought periods. Beans, maize, bananas and rice are the main crops with high-yielding varieties.

- Organization of farmers into cooperatives*. As members of cooperatives, famers can benefit from certain advantages, such as access to cash, loans, agricultural inputs and training, and support from local authorities and donors.*

- *Cultivation of drought-resistant crops or varieties*. In relation to cassava and sorghum cultivation, cassava is more developed while sorghum is neglected. New cassava varieties are currently being cultivated and are also pest resistant, in comparison to the local varieties that have been almost abandoned. Furthermore, cassava is well processed and is an important staple food in the diet of people.

- *Processing of agricultural products*. Processing crops contributes to the added value of the crop products and generates more income. Cassava processing, for example, has been developed for many reasons, including (i) it is the most drought-resistant crop; (ii) it grows in many agro-ecological zones; and (iii) its market is guaranteed and the demand for processed products is very high. Cassava flour, known locally as 'Ubugali', has been well incorporated into the diet of local people everywhere in the country.

- *Cultivation of early-maturing crops or varieties*. Early-maturing varieties of crops such as beans and maize can be used to combat climate challenges, but such crops are often drought intolerant and in times of severe drought this may result in crop failure and loss of productivity.

- *Storage of crop yields*. This strategy (i) provides food for households during prolonged periods of drought; (ii) provides seed for the next cultivation season; and (iii) generates income in periods when crop yields are in high demand.

- *Development of irrigation systems for rice production*. Data from the National Institute of Statistics Rwanda (NISR, 2012) for the Bugesera district indicate that irrigated land represents 3% of the total cultivated area, and that over the last five years rice production has risen from 4 to 7.5 tonnes per hectare (t/ha) (Bugesera district, 2013).

- *Early planting*. This strategy is interesting when rain falls at the expected time, otherwise early planting is unsuccessful. Its efficiency can be improved if reliable data on weather forecasts are available for the short-, medium- and long-term.

3.4 Availability of indigenous traditional knowledge on climate-smart seed varieties

Indigenous traditional knowledge (ITK) is community-based knowledge that people have been using for years, and which is for the most part not documented or protected. The origin of ITK should be recognized as lying foremost with the ITK holders and their communities, and should be the basis of intellectual property rights (IPRs) and access and benefit-sharing (ABS) management frameworks. It is, therefore, necessary to identify, document and protect ITK from indiscriminate exploitation, in order to ensure effective access and profitable commercialization for the benefit of communities. It is estimated that between 25,000 and 75,000 plant species are used for traditional medicine. Only 1% is known to scientists and accepted for commercial purposes. It has been assessed that over 95% of the world's genetic resources originate and are concentrated in developing countries (Friends of the Earth, 1995). Local communities and indigenous peoples hold the traditional knowledge associated with these genetic resources. It is difficult to separate access to genetic resources and knowledge, particularly because access to genetic resources very often coincides with knowledge of indigenous peoples and local communities.

In Rwanda, ITK from local communities consists of strategies that farmers use for mixed cropping, dry planting, erosion-control mechanisms, seed selection and the saving of seed from previous seasons. Farmers are aware of the impact of climate change on their environment and have mechanisms to cope with this impact (Ngoga, Mutabazi and Thomas, 2013). They implement strategies based on ITK to prevent and control plant diseases and pests using organic methods, including the use of manure; the use of crop-specific planting techniques, such as planting mixed varieties of beans or maize in the same plot; the practice of cyclical planting and harvesting to prevent the spread of diseases; and the use of traditional and organic preservatives for post-harvest storage. Farmers also have indigenous knowledge that they use to predict weather and select suitable varieties for the coming season.

Although farmers routinely use and apply ITK in many farming activities, national legislation is still not clear on ABS issues or farmers' rights. The law is vague in relation to who owns the genetic resources and the land; and with regard to which rules the pharmaceutical companies, botanical gardens or other institutions should comply with in order to access resources and traditional knowledge.

3.5 Materials held at the Rwanda National Genebank

The Rwanda National Genebank (RNGB) in Rubona has developed an operational plan that focuses not only on the conservation of forestry and agro-forestry species, but also on cultivated crop and pasture species, which are currently informally conserved (RAB, 2013). The list of accessions held in the RNGB that are adapted to different agro-ecological zones includes:

- 119 bean accessions (including ten improved varieties released in 2010)
- 30 maize accessions
- 45 soybean accessions
- 33 pea accessions for low altitude agro-ecological zones
- Four groundnut accessions for low altitude agro-ecological zones
- 240 sorghum accessions for low altitude agro-ecological zones (comprising 19 landraces and five improved accessions)
- 121 cowpea accessions for low altitude agro-ecological zones (all landraces)
- Three rice accessions for low altitude agro-ecological zones (all landraces)
- Eleven finger millet accessions
- Seven wheat accessions
- Three sunflower accessions
- Eight sweet potato varieties, all of which are improved.

3.6 Exchanges of PGRFA and information between different stakeholders

Rwanda, like every other country, is not self-sufficient in plant genetic resources, and depends on genetic diversity in crops from other countries. Plant breeders in Rwanda continue to rely on diverse plant genetic resources to facilitate the exchange of desirable traits for the improvement of crops.

The following cases highlight the achievements of research and breeding efforts in Rwanda[4].

- For wheat, 192 lines were evaluated at Kinigi station, and 26 lines were evaluated at Rwerere station. Based on yield data, eight lines were selected in the first season of 2013 and advanced to the second season of 2013 for further testing.

- In the sorghum programme, F1 seed was generated from an early-maturing farmer-preferred sorghum variety and a late-maturing farmer-preferred variety.

- In the sweet potato research activities, eight varieties with a yield average of 22.5 t/ha were released; four clones, namely RW11-2560, RW11-2910, Gihingumukungu, and Ukerewe are orange or yellow-fleshed storage roots, while the remaining four clones - RW11-17, RW11-1860, RW11-2419 and RW11-4923 - are white- or cream-fleshed varieties.

- New varieties of soybean, namely SB24, Sc. Saga, Sc. Squire and Sc. Sequel, with potential yield between 2.7 and 3.5 t/ha have also been released.

In addition, CGIAR centres have played a critical role in the exchange of PGRFA in Rwanda. PGRFA inflows into Rwanda between 2007 and 2014 (inclusive) comprise 5,701 accessions of different crops sent by different CGIAR centres using Standard Material Transfer Agreements (SMTAs) (see Table 2). Most notably, rice and wheat have the highest transfers with over 2,000 accessions for each crop. These transfers are mainly in the form of material under development or landraces, which are commonly sent to breeding programmes and research organizations.

Table 2. Inflows of PGRFA into Rwanda from CGIAR centres (2007 - 2014)

Crop	Samples
Andean roots and tubers	44
Bananas/plantain	6
Barley	37
Canavalia	1
Cassava	28
Coronilla	1
Cowpea	5
Dactylis	1
Faba bean/vetch	4
Forages	80
Gliricidia sepium	1
In-trust forage collection under the ITPGRFA	42
Lotus	1
Lupinus	1
Maize	417
Medicago	5
Phleum	1

[4] This section was adapted from RAB (2013), p.ii.

Pigeon pea	1
Potato	19
Rice	2,167
Triticale	78
Wheat	2,761
Total	**5,701**

Source: ITPGRFA Secretariat (2015)

3.7 Crop improvements in Rwanda resulting from access to and exchange of PGRFA

3.7.1 Bean research programme

The wild ancestor of the common bean was a climbing type of bean. The twining (climbing) ability, seeding, branching, rooting and tolerance to diseases and pests were features for survival in the thick tropical forests of Latin America, where the common bean was domesticated more than 10,000 years ago. It was very prolific (high seed production). The climbing beans grown in Rwanda have retained similar adaptive attributes of their progenitor. Beans came to Africa about 400 years ago, but they were not completely alien to Rwanda as demonstrated by the pockets of wild and semi-wild climbing beans that still exist in the northern highlands today.

Beans are the main staple food of the population of Rwanda, and provide a major source of protein and calories. The common bean (*Phaseolus vulgaris*) is an important subsistence crop for smallholders; it is a major source of protein and provides other nutrients such as iron and zinc. In Rwanda, around 29 kg of beans are consumed per person, per year – the highest consumption in the world. Rwanda is a relative newcomer to the bean export market; the country traded up to 6,500 tonnes of dry beans per year between 2005 and 2010.

The RAB and the Rwanda Agricultural Research Institute (ISAR) have released more than 30 climbing bean varieties in the last five decades. Fifteen were released more recently in 2010 and 2012. Besides higher yields (3.5 – 5.0 tonnes per hectare), the varieties had better resistance and tolerance to prevailing diseases and climatic stresses such as drought. Others, especially the navy-white, yellow, red kidney and red mottled seed types fetched premiums in local and regional markets, selling for as much as twice to four times more than ordinary prices.

More recently, eight of the released varieties were found to have higher contents of micronutrients, particularly iron and/or zinc. These varieties were intensively promoted for better nutrition and for the alleviation of anaemia and other micro-nutrient nutritional deficiencies, especially among children and women. The varieties released are adapted to the major agro-ecologies in the country. Better still, many of the Rwandan varieties have been adopted in many countries across Africa, where they had been introduced. With climbing beans, farmers are climbing out of poverty, and at the same time combating food and nutritional insecurity. The adoption of climbing beans is currently estimated at 65% in the country. It is close to 100% in many districts of the northern highlands. It is estimated that between 50,000 and 100,000 hectares in Rwanda are covered with climbing bean varieties (Table 3).

Table 3. Selection of crosses and populations developed in 2012/2013

2012B*	2013A**	2013A**
Cross	**Backcross (anthracnose)**	**Backcross (commercial parent)**
RWV3006 x Gitanga	F1 x G2333	F1 x RWV3006
RWV3316 x Gitanga	F1 x G2333	F1 x RWV3316
RWV3317 x Gitanga	F1 x G2333	F1 x RWV3317
RWV 2872 x Gitanga	F1 x G2333	F1 x RWV2872
Agorome x Gitanga	F1 x G2333	F1 x Agronome
Gasilida x Gitanga	F1 x G2333	F1 x Gasilida
RWV2361 x Gitanga	F1 x G2333	F1 x RW
RWV2070 x Gitanga	F1 x G2333	F1 x RWV2070
RWV2887 x Gitanga	F1 x G2333	F1 x RWV2887

*Key: *B – second growing season (September to December); **A – First growing season (February -April)*

Source: RAB Annual Report (2013)

The exchanges that resulted in the varieties listed above were facilitated mainly by CIAT, through the use of SMTAs, either as material under development or landraces from their collections. The Pan-African Bean Research Alliance (PABRA) gave essential support by providing a platform to facilitate exchanges of these materials between member countries. PABRA is a breeders' network that works in conjunction with CIAT; breeders have exchanged varieties and improved lines of beans between 13 countries in sub-Saharan Africa through the network. Rwanda is part of this network. Over 550 new varieties of beans have been released through this network in the 13 member countries.

3.7.2 Cassava breeding programme

Cassava (*Manihot esculenta* Crantz) is a staple food for approximately 500 – 800 million people living in developing countries (Bull et al., 2011), and worldwide it is second only to maize (*Zea mays* L.) in the production of starch (Howeler, Lutaladio and Thomas, 2013). In the developing world, cassava is amongst the top four most important crops in terms of production. The potential yield of cassava is estimated at 90 tonnes of fresh roots per hectare under well-managed conditions (El-Sharkawy, 2004). Cassava plays a key role in food security and income generation for many smallholder farmers in developing countries (Ceballos et al., 2004; El-Sharkawy, 2004; Tumuhimbise, 2013). In East Africa, cassava is eaten after boiling, or processed into flour to make porridge, local brew, and bread; sweet varieties lacking cyanogenic glycosides can be eaten raw (Kamau, 2006; Mkumbira et al., 2003).

In Rwanda, cassava is an important staple food and is currently being promoted as a cash crop through the establishment of cassava processing plants. In addition to its tuberous root, its leaves are treated as a vegetable known as 'Isombe'. Cassava is consumed in various forms (as a paste, bread or flour, boiled for breakfast, mixed with beans, vegetables, etc); methods of cooking and preparation vary from one individual to another. It occupies the third place after banana and sweet potato for reducing hunger and poverty in the country (FAOSTAT, 2011). Although cassava is a major food crop, its production is threatened by the lack of good cultivars (early bulking, high yielding, and disease resistant); low soil fertility; poor agronomic practices, and postharvest losses.

Farmers and breeders prefer cassava varieties based on traits such as cookability; delayed postharvest physiological deterioration (PPD); dry matter content; early bulking; good colour of flesh (preferably white); pleasant odour; satisfactory flour produced (good quality, taste, colour); high yield; long storage in the field; the degree of acceptability at market); multiple cuttings produced; multiple uses; resistance to pest and diseases; sweetness; viscosity, and Vitamin A content.

In the RAB, the development of new cassava varieties has been carried out to select clones that are resistant/tolerant to pests and diseases, and which are high-yielding and acceptable in taste and palatability to end users. An on–farm evaluation was carried out on four cassava clones (NASE3 0P/4, NASE3 0P/3, PDB/11, and PDB/13) during season A of 2012 in 17 sites countrywide. After an evaluation at harvesting time, three clones – NASE4 0P/4, PDB/11 and PDB/13 – were given preference by farmers.

3.7.3 Maize breeding programme

Maize was introduced in Rwanda in 1960 and has become a major crop for food security and income generation for small-scale farmers in Rwanda; it ranks first among pulse and grain crops in annual production. Maize cropping systems have experienced unprecedented development and radical changes over the past five years. Maize productivity increased from 1.2 tonnes per hectare (t/ha) in 2008 to 2.6 t/ha in 2012 as a result of the crop intensification programme, whose breeding objectives changed from the development of adapted open-pollinated varieties (OPVs) to hybrid varieties that are high yielding and stress tolerant. However, this level of productivity is still low and more crop improvement initiatives are being undertaken to achieve the potential for maize productivity in the country. The main varieties of maize planted in Rwanda include the following: M081, RHM102, M104, M102, Z607, KH500-46A, KH500-31A and RHM103. In 2013, twelve inbred lines, developed from ZM607 and Pool 32, were completed and are being used to generate hybrid varieties. In addition, twelve inbred lines were advanced from S5 to S6.

3.7.4 Rice breeding programme

Rice is a cereal crop that was introduced in Rwanda in the 1950s; its production has become a significant component of the agricultural sector in the country. Rice is grown in developed flood valleys or in marshland areas. Major varieties of rice available in Rwanda include the following: Basmati 370, Kigoli 370, Nerica 9, and WAT 9. These are improved varieties with pedigrees from India (Basmati) Rwanda (Kigoli 370) and the Africa Rice Center (Nerica 9).

3.7.5 Sorghum breeding programme

Sorghum is a resilient crop, particularly in relation to changing climatic conditions and pests and diseases. The sorghum breeding programme conducts variety maintenance and develops new varieties. In total, 234 sorghum varieties are being maintained. Breeders' seed, pre-basic seed and basic seed of the following released varieties of sorghum were produced at Rubona, Karama, Mututu and Nyamagabe stations: Kigufi, Ikinyaruka, IS21219, IS8193, IS20983, IS25377, N9, BM1, BM33, BM 27, Kat 369, Mabereyingoma and Muhimpundu. In total, 120 kg of breeder seed, 570 kg of pre-basic seed and 5,180 kg of basic seed were produced and distributed in 2012/13. These new varieties are currently being used by farmers for both beer and food production.

3.7.6 Sweetpotato breeding programme

Rwanda is the third largest consumer of sweet potato (*Ipomoea batatas* L.) in Africa per capita; nine out of ten farming households in Rwanda cultivate sweet potato. Sweet potato is becoming an important crop for food security, forming a major part of the diet of both rural and urban communities in Rwanda.

The varieties of sweet potato grown in Rwanda include white sweet potatoes and orange-fleshed sweet potatoes. In February 2013, the National Plant Variety Release Committee of Rwanda approved the release of the following six dual-purpose cultivars of sweet potato: RW1117, RW111860, RW112419, RW112560, RW112910, and RW114923 (RAB, 2013). In addition, orange-fleshed sweet potato (OFSP) vines from the International Potato Center have been distributed to farmers for trials through the Sweetpotato Action for Security and Health in Africa (SASHA) project, which has been implemented by CIP in Rwanda. The project has reached 50,000 direct beneficiaries.

3.7.7 Wheat and breeding programme

Wheat (*Triticum sativum* L.) is an important cereal crop for small-scale farmers at highland altitudes (1,900 – 2,500 metres above sea level) in Rwanda. The average national wheat yield increased from 900 kg/ha in 2007 to 2,100 kg/ha in 2012, while the potential mean wheat yields for Rwanda under low-, medium- and high-intensity production conditions should be 3,681 kg/ha, 3,986 kg/ha and 4,151 kg/ha respectively. One of the major factors constraining wheat productivity in Rwanda is the lack of high-yielding, pest- and disease-tolerant varieties. Selection for improved yield performance was carried out on three sets of wheat accessions from the International Maize and Wheat Improvement Center (CIMMYT).

Different germplasm evaluation trials were carried out at high elevation as an activity of the Africa-wide Rice Breeding Task Force, in collaboration with Africa Rice Center (AfricaRice). A total of 134 varieties from CIMMYT were evaluated in Cyabayaga, Nyagatare district, with 28 varieties being promoted to the next stages. One hundred varieties with tolerance to iron toxicity have been introduced in Rusuli and Rugeramigozi, in order to select parents to be used in breeding activities. In Rusuli and Rwamagana, 35 cold-tolerant varieties were advanced from multi-location environmental trials to participatory advanced trials (PAT), where farmers were invited to participate in selecting the best lines.

3.8 Access and benefit sharing for climate change adaptation: results of climate/crop modelling to identify potentially adapted materials for present and future climate-related challenges in selected communities in Rwanda

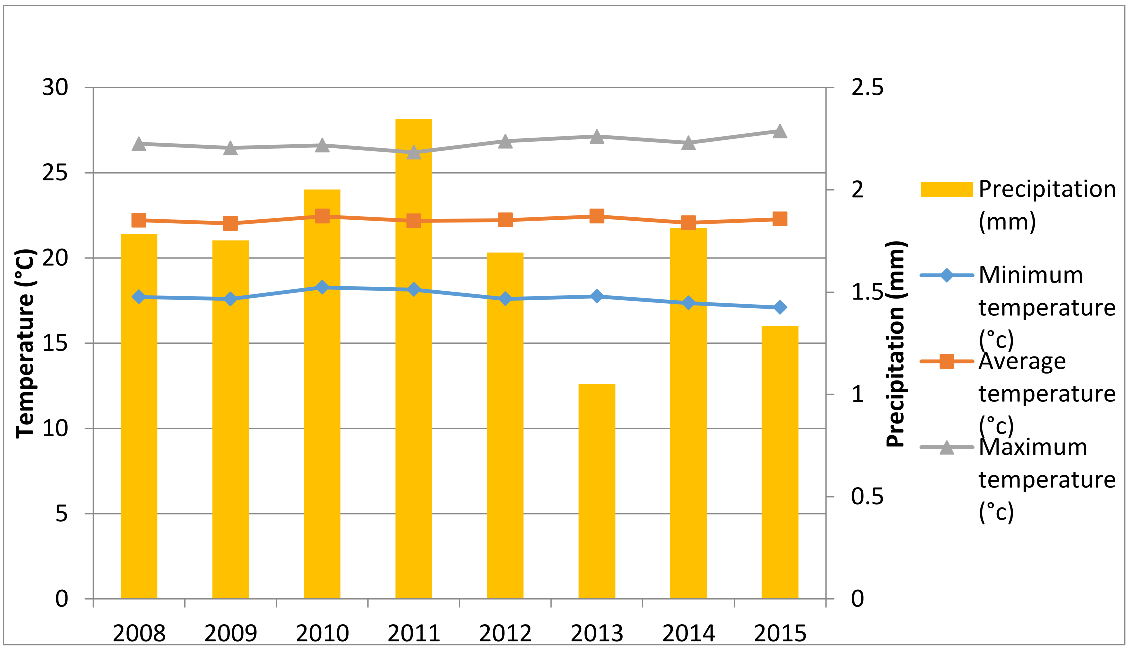
A report on global climate change scenarios, developed by the Intergovernmental Panel on Climate Change (IPCC), shows that there will be shifts in patterns of rainy seasons (IPCC, 2007). These patterns interfere with cropping systems, impacting on yields and food security. The IPCC's fifth assessment report recognized the importance of incorporating genetic diversity as one of the strategies for climate change adaptation and the improvement of crop tolerance to new conditions (IPCC, 2014). Furthermore, it recommends that access to genebanks be improved to support the development of varieties with appropriate adaptive characteristics, and that ITK be used to identify adaptive strategies that contribute to food security for farming communities. Ensuring farmers have access to plant genetic resources and varieties of crops that are suitable, and which can withstand climate-related challenges through various channels – i.e. breeding and research, or the identification of potentially adaptable material from communities or from national, regional or international genebanks – depends on having the necessary access and benefit-sharing regulations and policies in place. This study uses two reference sites to demonstrate the changing climates and changing needs for genetic resources in these communities.

The insights presented below correspond to climate analyses and participatory research conducted with farmers from the two study sites in Rwanda (Bugesera and Rubaya). To start with, reference sites and crops of interest were identified based on the relative importance of these crops for the communities' economies and for food security. For the selected sites already mentioned above, the common bean was selected as the reference crop based on farmers' preferences as well as the relative importance of beans as a source of protein and as an important contribution to smallholders' livelihoods. A participatory action research and learning approach was used to facilitate discussions with farmers from the two selected communities about changes observed in climate and weather patterns; their coping mechanisms; preferred varieties in terms of yield, drought tolerance, and resistance to pests and diseases; and desirable traits for climate change adaptation.

An analysis of climate change scenarios resulted in the identification of present and future climate-related stresses in the selected reference sites. Thereafter, a combination of GIS and climate modelling, based on selected bioclimatic variables of minimum, maximum and average temperatures, as well as average precipitation for bean growth and development, was used to identify accessions suitable for the four sites under two scenarios: present and future projected (2050s) climate and weather patterns (Appendix 5). Three possible sources of these accessions were identified as i) material in farmers' fields found and conserved *in situ* through farmer-managed systems; ii) national genebank collections from the RNGB; and iii) materials held by different genebanks around the world including CGIAR genebanks, available through the database of Genesys. The first tranche of 20 accessions of beans was identified from farmers' fields and the RNGB, and a further 20 were identified from regional collections held by CIAT. These accessions were multiplied and distributed to farmers for testing.

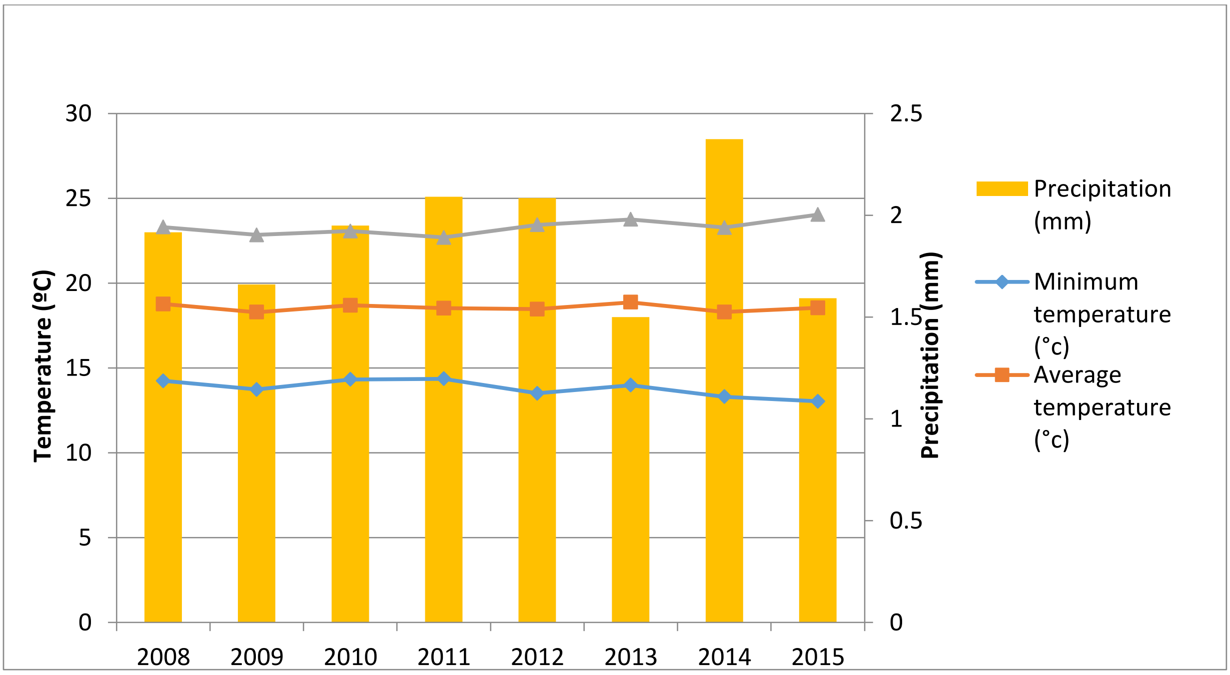
Following climate analysis, past climate trends indicate that in both the two sites minimum temperatures increased slightly between 2008 and 2015; precipitation also increased, albeit with a lot of variability. This is in line with the perceptions of farmers who have reported increased dry spells with erratic rainfall of increasing amounts and shifting planting/growing seasons in the two sites (Figures 4 and 5).

Figure 4. Trends in temperature and precipitation for Bugesera, Rwanda



Source: aWhere weather data

Figure 5. Trends in temperature and precipitation for Rubaya, Rwanda



Source: aWhere weather data

A look at the present and future (2050s) scenarios for Rwanda suggests that temperatures will increase by [1.3 - 1.4 ºC], and that precipitation will increase by 50 - 100 millimetres (mm) in (Table 4). A look at the climate graphs (Appendix 5) also reveals a shift in the growing season and heavy erratic rainfall in the reference sites. Based on the predicted increase in temperatures and precipitation, bean crop yields will be lower, while the excessive humidity resulting from an increase in precipitation will lead to a greater prevalence of fungal and bacterial diseases and pests.

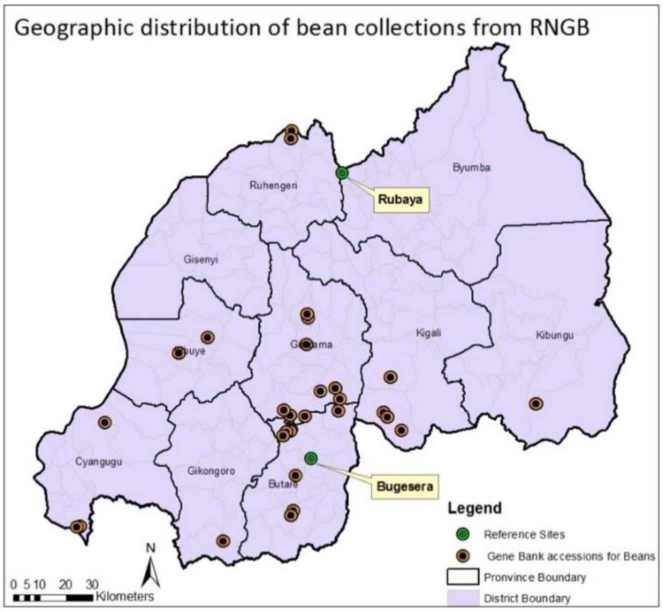
Table 4. Changes in temperature and precipitation

Site	Average temperatures - present (ºC)	Average temperatures - 2050s (ºC)	Temperature difference - present and 2050s (ºC)	Average Precipitation - present (mm)	Average precipitation - 2050s (mm)	Difference in precipitation - present and 2050s (mm)
Bugesera	20.35	21.75	1.4	1184	1225	41
Rubaya	16.35	17.75	1.4	1129	1254	130

Source: Worldclim

An assessment of bean genetic materials potentially adapted to present climatic conditions of Rubaya revealed the existence of 28 accessions available in the RNGB. When the climatic conditions projected for the 2050s were considered, the number of potentially adaptable bean accessions from the RNGB decreased from 28 to 16. Twenty-eight accessions were identified in the regional collections held by CIAT as being potentially adaptable to the present climatic conditions of Rubaya, while 16 accessions, located in six countries (Ethiopia, Congo Democratic Republic of the Congo, Rwanda, Uganda, Kenya and Tanzania) were identified as being potentially adaptable to the future projected climate of the 2050s. Currently, Rubaya's highland-type climate is suitable for climbing bean varieties, but as temperatures increase in the 2050s Rubaya will be more suitable for bush varieties of beans.

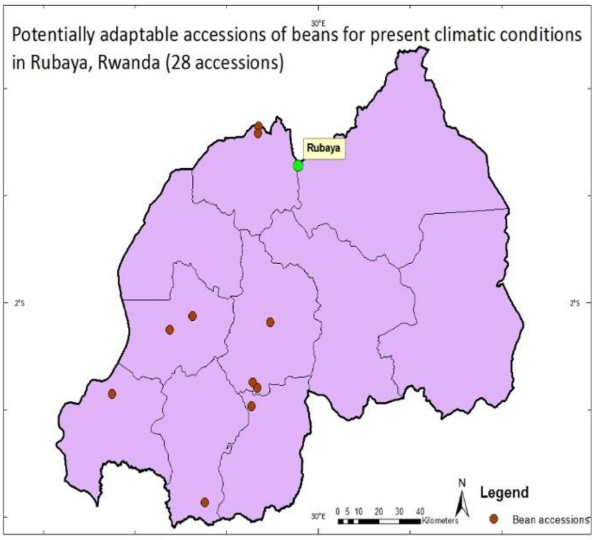
Figure 6. Map showing geographical distribution of collections of beans from the RNGB (109



accessions)[5]

[5] Figures 6 – 11 were developed by the authors using data from Genesys and the RNGB.

Figure 7. Maps showing geographical spread of accessions of beans potentially adaptable to present and future climatic conditions of Rubaya



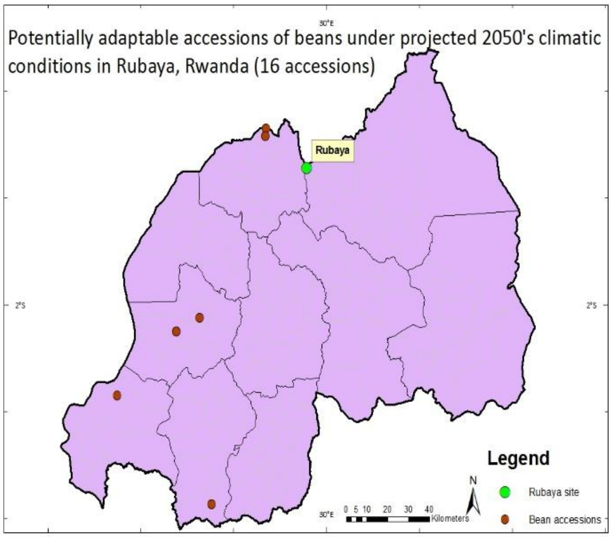


Figure 8. Map of regional collections of beans from East Africa held by CIAT

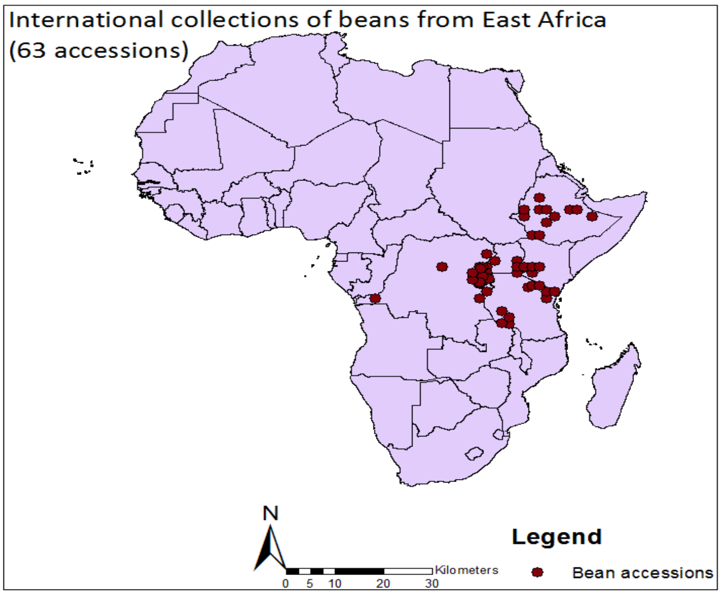
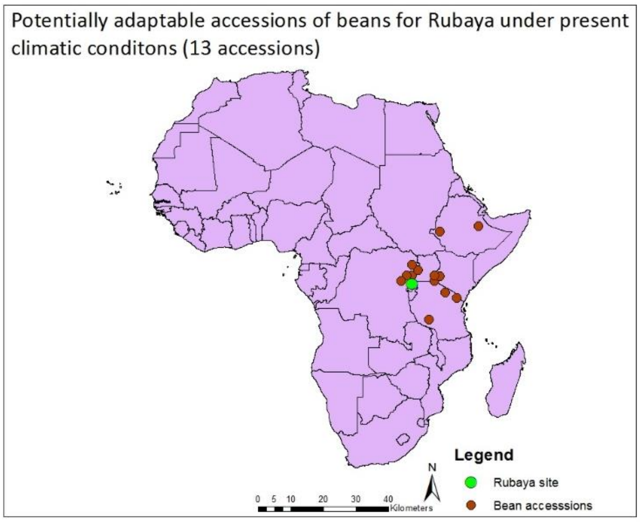
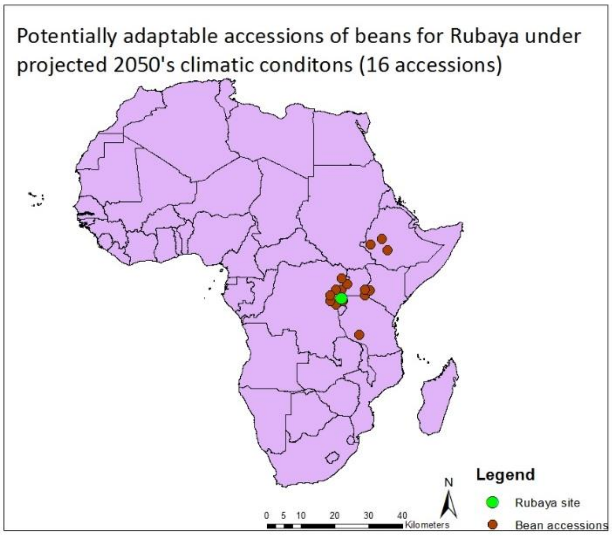


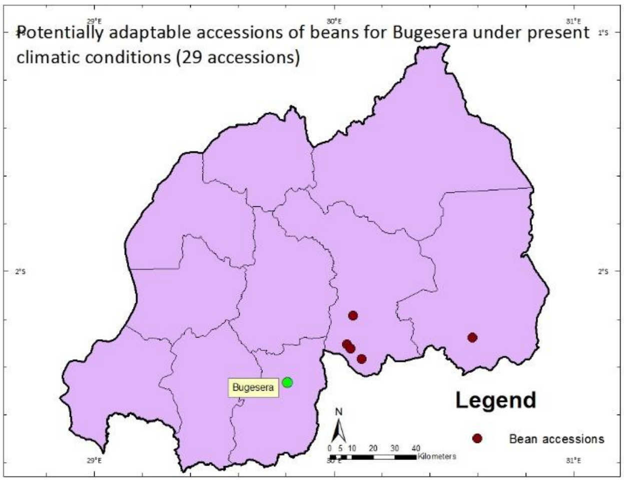
Figure 9. Maps showing distribution of accessions of beans potentially adaptable to present and future climatic conditions of Rubaya





For the Bugesera site, 29 out of 101 accessions held by the RNGB are suitable for present climatic conditions; while the number of genebank accessions potentially adaptable to the projected climatic conditions of the 2050s decreases to 21 (Figure 10). Looking at regional collections held by CIAT, 15 out of 65 accessions are suitable for present climatic conditions in Bugesera, while ten accessions are suitable for the projected climatic conditions of the 2050s (Figure 11). Therefore, there are fewer bean accessions in national and CIAT collections for the 2050's climate than there are for today's climate (see Figures 10 and 11).

Figure 10. Map showing the location of national collections of beans potentially adaptable to the climatic conditions of Bugesera at present and in the 2050s



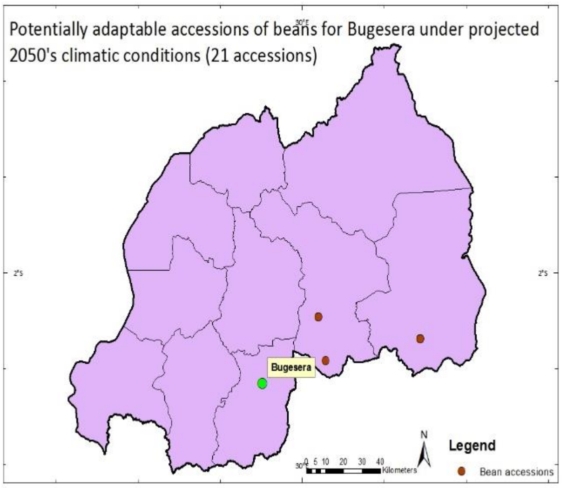
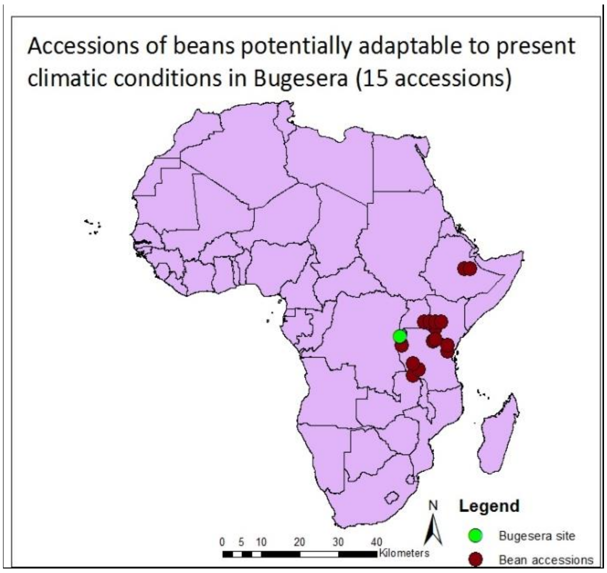
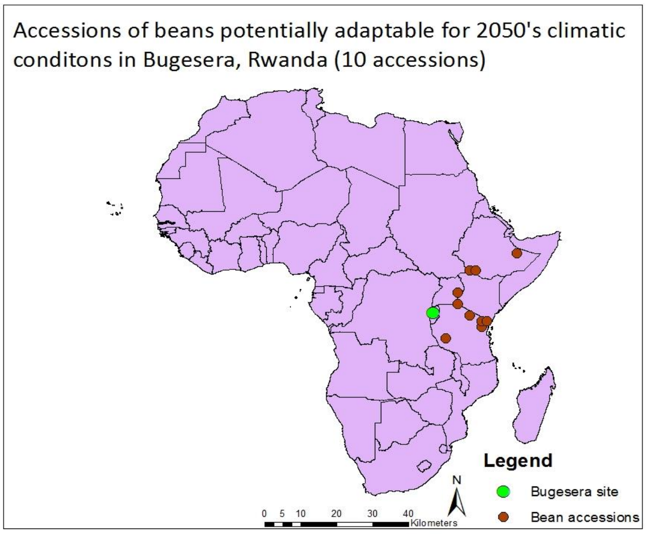


Figure 11. Map showing potentially adaptable collections of beans from CIAT for Bugesera under present and future climatic conditions





3.9 Policy initiatives to meet the challenges of ABS in Rwanda

Rwanda's policy of land consolidation and its programme of crop intensification have led to an evolution of the Rwandan agricultural sector. Under the programme, the government procures improved seed and fertilizers, which it distributes to farmers in selected zones chosen for their food crop production potential, focusing on a few priority crops. The programme has had a negative impact on the activities of the RNGB because local varieties of crops cannot be grown freely by farmers. This has led to a loss of genetic diversity and limited access to diverse seed.

In 2010, Rwanda became a contracting party of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). In March 2012, Rwanda ratified the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from the Utilization of Genetic Resources of the Convention on Biological Diversity (Nagoya Protocol/CBD). These two ratifications then led to the development of an enabling regulatory framework for access and benefit sharing in the country. A ministerial order governing access to PGRFA and the fair and equitable sharing of benefits arising from their utilization in Rwanda has been prepared, but there is a gap regarding the appropriate ABS mechanism for non-Annex 1 PGRFA. In a step towards implementing the Nagoya Protocol in Rwanda, a Nagoya Protocol Steering Committee was recently formed, and a task force on the mutual implementation of the ITPGRFA and the Nagoya Protocol has been established. The process has also involved the identification of relevant stakeholders for the implementation of ABS.

In addition to the aforementioned activities, recent capacity-building initiatives targeted breeders and other researchers on the use of SMTAs for the transfer of materials, and on modalities for carrying-out collections from farmers' fields using prior informed consent (PIC). Awareness-raising activities, focused on the ITPGRFA and other ABS issues related to the Nagoya Protocol, have also been carried out. In 2013 and 2014, other capacity-building initiatives targeted breeders and researchers to use GIS and crops suitability modelling to identify PGRFA that are suitable for climate change adaptation.

3.10 The role of community-based initiatives in access to and exchange of PGRFA

Community-based initiatives have played a critical role in the access to and exchange of PGRFA. Although some are informal, or focus on the distribution of relief seed, several initiatives have not only helped to improve access to seed in times of disaster but they have also helped to restore lost seed varieties, and in some cases introduce new varieties of seed to farmers; these initiatives are further discussed below.

3.10.1 The role of research institutions in seed-related disaster relief: Seeds of Hope in Rwanda

A coalition of agricultural research centres, Seeds of Hope (SOH), was involved in the rebuilding of Rwanda after the genocide of 1994. The involvement of research in emergency relief and rehabilitation was unusual at the time and SOH had to forge its unique complementary role.

3.10.2 Finding the seeds of recovery close to home: Seed Systems Under Stress Program helps African farmers buy and use locally available seed

Louise Sperling (2007) found that stressed communities usually need help in restoring the farmers' ability to buy and use locally available seed, more than they need seed imports. Improving the effectiveness of seed-related responses to disaster, seed systems are seen as central to smallholder agriculture, and seed aid as key to supporting it. Through extensive collaborative efforts, Sperling notes that changes are the result of several mutually reinforcing synergies: research to polish technical and social insights; non-governmental organizations (NGOs) with wide experience on the ground to shape practice; and the United Nations' normative clout for promoting better practice.

She describes the programme as having helped define the role of research organizations in restoring germplasm, seed systems and research capacity to countries that have suffered cataclysms. In terms of farmers' involvement, she realized that "women bean farmers know a great deal about managing beans and targeting bean mixtures according to diverse growing conditions, whether poor soils, richer soils or sowing under stands of banana" (Sperling, 2007). She noted that with about 1,500 phenotypes found throughout the country, a Rwandan woman may test perhaps 100 bean varieties during her life. Both the Rwanda research system and the CIAT team were highly geared towards impact. The programme focused on strengthening seed systems that are under stress, and on addressing the more urgent needs of drought-tolerant varieties.

"Likewise, the diversity of local varieties is often maintained during disasters, while new varieties may be lost, especially if supplies have not been sufficiently integrated into the routine functioning of local seed channels. The programme showed, in short, that seed-related problems in crises are not so much the lack of seed - be it grain, cuttings, tubers or other planting materials - but more the lack of access to that seed because farmers cannot afford it as a result of the crisis or the breakdown of social networks" (Sperling, 2007).

In conclusion, Sperling states that "seed-aid providers need to appreciate that relief seed is not effectively used when it is treated as a logistic exercise, narrowly focusing on transporting seed as an input. Instead, seed security must be assessed, farmers' needs understood and strategies developed to strengthen seed systems" (Sperling, 2007).

Over the past decade, the CGIAR's post-crisis rebuilding approach has grown beyond technology transfer to emphasize strategic research that helps partners to:

- diagnose and solve food security problems
- rebuild human and institutional capacities for agricultural research; and
- make relief aid more effective and efficient.

4. CONCLUSIONS

Agriculture in Rwanda has been rendered vulnerable due to climate change. Climate change is leading to biodiversity losses, increased incidences of pests and diseases, and ultimately low productivity and food insecurity. Subsequently, Rwanda has introduced several measures to integrate climate change in its agricultural policy and planning; these have included the restoration of lost PGRFA, breeding and crop improvement, conservation *in situ* and *ex situ*, irrigation, and sustainable use of natural resources such as forests and wetlands. Although these adaptation measures have been initiated to cope with climate extremes, more work needs to be done to ensure present and future food security and livelihoods are improved.

The use of PGRFA has been identified as one of the most useful adaptation strategies. The cultivation of selected crops and varieties with traits such as high productivity, drought resistance, early maturity, and disease and pest resistance, will require a system of facilitated access to PGRFA that are potentially adaptable, and investment in breeding and crop improvement. Past trends in PGRFA exchange in Rwanda show that the CGIAR centres are the most important partners in facilitating access to and distribution of PGRFA for various breeding programmes. The RAB's breeding programmes have also played a critical role in crop improvement and in the dissemination of improved varieties to farmers. The RNGB is at the forefront of restoring varieties that were lost during the genocide in 1994, but it still needs to be strengthened to increase the number of collections in the genebank, conduct a characterization of the collections, and improve on information systems, maintaining records on exchanges and movement of PGRFA so that genebank materials are more accessible to breeders.

Although there are still no clear mechanisms in place for ABS, recent policy developments in Rwanda have seen an attempt by the main stakeholders to implement ABS according to the Nagoya Protocol and the ITPGRFA in a mutually supportive manner. The setting-up of committees to take care of ABS issues in both the ITPGRFA and the Nagoya Protocol is seen as a positive step towards ensuring that ABS mechanisms are in place. Capacity building and awareness raising among stakeholders, such as breeders and farmers, are also very important to ensure that ABS processes are inclusive, and that any mechanism that is put in place is consultative.

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6. APPENDICES

Appendix 1. Questionnaire on integrated seed sector development in Africa: Global policies and national realities

Rwanda

Introduction

This study intends to understand the national action research case studies regarding climate resilient seed systems and access and benefit-sharing policies in Rwanda. It is part of the efforts to be compiled by the Centre for Development Innovation, Wageningen, the Netherlands to formulate the project on Integrated Seed Sector Development in Africa.

QUESTIONNAIRE

Interviewer's names:

Date:

Interviewees' names:

District/Sector:

Institution:

1. What are the 3 critical climate changes effects in Rwanda?

   a. ………………………………………………….
   b. …………………………………………………….
   c. ……………………..

   Explanation: ………………………………………………………..

2. What are the impacts of climate change on agriculture in Rwanda (5 major points starting by most important):

   a. ………………………………………….
   b. …………………………………………………….
   c. …………………………………………………….
   d. ……………………………………………………..
   e. ………………………………….

   Explanation: ……………………………………………………

3. What are the five crops (and varieties) most affected by climate change in Rwanda?
    a. ……………………………………………
    b. ………………………………………………
    c. ……………………………………………
    d. ………………………………………………
    e. ……………………………………………

Explanation: ………………………………………………………………

4. Please describe in five lines the predicted changes in the country due to climate change?
    a. ……………………………
    b. ……………………………
    c. ……………………………………
    d. ………………………………

Explanation: ……………………………………………………………..……

Please give at least 3 programmes being developed on climate resilient seed variety in Rwanda?

e. ………………………………………………
f. ……………………………………………
g. ………………………………………………

Explanation: ……………………………………………………………………………

5. Is there any indigenous knowledge available on Climate Smart Seed varieties? Enumerate 3 cases:
    a. ……………………………………………………
    b. ……………………………………………………
    c. ……………………………………………………

    Explanation: ……………………………………………………

6. How exchanges of PGRFA (Plant Genetic Resources for Food and Agriculture) and information between different stakeholders in the country were exchanged in three years past?

   a. Fill the table

PGRFA (Crops) in exchange from 2011(PGRFA	Country/Stakeholder provider	Country /Stakeholder receiver	Period of exchange	Quantity and purpose of exchange

Explanation: …………………………………………………………………………………

   b. What kind of agreements with what conditions seeds were exchanged.
      i. ……………………………
      ii. …………………………………………………………………………………………………
      iii. …………………………………………………………………………………………………

   Explanation: ………………………………………………………………………

   c. What has worked well in terms of accessing/exchanging genetic resources (nibihe byakozwe neza hagati yo kubasha kubona no guhanahana imitungo ndangakamere)?
      i. …………………………………
      ii. ………………………………………………………………………
      iii. ………………………………………………………………………

   Explanation:………………………………………………………………………………………

   d. What lessons learned in terms of information and developing benefits?
      i. …………………………………………………………………………………
      ii. ……………………………………………………………………………………………….
      iii. …………………………………………………………………………………………………
      iv. …………………………………………………………………………………………………

   Explanation: ……………………………………………………………………………

   e. Where have there been challenges?
      i. ………………………………
      ii. …………………………………………………………………………………………………
      iii. …………………………………………………………………………………………………

   Explanation: ………………………………………………………………………..…………………

7. What are the policy initiatives needed to remedy to above mentioned challenges (If any)?
   a. ………………………………………………………………………..……………
   b. ……………………………………………….……………………………………

   Explanation:………………………………………………………………………

8. According to climate/crop modelling exercises, what are the potentially adapted materials held in national or international collections?

Potentially adapted material	Country/Source of germplasm	Country of current collection

Explanation: ……

Appendix 2. List of survey respondents

No	Names	District	Institution
1	Akimana Ange	Gicumbi	Amakiriro Coop
2	Ananie Niyibizi	Kicukiro	RAB
3	Assouman	Kicukiro	National Agricultural Export Development Board (NAEB)
4	Barahukwa Charles	Gicumbi	Imbonerahamwe Coop
5	Bigirimana Joseph	Huye	RAB
6	Bizeye Barnabe	Huye	RAB
7	Cwezi Evariste	Gicumbi	Imbonerahamwe Coop
8	Cyamweshi K. Athanase	Karongi	RAB
9	Gakuru Clarice	Gasabo	Ubumwe Coop
10	Gashaka Gervais	Huye	RAB
11	Gasore Alfred	Kicukiro	NAEB
12	Gatarayiha Celestin	Kicukiro	NAEB
13	Ishimwe Theoneste	Kicukiro	RAB0
14	Jules Muhinda	Bugesera	RAB
15	Kabayiza Eric	Kicukiro	NAEB
16	Kabayiza Innocent	Gasabo	Ubumwe Coop
17	Karimunda Emmanuel	Gicumbi	Imbonerahamwe Coop
18	Kayumba John	Karongi	RAB
19	Kazindu Janvier	Huye	RAB
20	Lambert	Huye	RAB
21	Mateka Elias	Gicumbi	Imbonerahamwe Coop
22	Mbabazi	Gicumbi	Imbonerahamwe Coop
23	Mpoberabanzi Silas	Gicumbi	Imbonerahamwe Coop
24	Mukantaganda Bellancille	Gicumbi	Amakiriro Coop
25	Mupenzi Mutimura	Huye	MINAGRI
26	Muragijimana Florida	Gicumbi	Imbonerahamwe Coop
27	Musabyeyezu Uwamariya	Gicumbi	Amakiriro Coop
28	Musana S Bernard	Bugesera	RAB
29	Musine Juvenal	Kicukiro	Imbaraga Coop
30	Musore Innocent	Gasabo	Voice of Community Organization (VCO)
31	Mwungura Marc	Bugesera	RAB
32	Nakabonye Serafine	Gicumbi	Amakiriro Coop
33	Ngendo Martin	Kicukiro	NAEB
34	Ngenzi Mazimpaka	Huye	RAB
35	Ngoga G. Tenga	Bugesera	RAB
36	Niyibizi Pascal	Gasabo	Challenged Kids International (CKI)
37	Niyikiza Daniel	Gasabo	RAB
38	Niyongabo Damien	Gasabo	RAB
39	Nyirigira Antoine	Huye	RAB
40	Octave	Bugesera	Ubumwe Coop
41	Rudahunga Damascen	Gasabo	CKI

42	Rugimbana Claude	Karongi	RAB
43	Ruhakana Albert	Huye	RAB
44	Runezerwa Joseph	Gasabo	VCO
45	Rutayisire Amandin	Huye	RAB
46	Rutebuka Jules	Gasabo	RAB
47	Shirimpumu Alexis	Huye	RAB
48	Twagirimana Olivier	Kicukiro	NAEB
49	Umuhoza Liliane	Gicumbi	Amakiriro Coop
50	Uwayezu Antoine	Gicumbi	Amakiriro Coop
51	Uwimana Jacque	Gasabo	CKI
52	Uwimana Jeannette	Gasabo	Ubumwe Coop

Appendix 3. Bioclimatic variables important for bean growth and development

Bioclimatic variable value

**Annual mean temperature [1]

Mean monthly temperature range [2]

Isothermality (2/7) (* 100) [3]

Temperature seasonality (STD * 100) [4]

Max. temperature of warmest month [5]

Min. temperature of coldest month [6]

**Temperature annual range (5-6) [7]

Mean temperature of wettest quarter [8]

Mean temperature of driest quarter [9]

Mean temperature of warmest quarter [10]

Mean temperature of coldest quarter [11]

**Annual precipitation [12]

Precipitation of wettest month [13]

**Precipitation of driest month [14]

The variables marked with ** are important for bean growth and physiological development

Appendix 4. Present and predicted future temperature and precipitation in selected reference sites in Rwanda

1. **Bugesera, Rwanda: Current climate and predicted future climate of the 2050s**

Bugesera: Current climate

x:29.80623 y:-2.46102 alt:1514

worldclim_2-5m

	T.min	T.max	Rain
Jan	15.1	25.8	108
Feb	14.9	25.7	119
Mar	14.9	25.6	144
Apr	15.2	25.3	175
May	15.2	25	120
Jun	14.2	25.7	21
Jul	13.9	26.7	8
Aug	14.3	27.4	28
Sep	14.3	27.1	77
Oct	14.5	26.3	123
Nov	14.6	25.5	138
Dec	15.1	25.4	123
Year	14.7	26.0	1184

Bugesera: Future climate (2050s)

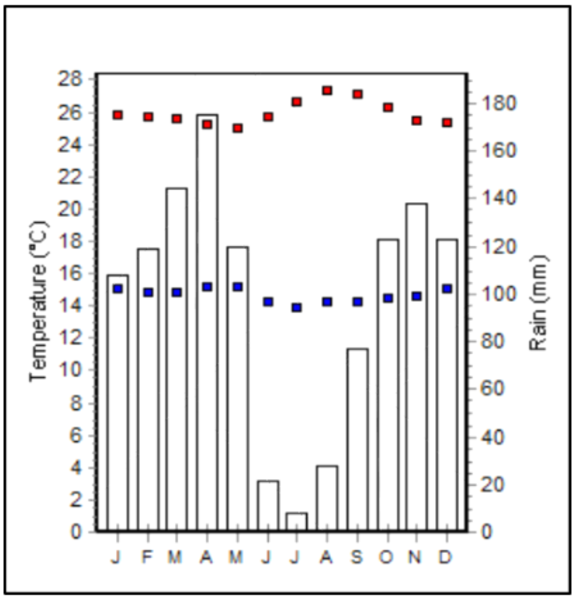
x:29.80623 y:-2.46102 alt:1514

wc_ccm3_2-5m

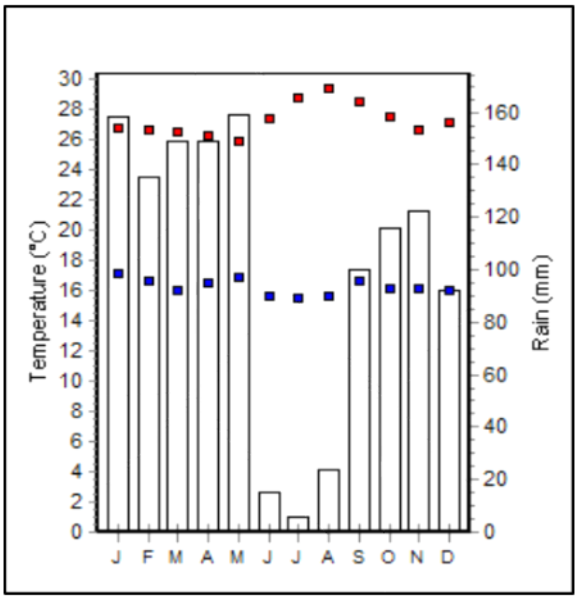
	T.min	T.max	Rain
Jan	17.2	26.8	158
Feb	16.6	26.7	135
Mar	16	26.5	149
Apr	16.5	26.3	149
May	16.9	25.9	159
Jun	15.6	27.4	15
Jul	15.5	28.8	6
Aug	15.6	29.4	24
Sep	16.6	28.5	100
Oct	16.1	27.5	116
Nov	16.2	26.7	122
Dec	16	27.1	92
Year	16.2	27.3	1225

Climate graph for Bugesera, Rwanda: Current climate and predicted future climate of the 2050s

Bugesera: Current climate



Bugesera: Future climate (2050s)



2. Rubaya, Rwanda: Current climate and predicted future climate of the 2050s

Rubaya: Current climate

x:29.91349 y:-1.47701 alt:2120

worldclim_2-5m

	T.min	T.max	Rain
Jan	10.5	22.6	78
Feb	10.6	22.5	101
Mar	10.7	22.3	128
Apr	11.2	21.4	183
May	11.2	21	115
Jun	10.1	21.7	29
Jul	9.9	22.5	13
Aug	10.6	22.7	40
Sep	10.6	22.7	103
Oct	10.6	22.3	116
Nov	10.6	21.6	127
Dec	10.9	22.2	96
Year	10.6	22.1	1129

Rubaya: Future climate (2050s)

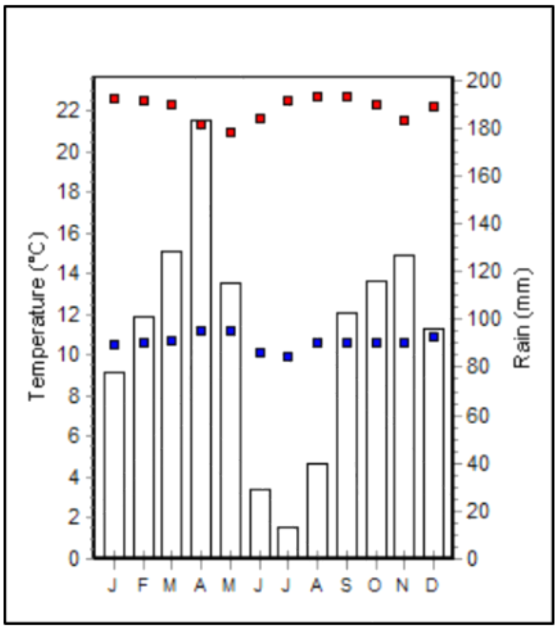
x:29.91349 y:-1.47701 alt:2120

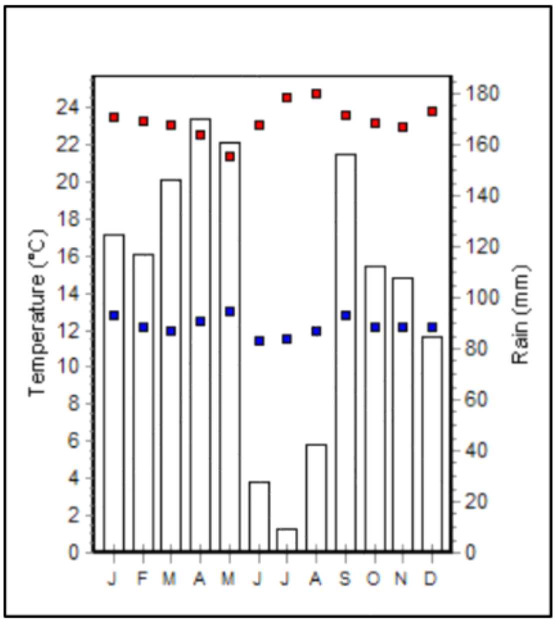
wc_ccm3_2-5m

	T.min	T.max	Rain
Jan	12.8	23.5	125
Feb	12.2	23.3	117
Mar	12	23.1	146
Apr	12.5	22.5	170
May	13	21.4	161
Jun	11.4	23.1	28
Jul	11.5	24.5	9
Aug	12	24.7	42
Sep	12.8	23.6	156
Oct	12.2	23.2	112
Nov	12.2	22.9	108
Dec	12.2	23.8	85
Year	12.2	23.3	1259

Climate graph for Rubaya, Rwanda: Current climate and predicted future climate of the 2050s

Rubaya: Current climate **Rubaya: Future climate (2050s)**





Appendix 5. Application form for a permit to import plant and plant products

REPUBLIC OF RWANDA

MINISITERI Y'UBUHINZI N'UBWOROZI

MINISTRYOF AGRICULTUREAND ANIMAL RESOURCES

OFFICE OF AGRICULTURE AND LIVESTOCK INSPECTION AND CERTIFICATION SERVICES

APPLICATION FORM FOR RE-EXPOR OF PLANTS AND PLANT PRODUCTS

Director General
Agriculture and Livestock Inspection and Certification Services
Ministry of Agriculture and Animal Resources (MINAGRI)
P.O.BOX 621 KIGALI-RWANDA

I/We hereby apply for re-export of plants and plant products as described below in accordance with the plant health law and Regulations made there in.

Name and address of applicant	Name and address of exporter
Name and address of importer	To Plant Protection Organization of
Name of plant	Botanical name
Description : (seed, cuttings, fruit strain, variety, cultivar, unprocessed, fresh, frozen, cooked);	Quantity declared
Number of packages	Country of origin/production