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Climate-resilient seed systems & access and benefit-sharing in Uganda
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EXECUTIVE SUMMARY

Climate change is a key issue affecting agriculture in Uganda. Recently, notable changes in climate, such as shifting seasons, erratic rainfall; and an increase in temperature, pests and diseases, have led to losses in productivity and genetic resources. Among the strategies identified for coping with the effects of climate change is the development of new varieties of crops through plant breeding and access of genetic resources necessary for communities to adapt to climate change. The exchange of genetic materials is also highly dependent upon an enabling policy, institutional and legal environment, and access to information crucial for breeders and local communities.

This study looked at Uganda's prevailing climate challenges, and the requisite access to and exchange of genetic resources for climate change adaptation. Secondary data from national gene banks, CGIAR centres, breeding programmes and international databases were analysed to reveal the trends in access to and exchange of genetic resources. Information from various breeding programmes, obtained through interviews with key informants, also provided insights into the processes, quantities and challenges involved in exchanging genetic resources for climate change adaptation. A case study of two communities revealed climate change related challenges that communities are facing, and identified potentially adaptable genetic resources in gene bank collections of the International Center for Tropical Agriculture (CIAT), using GIS and crop suitability modeling tools.

Findings from the study showed that CGIAR centres have been crucial in providing genetic resources to breeding programmes for the development of new varieties. Several projects, regional initiatives and breeders' networks have also played and continue to play a major role not only in the transfer of technology and skills but also in the movement of plant genetic resources for food and agriculture (PGRFA) across the region in East Africa, which have been used to develop new varieties of crops that are important for food security and livelihoods. A major challenge identified in the study is the consolidation of information related to these exchanges so that it can be accessible to stakeholders. The study also found that as climate changes, PGRFA requirements will change, requiring the country to access genetic resources from other countries, which would invariably increase interdependence.

There is a need to provide the necessary structures for access and benefit sharing (ABS), including a clear institutional framework for ABS, information-sharing mechanisms, and the harmonization and implementation of ABS laws under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), and 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), in a mutually supportive manner.

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ACRONYMS

ABS	Access and benefit sharing
AEZ	Agro-ecological zones
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
CBD	Convention on Biological Diversity
CBO	Community-based organization
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CCD	Climate Change Department
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
CSB	Community seed bank
DARS	Department of Agricultural Research Services, Malawi
DRD	Division of Research and Development, Tanzania
EAC	East African Community
EAAPP	East African Agricultural Productivity Programme
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus group discussion
FHIA	Honduras Foundation for Agricultural Research
GIS	Geographic information system
GRPI	Genetic Resources Policy Initiative
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IIAM	Institute of Agricultural Research of Mozambique
IITA	International Institute of Tropical Agriculture
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated pest management
IRRI	International Rice Research Institute
ISSD	Integrated seed sector development
ITC	Bioversity International Musa Transit Centre, Belgium
ITK	Indigenous traditional knowledge
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
KALRO	Kenya Agricultural and Livestock Research Organization
KARI	Kenya Agricultural Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries (Uganda)
MAT	Mutually agreed terms
MINALOC	Ministry of Local Government of Rwanda
MLS	Multilateral System of Access and Benefit Sharing of the ITPGRFA
MTA	Material transfer agreement
Nagoya Protocol	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
NaCRRI	National Crops Resources Research Institute
NAADS	National Agricultural Advisory Services
NaLIRRI	National Livestock Resources Research Institute
NAPA	National Adaptation Programme of Action
NARL	National Agricultural Research Laboratories
NARO	National Agricultural Research Organization
NARS	National Agriculture Research System

NaSARRI	National Semi-Arid Resources Research Institute
NBRP	National Banana Research Program
NEMA	National Environment Management Authority
NGO	Non-governmental organization
NRI	Natural Resources Institute, UK
NZARDI	Ngetta Zonal Agricultural Research and Development Institute
OPV	Open-pollinated variety
PGR	Plant genetic resources
PGRC	Plant Genetic Resources Centre
PGRFA	Plant genetic resources for food and agriculture
PIC	Prior informed consent
PVP	Plant variety protection
PVS	Plant variety selection
RCA	Rwanda Cooperative Agency
RCoE	Regional centre of excellence
SMTA	Standard Material Transfer Agreement
TRIPS	Agreement on Trade-Related Aspects of Intellectual Property Rights
UNCST	Uganda National Council for Science and Technology
UNDP	United Nations Development Programme
UNEP-GEF	United Nations Environment Programme – Global Environment Facility
UNGB	Uganda National Gene Bank
UNMA	Uganda National Meteorological Authority
UPOV	International Union for the Protection of New Varieties of Plants
USDA	United States Department of Agriculture
VUP	Vision 2020 Umurenge Program

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Climate change has become a global issue of concern because it poses a threat to people, ecosystems, livelihoods and food production. The Intergovernmental Panel on Climate Change (IPCC) has pointed out that human activities are altering climate systems, and that global mean temperatures are projected to increase in the range of 1.4 to 5.8 degrees centigrade (°C) during the period 1990 to 2100 (Niang et al., 2014). In order to address these challenges, carbon emissions must be reduced, global policies must be put in place to combat climate change, and countries should plan for present and future adaptation. In Africa, temperatures are predicted to rise beyond the global average, while rainfall is expected to be more erratic with shorter rainy seasons (Niang et al., 2014). The effects of these projected climatic changes will be reflected in loss of yields and genetic diversity, threatening global food security. Current climate change projection models show that both temperature and precipitation are expected to increase in East Africa, and that climate uncertainty and the number of extreme events, such as droughts or floods, will most likely increase the vulnerability of the rural poor.

Uganda lies within a relatively humid equatorial climate zone, and the topography, prevailing winds, and lakes and rivers cause large differences in rainfall patterns across the country. Current and past trends indicate that the timing of rainfall can vary considerably; the onset of rainy seasons can shift by 15 to 30 days (earlier or later), while the length of the rainy season can change by 20 to 40 days from year to year. No significant change in average annual rainfall has been detected in the 60-year historical record. An analysis of average annual temperatures between the periods 1951-1980 and 1981-2010, shows a notable increase of approximately 0.5-1.2 °C for minimum temperatures and 0.6-0.9 °C for maximum temperatures. This warming trend is projected to continue, with some models projecting an increase of more than 2 °C by 2030 and by up to 4.3 ºC by the 2080s (Hepworth and Goulden, 2008). In the future, changes in rainfall patterns and total annual rainfall are also expected as the climate of Uganda may become wetter on average, and the increase in rainfall may be unevenly distributed, occurring as more extreme or more frequent periods of intense rainfall. Regardless of changes in rainfall, changes in temperature are likely to have significant implications for agriculture, water resources, food security, and natural resource management. Agriculture is likely to be one of the sectors most affected by these changes, with repercussions on the livelihoods of farmers and the environment; this is likely to exacerbate agricultural production and food insecurity.

As the effects of climate change threaten cropping systems, crop genetic resources will be essential for climate change adaptation if properly managed, studied, made readily available and deployed appropriately and in a timely manner. The diversity of genetic traits of crops represents our most important resource for adapting agriculture to the twenty-first century. A study on the impacts of climate change on food production in different agro-ecological zones of East Africa showed that for farmers, changing varieties is one of the main strategies for adapting to temperature alterations, and is the single most important strategy, after soil conservation, for adapting to changes in precipitation patterns (IFPRI, 2008). However, roughly half of the farmers surveyed by the International Food Policy Research Institute (IFPRI) were unable to use different crop varieties, principally due to a lack of available information or lack of access to the required varieties. This indicates that improving farmers' access to information and quality seed of adaptable varieties will considerably enhance their ability to sustain food production in the face of climate change, through the increased use of plant genetic resources for food and agriculture (PGRFA).

Ensuring facilitated access to genetic resources at national and international levels, either through the Multilateral System of Access and Benefit Sharing of the International Treaty on Plant Genetic Resources for Food and Agriculture (MLS/ITPGRFA), or through 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), leads to increased use of plant genetic resources (PGR) for climate change adaptation. Countries will be increasingly dependent on germplasm from foreign sources as climate changes require them to look further afield for useful traits or species.

This study analyses the various processes of access and benefit sharing (ABS) in the context of climate change in Uganda, with a view to understanding the trends in access to PGRFA and the roles of various institutions in the process, as well as the policy and legal environment. A review of different approaches to ABS has been conducted at different levels, namely:

International to national exchange; for example, between (i) national gene banks from different countries; (ii) CGIAR centres and national gene banks; (iii) foreign national gene banks and academic or research institutions; (iv) advanced research institutes abroad and local research institutes; (v) local community gene banks and community gene banks in other countries; (vi) CGIAR centres and breeders through research projects; and (vii) CGIAR centres and local farmers' groups.

National exchange between different actors; for example, between (i) breeding programmes; (ii) national gene banks and breeders, communities and other users; (iii) communities; and (iv) communities and the private sector.

2.0 METHODOLOGY

Data from different sources were analysed to show trends in inflows and outflows of PGRFA in and out of the country and within the country; the data were obtained from the Uganda National Gene Bank (UNGB), various breeding programmes and from the database of Genesys, a global portal to information on PGRFA[1]. A survey was sent to key informants from 19 agricultural institutes in Uganda to provide information on germplasm exchange; 14 informants responded to the survey request. The survey and list of respondents are included as Annexes 1 and 2.

A case study of two reference sites, namely Hoima and Sheema, was used to demonstrate present and future climate-related challenges and changing PGRFA needs. These reference sites have different agro-ecologies although they both produce beans as a major food crop. The strategy involved a step-by-step methodology combining various participatory approaches, including scoring and ranking exercises, in focus group discussions (FGDs) with farmers, and using GIS and crop suitability modeling tools to select suitable varieties for climate change adaptation. The process was participatory and involved scientists and farmers working with breeders throughout the process. Using the modeling tools, together with the passport data of accessions in reference collections, potentially adaptable materials were identified in three distinct tranches. The first set of 20 varieties of beans were identified from the community seed bank in Kiziba, the local community in Hoima, and the UNGB. These were obtained, multiplied and tested by a group of farmers in Sheema and Hoima. The local varieties performed best in terms of drought tolerance, disease and pest resistance, and yield.

A second tranche of ten potentially adaptable bean varieties held at the Rwanda National Genebank (RNGB) were identified using GIS, climate and crop suitability modeling, by matching collections obtained from sites in Rwanda that had a similar climate to the reference sites in Uganda. A third tranche of 20 potentially adaptable varieties, originally collected in Ethiopia, Congo, Tanzania, Kenya and Rwanda, were identified through the Genesys database as being held in the gene bank of the International Center for Tropical Agriculture (CIAT) in Colombia and available under the Standard Material Transfer Agreement (SMTA) pursuant to CIAT's Article 15 agreement with the Governing Body

[1] See https://www.genesys-pgr.org, accessed 30 November 2016.

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. These will be tested in the September – December 2016 planting season in the two sites.

Strategies, policies, laws, regulations and guidelines related to access and benefit sharing of PGRFA were also analysed to provide insights into the ABS regulations on access to and exchange of genetic materials required for climate change adaptation. These included (i) the national policy on PGRFA; (ii) the national seed policy; (iii) the 2007 guidelines on ABS; and (iv) the memorandum of understanding (MoU) between three main institutions involved in ABS, namely the Plant Genetic Resources Centre (PGRC), the National Environment Management Authority (NEMA), and the Uganda National Council for Science and Technology (UNCST).

3.0 RESULTS AND DISCUSSION

3.1 The impacts of climate change in Uganda and recent developments towards increasing adaptive capacity

The IPCC predicts that there will be a 1.5 to 2 °C increase in mean temperatures by the 2050s, rainfall will become more erratic with flooding in some instances, and there will be a general shortening of the growing season (Niang et al., 2014). Consequently, the effects on agricultural production would be a reduced output in maize production; a reduction in areas suitable for coffee production; a decrease in production of other important food crops, such as bananas, beans, sweet potato and cassava; erosion and land degradation, and an overall diminished area for cattle grazing (Hepworth and Goulden, 2008). In addition, crop vulnerability to diseases, for instance bacterial, fungal and viral diseases in bananas, coffee, sorghum, maize, rice, sweet potato and cassava, could increase. As a result of these challenges in Uganda, a number of research and breeding programmes have embarked on developing new varieties for climate-related effects and other constraints including pests and diseases. Details about these initiatives are set out in Table 1 below.

Table 1: Effects of climate change on major food crops and related breeding programmes in Uganda

Crop	Climate-related effects	Varieties released for climate-related stresses (5-10 years)	Breeding programme/research organization
Maize	Reduced output, increased pests and diseases	6 varieties	Maize research programme of the National Agricultural Research Organization (NARO) at Namulonge
Bananas	Reduction in suitable areas, increased incidence of diseases (eg. Banana Xanthomonas Wilt - BXW)	1 variety	Banana research programme, and National Agricultural Research Laboratories (NARL) at Kawanda
Sweet potato	Reduced output and increased incidence of fungal diseases	1 variety	International Potato Center (CIP)/NARO
Cassava	Reduced output and increased incidence of fungal diseases	3 varieties	NARO
Beans	Reduced output and increased incidence of pests	3 varieties	CIAT/NARO
Coffee	Over 50% reduction in suitable areas for growth	None	
Rice	Reduction in output and increased incidence of pests and diseases	1 variety (Nerica 4)	The Africa Rice Center (AfricaRice)/NARO
Tea	Reduction in suitable/viable areas	None	
Sorghum	Increase in suitable areas, but with greater prevalence of pests and disease (eg. Striga)	7 varieties, 5 of them in 2016	National Crops Resources Research Institute (NaCRRI)

Source: Various breeding programmes

According to Uganda's National Adaptation Programme of Action (NAPA), as part of its adaptation strategies Uganda has embarked on a number of short-, medium- and long-term activities, which involve establishing policies and investment strategies that address large-scale, long-term threats to agricultural production and value chains, livelihoods, and agricultural institutions. Some of the strategies include strengthening meteorological services; reforestation; establishing a climate change facility within the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), and integrating climate change into agricultural strategies. The strategies also include recommendations that facilitate local adaptation over shorter time periods, with an emphasis on improving the content and pathways for communicating information between researchers, scientists, and farmers on weather and access to improved varieties.

Various programmes funded by the United States Agency for International Development (USAID) and the Word Bank have strengthened the capacity of the Uganda National Meteorological Authority (UNMA); the Climate Change Department (CCD); and MAAIF to (i) improve the production, distribution and use of climate information that responds to the needs of decision makers, as well as those of farmers and other stakeholders; (ii) develop national climate datasets and information; (iii) develop and routinely use downscaled climate projections; and (iv) develop a platform/mechanism for results (current trends and projections) to be shared at regional, national, district, and local levels. The same donors have also assisted the government of Uganda to create a multi-sectoral coordinating committee, led by the CCD, to regularly meet and plan cross-sector coordination and strategic investment regarding long-term climate change impacts. The committee is currently mainstreaming a climate change perspective into the programming of agricultural and natural resource management services.

3.2 Exchange and access of PGRFA in Uganda

3.2.1 Uganda National Gene Bank inflows and outflows

The Plant Genetic Resources Center (PGRC) of NARO, home of the Uganda National Gene Bank (UNGB) is the main institution responsible for the outflow of PGRFA in the country. Any material leaving the UNGB must be authorized by the PGRC, which has been designated as the organization that is responsible for providing clearance for access of PGRFA in the public domain. Table 2 presents a summary of the accession requests received by the UNGB from commercial and academic institutions and the number of material transfer agreements (MTAs) signed. Trends show that there has been an increase in the number of accessions being requested, especially by academic institutions and breeders (see Table 2).

Table 2 shows that in the last 14 years, the UNGB has supplied a total of 1,435 genetic materials to two research institutions within Uganda, and to various institutions outside Uganda, namely the Millennium Seed Bank in the UK, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the Agricultural Plant Genetic Resources Conservation and Resource Centre in Sudan, the Norwegian

Institute of Science and Technology, and the Svalbard Global Seed vault, using SMTAs. Annexes 3a and b give a detailed summary of accessions of duplicated materials from the UNGB in Svalbard and ICRISAT, and of the materials distributed, according to institute and individual recipient.

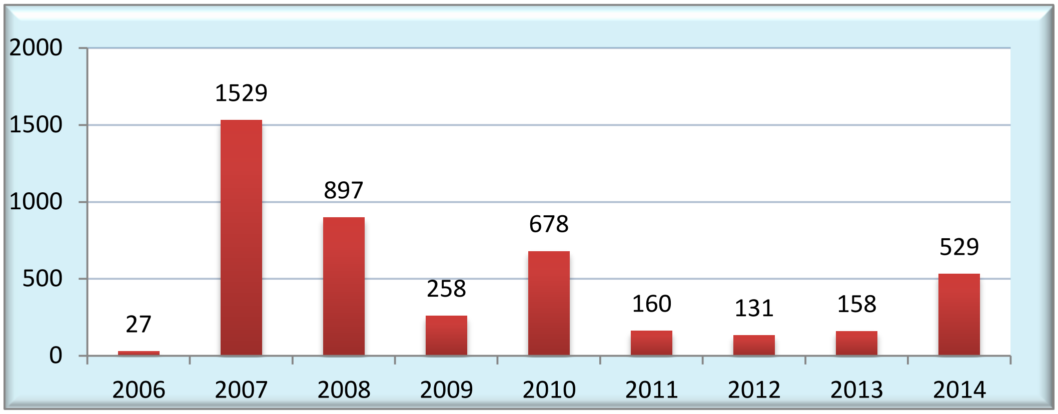
Table 2: PGRFA sent from the UNGB to recipients in and outside Uganda (2001-2015)

International transfers	**Domestic transfers**	**Total no. of accessions**
ICRISAT, Nairobi		20
	NaCRRI	8
Millennium Seed bank, UK		12
	National Semi-Arid Resources Research Institute (NaSARRI)	56
Norwegian University of Science and Technology		4
Agricultural Plant Genetic Resources Conservation and Research Centre, Sudan		15
ICRISAT, India		556
Svalbard Global Seed Vault, Norway		764
Total		**1,435**

Source: UNGB

The rate of acquisition of new materials by the UNGB has been fluctuating over the years, with most accessions deposited from collections carried out countrywide (Figure 1). The highest number of deposits were made in the year 2007/8, mostly from collecting missions organized by the UNGB. Some deposits were carried out as part of projects to repatriate germplasm that was originally collected many years ago and which had been conserved in CGIAR gene banks.

Figure 1: Trends in PGRFA inflows into the UNGB (2006-2015)



Source: UNGB

Over the past ten years, the UNGB has received only 53 accessions from other international gene banks and research institutes. Table 3 indicates that the UNGB received 22 seed samples of *Phaseolus*, ten of quinoa and two of *Artemisia,* from three research institutes for research purposes using SMTAs.

Table 3: Materials acquired by the UNGB from sources outside Uganda (2005-2015)

Provider	**Year**	**Crop**	**No. of accessions**
United States Department of Agriculture (USDA)	2005	Quinoa	10
National Gene Bank, Vietnam	2010	*Artemisia*	2
Bioversity International *Musa* Transit Centre (ITC), Belgium	2010	*Musa* germplasm	20
Rwanda National Genebank	2014	*Phaseolus*	10
CIAT-Columbia	2015	*Phaseolus*	11
Grand Total			**53**

Source: UNGB, 2015

Bean germplasm obtained from the Rwanda National Genebank and CIAT-Columbia was specifically requested for climate change adaptation in two communities (Hoima and Sheema) where Bioversity international, together with NARO-PGRC, has been conducting participatory research with farmers. The two organizations have been helping farmers identify germplasm that is suitably adaptable to their present and future climate challenges. The germplasm is currently being field tested with farmers.

3.2.2 PGRFA flows into and out of the CGIAR and other research centres

International research centres are key players in the movement of PGRFA in and out of the country. Like other developing countries, Uganda relies heavily on foreign-sourced germplasm for its breeding and research programmes.

The most significant international distributions of PGRFA originally collected from Uganda are through the collections hosted by the CGIAR centres. The CGIAR gene banks currently conserve 11,937 accessions of a range of crops that were originally collected from Uganda[2].

The inflow of materials from CGIAR centres to Uganda is also significantly large. Table 4 below gives a summary of the materials sent from CGIAR centres (both gene banks and breeding programmes) to recipients in Uganda, under the SMTA, from 2007 to 2014 (inclusive). Annexes 4 and 5 provide details of inflows and outflows of PGRFA between CGIAR centres and Ugandan organizations, for the period 1979-2010.

[2] Genesys: https://www.genesys-pgr.org, accessed 30 November 2016.

Table 4: Inflows of materials from CGIAR centres to Uganda using the SMTA (2007-2014)

Crop	**No. of accessions**
African yam bean	3
Banana/plantain	110
Calliandra calothyrsus	1
Cassava	31
Chickpea	58
Cowpea *et al*	9
Faba bean/vetch	3
Gliricidia sepium	1
Groundnut	136
In-trust forage collection under ITPGRFA	161
Leucaena trichandra	1
Lupinus	14
Maize	456
Medicago	1
MoringaÂ oleifera	1
Pearl millet	21
Pigeon pea	260
Potato	34
Pueraria	8
Rice	3,846
Sesbania sesban	1
Sorghum	47
Sweet potato	153
Trifolium	1
Wheat	4,443
Yams	18
Total	**9,818**

Source: ITPGRFA Secretariat, 2015

3.2.3. Exchange of PGRFA through breeders' networks and projects

The East African Agricultural Productivity Programme

Exchange of PGRFA also occurs through breeders and their networks, sometimes through regional projects implemented by several countries. The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) has been coordinating one such initiative: the East African Agricultural Productivity Programme (EAAPP). The development objective of EAAPP is to enhance regional specialization in agricultural research; strengthen collaboration in agricultural training and technology dissemination; and facilitate increased transfer of agricultural technology, information and knowledge across national boundaries. EAAPP is a ten-year programme with two phases. Phase I, approved in 2009, focused on capacity building and the establishment of regional centres of excellence (RCoEs), through infrastructure and human resource development; technology generation and dissemination; and the development of improved seed and new breeds (ASARECA, 2016). EAAPP is a regional partnership of the governments of Ethiopia, Kenya, Tanzania and Uganda with ASARECA and the World Bank. EAAPP focuses on agricultural research and development for four selected commodities: cassava (Uganda), dairy (Kenya), rice (Tanzania) and wheat (Ethiopia); RCoEs have been set up by national agricultural research systems (NARS) in the selected countries for the specific crops. The exchange of PGRFA for research is facilitated through EAAPP in the project countries (Table 5).

Table 5: EAAPP exchanges of PGRFA using SMTAs (2010-2015)

Crop	**Institution or organization**	**No. of accessions**
Forage legumes	CIAT-Kenya Kenya Agricultural Research Institute (KARI) – Alupe NaCRRI – Uganda	5 23 8
Cassava	NaCRRI- Uganda	19
Sweet potato	NaCRRI-Uganda CIP-Lima - Peru North Carolina University -USA	214 317 191

Source: EAAPP, 2015

For the dairy component, EAAPP received 36 samples of *Canavalia brasiliensis spp*; *Desmanthus virgatus spp; Desmodium uncinatum spp. cv.* (Silverleaf)*; Lablab purpureus spp; Macroptilium bracteatum cv.*

(burgundy bean); Napier grass accessions (Kakamega 1, Kakamega 2, and River bank,); and *Brachiaria spp,* from three research institutes: CIAT-Nairobi provided five samples, while Alupe station in Kenya and NaCRRI of Uganda provided 23 and eight samples respectively. Of the 36 samples, three accessions of forage germplasm, namely Kakamega 1, Kakamega 2 and Napier 16702, were distributed to Burundi and Rwanda between 2010 and 2015.

The cassava programme at NaCRRI sent five genotypes of stem cuttings to the Natural Resources Institute (NRI) in the UK in 2012 for virus cleaning. The programme also sent four genotypes of cassava germplasm to the Ethiopian Institute of Agricultural Research (EIAR), five genotypes to the Kenya Agricultural and Livestock Research Organization (KALRO) in Kenya and five genotypes to Tanzania. Standard Material Transfer Agreements were signed and an additional condition was that any publications would be shared.

Between 2007 and 2014, NaCRRI supplied 214 accessions of landraces and released cultivars of sweet potato to four research institutes for research purposes, as part of the Sweetpotato Breeding and Genetics Program (see Annex 6); SMTAs were used for the transfers. In 2015, 508 lines of segregated populations of sweet potato were sent to NaCRRI from two research institutes, namely CIP-Lima and North Carolina State University, for research purposes.

Exchange of PGRFA through the Banana Breeding Programme

In Uganda, banana is a priority crop for food security, income and livelihoods; consequently, the Banana Breeding Programme is one of the most vibrant breeding programmes in the country. Table 6 shows the 99 samples of Musa germplasm that were sent to National Agricultural Research Laboratories (NaRL), as part of the Banana Breeding Programme, by five research institutes in 2012 and 2014, for research purposes. Ugandan banana breeders have been able to develop and release hybrids using Musa germplasm accessed through the Banana Breeding Programme. The new banana varieties that have been developed in Uganda are: (i) Kabana 7H, commonly referred to as 'Kiwangazi', which was developed in 2013 specifically for drought and disease tolerance; (ii) Kabana 6H, which was developed in 2010; and (iii) cooking bananas[3]. The Kabana 7H and Kabana 6H varieties are being bred in Uganda for their resistance to Black Sigatoka and tolerance to banana wilt and nematodes; and because they have

[3] Information obtained from a banana breeder.

an extended plantation life of over five years. Local landrace Yangambi Km5, a juice banana, was accessed in 2000 from the Democratic Republic of the Congo (DRC), and was developed and released as Kabana 5H. Interestingly, the widely grown Kabana 3 and Kabana 4, which are both dessert bananas, replaced Bogoya, a local variety of dessert banana, because they are resistant to Fusarium. In order to achieve the different objectives of the breeding programmes in Uganda, numerous crop germplasm accessions have been exchanged. Annexes 7 and 8 show the banana germplasm that has been exchanged by plant breeders in pursuit of developing improved bananas, and the varieties released as a result between 2000 and 2015 in Uganda (See also Table 6 below).

Table 6: Inflows of banana cultivars to the Banana Breeding Programme in Uganda (2010-2015)

Provider Institution	**Year**	**Crop and nature of sample**	**Number of samples**	**Purpose**
Bioversity International *Musa* Germplasm Transit Centre (ITC), Belgium; and Katholieke University, Leuven, Belgium	2012	Musa germplasm: proliferating tissue, rooted plantlets, lyophilized leaf tissues	25	Research: banana improvement
Honduras Foundation for Agricultural Research (FHIA)	2012	Musa germplasm: hybrid	5	Research: banana improvement
Bioversity/ITC	2012	Musa germplasm: landrace and hybrid	2	Research
National Banana Research Program (NBRP)	2012	Musa germplasm: hybrid AAA	1	Research
NBRP/International Institute of Tropical Agriculture (IITA)	2012	Musa germplasm: hybrid AAA	2	Research
Bioversity/ITC and Katholieke University, Leuven, Belgium	2012	Musa germplasm: leaf samples	64	Research: studying genetic diversity of parent lines
IITA/NARO	2014	'NARITA' hybrids under evaluation	27 lines	Multi-locational evaluation in the region
Grand total				**99**

Source: National Banana Breeding Programme, 2015

In 2014, Bioversity International received 27 lines of NARITA hybrids from IITA for multi-locational evaluation in the region. These materials were distributed as PGRFA under development through an STMA, with additional conditions that the recipient would share research data generated, and would recognize the provider in any publications. As a result of these exchanges, some cultivars released into Uganda, like FHIA 17 and FHIA 23, have become very popular in the market.

Cassava Breeding Programme

NARO's Cassava Breeding Programme has been conducting research on disease and pest management over the past ten to fifteen years. Thirty cassava clones have been sent to NARO by IITA, for research purposes, in the form of open-pollinated seeds, cuttings of elite breeding lines, and tissue culture materials of released varieties and advanced breeders' lines (see Table 7).

Table 7: Inflows of cassava cultivars from IITA to NARO

Recipient institution	**Year**	**Crop and nature of sample**	**Number of samples**	**Purpose**
NARO	2005	Cassava open-pollinated seed	1	Breeding
NARO	2012	Cassava cuttings of elite breeding lines	4 clones	On-station and on-farm evaluation
NARO, Department of Agricultural Research Services (DARS) – Malawi; Institute of Agricultural Research of Mozambique (IIAM); Division of Research and Development (DRD) – Tanzania; KARI - Kenya	2014	Cassava tissue culture materials of released varieties and advanced breeding lines	25 clones	On-station evaluation
Total				30

Source: Cassava Breeding Programme, 2015

From the cassava cultivars that were introduced to NARO in 2005, one elite breeding line was identified (TZ-130 or NAM 130) following on-farm evaluation, and it was released by NARO in 2015 as NASE 20.

From the advanced breeding lines, one clone was identified in 2012 (MM 2006/130) for official release in 2015 as NASE 21.

Outflows of cassava germplasm from NARO to IITA in 2015 alone included 200 cuttings from six varieties provided for breeding purposes. The transfer was carried out without an SMTA because the relevant institutions had drafted an agreement to ensure that any materials generated would be for research purposes only.

3.2.4 Exchange of germplasm between communities

Climate change, exacerbated by severe weather patterns, is already interfering with cropping systems, impacting on yields and food security, and particularly affecting the most vulnerable, poor small-scale rural farmers. Future farming and food systems will face even more substantial, albeit distinct, changes in their environments with new pests and diseases and other challenges affecting agricultural production. Faced with losing their diversity, farmers look for new sources of germplasm among other farming communities in order to restore lost diversity. Three community seed banks (CSBs), established with the support of Bioversity International in three agro-ecological zones, provide a good example of germplasm exchange within communities.

The Kiziba CSB, located in Kabwohe, in Sheema district, western Uganda, is a bean seed/gene bank that was established in 2010 with financial support from the Global Environment Facility of the United Nations Environment Programme (UNEP-GEF), and technical support from Bioversity International and NARO-PGRC. A group of farmers came together to create an informal seed network, having realized that there was a lack of good quality seed from a reliable source, and a considerable level of diversity loss in their community, among other factors. The decision to set up the network was reached after a period of farmer-scientist interaction, through a series of training workshops on pests and disease problems, seed quality production and related agronomic practices, and confidence building. The seed/gene bank was then constructed and farmers were able to deposit local varieties that they had in their community. At the time, there were about 20 varieties available locally; NARO-PGRC also provided eleven additional varieties from the National Gene Bank, which had been 'lost' and were re-introduced to the community. A further 38 varieties were obtained from farmers in other communities, making a very wide diversity base of 69 varieties available for the community to choose from.

Another CSB, established in Mityana in 2013/14 from an informal seed network of farmers, has about 20 varieties of beans. NARO-PGRC and Bioversity international supported the repatriation of ten varieties from the National Gene Bank and an additional 20 varieties of beans were introduced from Kiziba CSB. A third CSB, established from an informal network of farmers in Nakaseke in 2013, has also benefited from 20 varieties from other sites, i.e. Kiziba CSB and Rubaya sites, and some 25 varieties from the National Gene Bank. An additional CSB has been constructed in Rubaya, where there are over 30 varieties of beans suited to high altitude areas. In Rubaya, the exchange of germplasm goes beyond the borders and at least three varieties from Rwanda have been exchanged between farmers across the border (Table 8). In addition to this, every year each site conducts a seed fair, and farmer exchange visits have been organized, where farmers exchange varieties of bean seed, millet, sorghum and maize.

Through training workshops, coupled with farmer knowledge, basic practices in seed selection and processing to produce quality seed were identified. The gene/seed banks are managed by farmers themselves and are registered as community-based organizations (CBOs). The CSBs are also linked with the National Gene Bank, which holds duplicates for them in a black box and provides some varieties from its collections to the CSBs for restoration. Technical and operational backstopping, and capacity building, are provided by the National Gene Bank and Bioversity international. Furthermore, one of the CSBs - the Kiziba CSB - is in the process of negotiating with the private sector and the Netherlands-funded integrated Seed Sector Development Initiative (ISSD), to start producing quality-declared seed. This will ensure sustainability and profitability for the CSB, while at the same time safeguarding seed security for the surrounding communities.

Table 8: Summary of seed exchange between communities with CSBs

CSB or Farmers' group	Location	Crops	Seed production and multiplication	Number of varieties from the National Gene Bank	Total number of varieties	Number of farmers benefiting	Partnerships
Kiziba CSB	Sheema – western Uganda	Beans	Yes	23	69	900	Bioversity International, NARO-PGRC, National Agricultural Advisory Services (NAADS)
Nakaseke CSB	Central Uganda	Beans	No	13	29	200	Bioversity International, NARO-PGRC
Rubaya CSB	South-western Uganda	Beans, millet, sorghum, potato	No	15	23	234	Bioversity International, NARO-PGRC
Jing Komi farmers' group	Northern Uganda		Yes	-	-	218	NAADS, ISSD
Pagwari farmers' association	Northern Uganda		Yes	-	-	Unknown	NAADS, ISSD

Source: *Authors' compilation from field research in 2014*

3.2.5 Exchange of germplasm between communities in different countries

The exchange of germplasm between a community in Uganda and a community in Rwanda occurred as a result of an exchange visit organized for the Rwandan farmers to visit a CSB in Uganda and interact with a community that was facing similar climate-related challenges. The visit was carried out in the second phase of the Genetic Resources Policy Initiative (GRPI2), as part of training and capacity building for farmers, scientists and breeders on the use of genetic diversity for climate change adaptation. Members of Kundisuka farmers' cooperative in Rwanda visited the Kiziba CSB in Uganda where they selected some of the varieties of beans from the community gene bank in Uganda, through a participatory variety selection process that involved farmers, breeders and extension workers from Rwanda and Uganda. The selected varieties provided a rich diversity that the farmers could use to adapt to climate change and enhance their collections.

The Rubaya CSB, managed by the Kundisuka farmers' cooperative, is located in the Rubaya sector of Gicumbi district in northern Rwanda. A community gene bank and seed storage facilities were constructed with support from the Vision 2020 Umurenge Program (VUP)[4] and the Ministry of Local Government of Rwanda (MINALOC). The storage facilities are used for storing the priority crops of the region (maize, wheat, beans, and Irish potato), but farmers are free to use the gene bank facility for the storage and conservation of other seed and planting materials. Farmers also use the storage facilities to store bumper harvests, which they can sell or use for home consumption during the off-season. They have not yet embraced activities such as seed selection and processing, and they have also not yet utilized the seed bank to the level required to make good quality seed available for the local community. The community seed bank serves approximately 200 farmers, who mainly use the facilities to store their produce during harvest time.

The government of Rwanda has identified priority crops for food security, namely maize, wheat, rice and potato, and has incorporated these crops in its agricultural intensification programme, through which it distributes improved varieties and inputs, such as fertilizers, freely to farmers. Its policy of land consolidation and the cultivation of priority crops in Rwanda has had a negative impact on the operation of activities of the CSB because the local varieties of different crops cannot be grown freely by farmers. However, the Rwanda Cooperative Agency (RCA) provides advice to committee members of the farmers'

[4] VUP is an integrated local development programme that was established in 2007 to accelerate poverty eradication, rural growth and social protection and is supported by the United Nations Development Programme (UNDP).

cooperative on how to create a balance between growing the varieties prescribed by the government's agro-intensification programme and their own varieties of choice. The local CSB has 16 varieties of bean seed, including seven varieties that were recently sent by the Rwanda National Genebank.

Under Ugandan regulations, *in situ* materials in farmers' fields are exchanged through the Nagoya Protocol, and regulations pertaining to this are outlined in the 2007 guidelines on ABS. For the exchange of seed between two communities, prior informed consent (PIC) from the communities is mandatory as a requirement for the negotiations that culminate in the signing of a material transfer agreement (MTA) and, eventually, payments being made to the communities This process is complicated, long and tedious for farmers, and consequently they prefer to work with the central authorities on PGRFA, i.e. the national gene banks, who negotiate on behalf of the two communities. In the case of the Kiziba community seed/gene bank, since it comprises a mix of materials – some from the National Gene Bank of Uganda and others from farmers' collections, several options are currently being considered; for example, voluntary inclusion in the MLS through the National Gene Bank, and then the provision of free access to farmers. However, modalities for voluntary inclusions have still not been worked out under the current process of review of ABS legislation in Uganda.

3.3 Importance of ABS for climate change adaptation: the use of climate and GIS modeling to identify adaptable bean germplasm in two communities in Uganda.

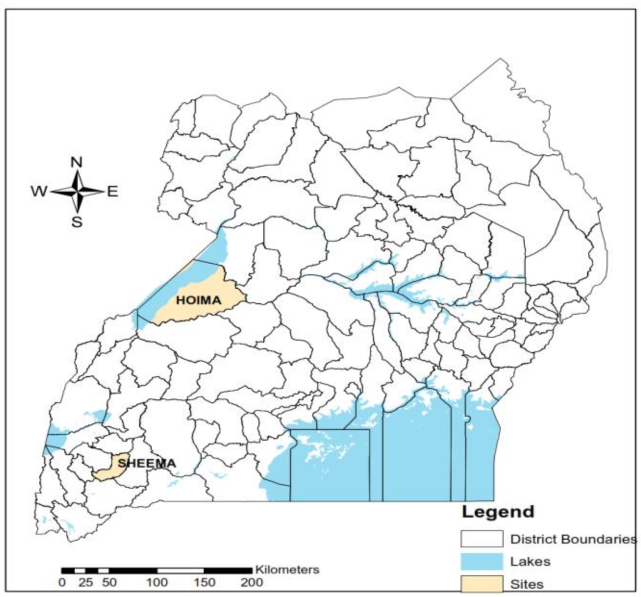
3.3.1 Background information on selected sites

Hoima district

Climate change is affecting many communities in Uganda. Changes in precipitation and temperatures, shifting seasons; and increased incidences of pests, diseases and invasive species, have led to lower agricultural productivity. As part of strategies for adaptation, communities will require access to adaptable germplasm from further afield. Two communities in Uganda that have different agro-ecologies and experience different climatic challenges were selected for a case study, to determine their present and future genetic resource needs. The communities were visited to identify their climate challenges, and climate data were analysed to determine present and future climate profiles. Using climate and geographic information system (GIS) modeling technologies, potentially adaptable germplasm was identified from a collection of beans originating from East Africa and held by CIAT's gene bank.

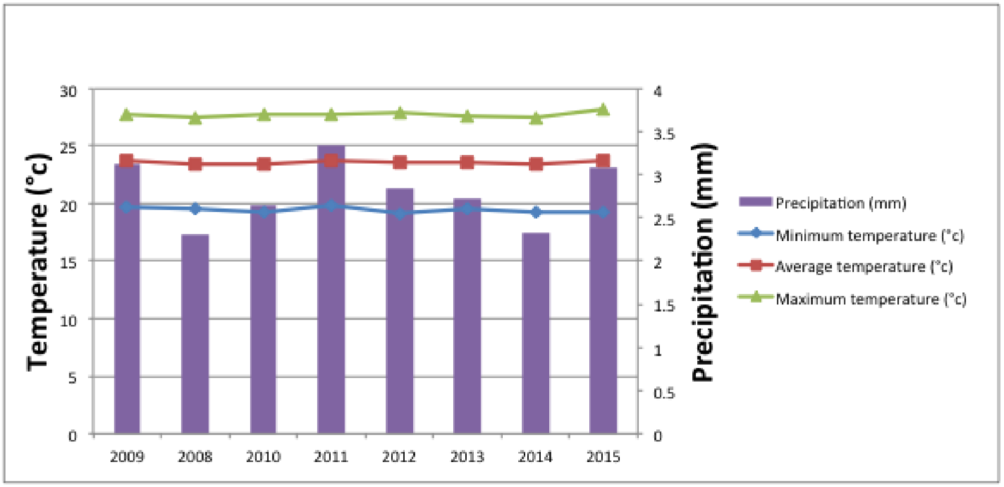
The reference sites selected are represented in a map in Figure 2. Hoima district, a reference site of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), is located in western Uganda between 1° 00′-2° 00′ N and 30° 30′-31°45′ E. It is bordered by Lake Albert in the west, Bundibugyo and Kibaale in the south, Masindi in the north-east and Kiboga in the east. The district covers 3,664.1 km^2 and lies within an altitude range of 621 metres and 1,158 metres above sea level (masl), making it one of the lowest and hottest areas in Uganda. It forms part of Uganda's cattle corridor, with mixed farming and livestock systems. Average annual rainfall is 1,000 millimetres (mm), and temperatures range between 20 °C and 30 °C. An analysis of trends in temperature and precipitation in Hoima from 2008 to 2015 indicate that there has been a slight increase in maximum temperatures by about 0.5°C, and rainfall has been fluctuating but has not shown a significant decrease in quantities (Figure 3).

Figure 2: Map showing the location of reference sites in Uganda



Source: *Authors*

Figure 3: Average annual temperatures and precipitation for Hoima (2008-2015)



Source: aWhere weather data, 2015

A further analysis of present and future climate projections indicates that on average Hoima will be one degree warmer in the 2050s, and rainfall amounts will increase (see Tables 9a and b). Figure 4 also shows that there will be a shift in seasons, with fewer rainy days even though the rainfall amounts will increase overall.

Table 9a: Hoima, present climate

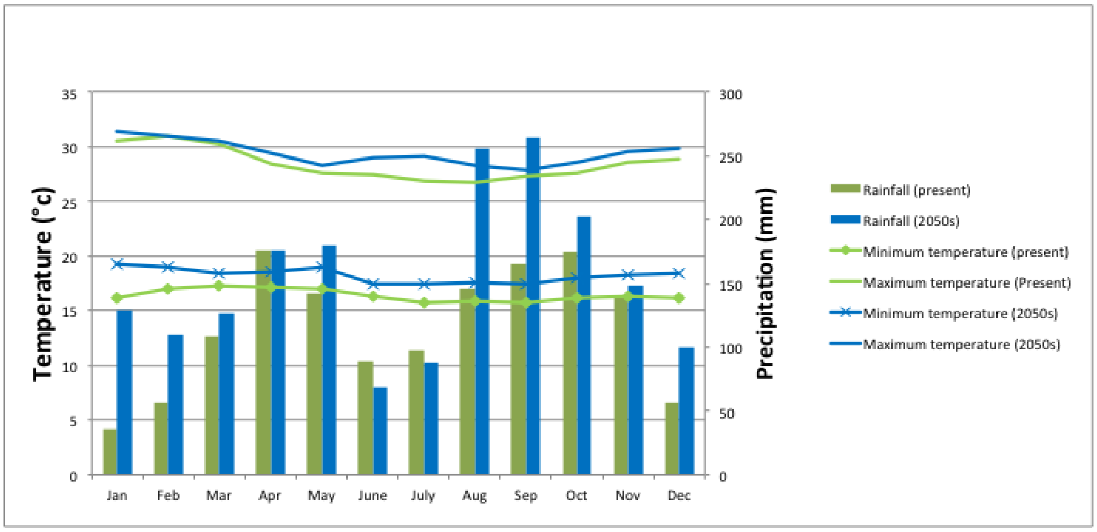
x:31.43318 y:1.48300 alt:1187 worldclim_2-5m	T. min	T. max	Rain
Jan	16.2	30.6	36
Feb	17	30.9	56
Mar	17.3	30.2	108
Apr	17.2	28.4	176
May	17	27.6	142
Jun	16.3	27.5	89
Jul	15.7	26.8	98
Aug	15.9	26.7	146
Sep	15.8	27.3	165
Oct	16.2	27.6	175
Nov	16.3	28.5	139
Dec	16.2	28.8	57
Year	16.4	28.4	1387

Table 9b: Hoima, 2050's climate

X:31.43318 y:1.48300 alt:1187 wc_ccm3_2-5m	T. min	T. max	Rain
Jan	19.3	31.4	129
Feb	19	30.9	109
Mar	18.4	30.6	126
Apr	18.5	29.4	176
May	19	28.3	180
Jun	17.4	29	68
Jul	17.4	29.1	88
Aug	17.6	28.3	256
Sep	17.5	27.8	264
Oct	18	28.6	203
Nov	18.3	29.5	148
Dec	18.4	29.8	100
Year	18.2	29.4	1847

Source: Worldclim

Figure 4: Present and predicted future climate in Hoima



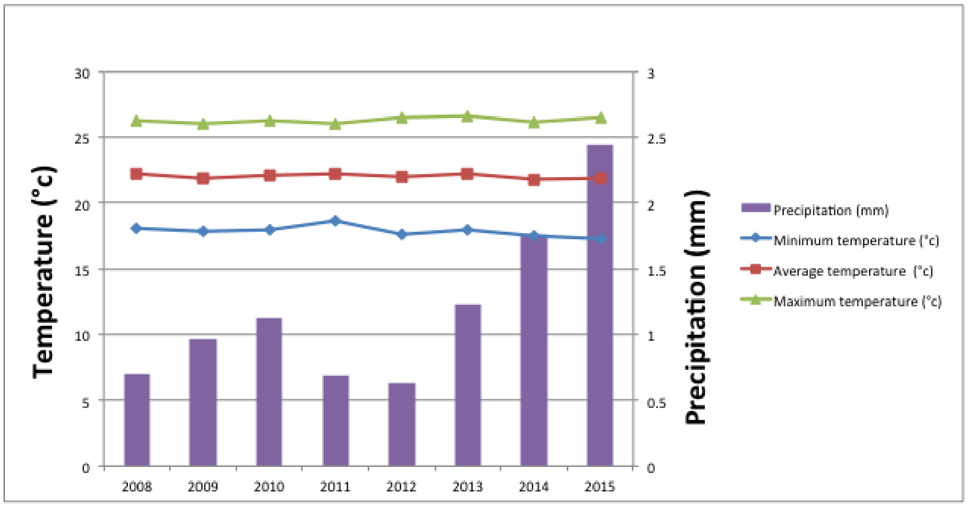
Source: Worldclim, 2015

Sheema district

Sheema district covers an area of 1,846.4 km^2 in western Uganda, with an average elevation of about 1,800 masl. The district receives an average annual rainfall of 1,200 mm (see Figure 2), and temperatures range between 17 °C and 30 °C. The landscape comprises large plains where animal ranching, and therefore milk and beef production, is predominant. Crops grown in this region include millet, beans, bananas and horticultural crops (fruits and vegetables).

An analysis of trends in temperature and precipitation between 2008 and 2015 shows a slight increase in maximum temperatures by around 0.6 °C (see Figure 5). The rainfall amounts have also increased, with farmers reporting increased erratic rainfall, and the shifting and shortening of seasons over the years. Annex 9 provides a summary of characteristics of the two reference sites.

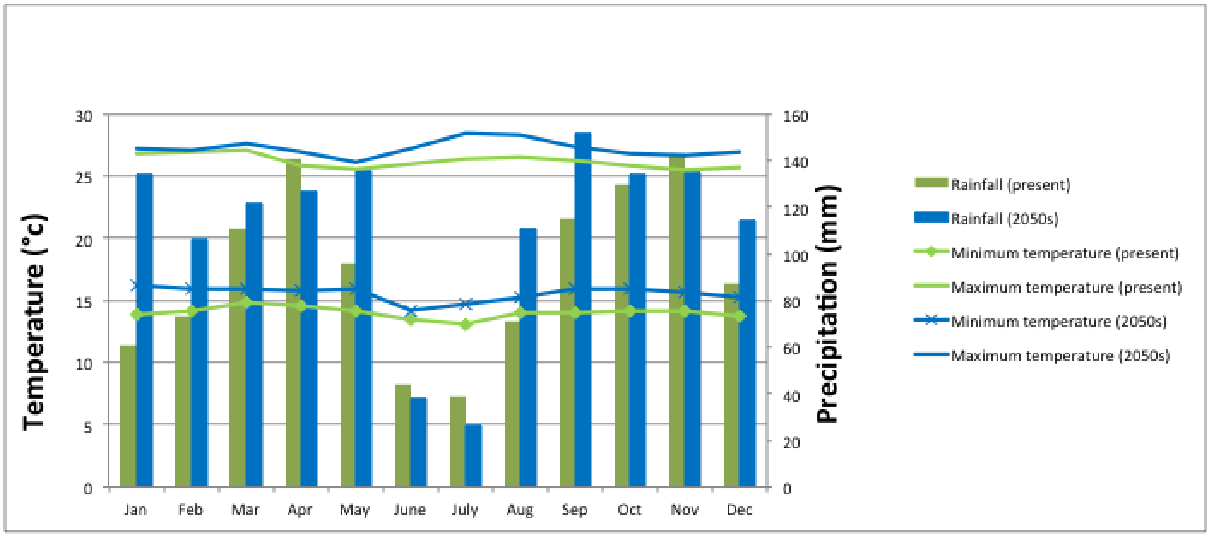
Figure 5: Average annual temperatures and precipitation in Sheema



Source: aWhere weather data, 2015

An examination of present and future projections indicates that temperatures will rise by 1.2 °C by the 2050s. It is expected that rainfall will increase overall as the seasons shift, with the dry season shortening and the rainy season lengthening (See Figure 6, and Tables 10a and b).

Figure 6: Present and predicted future climate in Sheema



Source: Worldclim, 2015

Table 10a: Sheema, present climate

x:30.37823 y:-0.57879 alt:1476

worldclim_2-5m

	T. min	T. max	Rain
Jan	13.9	26.8	61
Feb	14.2	27	73
Mar	14.8	27.1	111
Apr	14.6	25.8	141
May	14.2	25.6	96
Jun	13.4	26	44
Jul	13.1	26.4	39
Aug	14	26.6	71
Sep	14	26.3	115
Oct	14.2	25.8	130
Nov	14.1	25.5	143
Dec	13.7	25.7	87
Year	14.0	26.2	1111

Table 10b: Sheema, 2050's climate

x:30.37823 y:-0.57879 alt:1476

wc_ccm3_2-5m

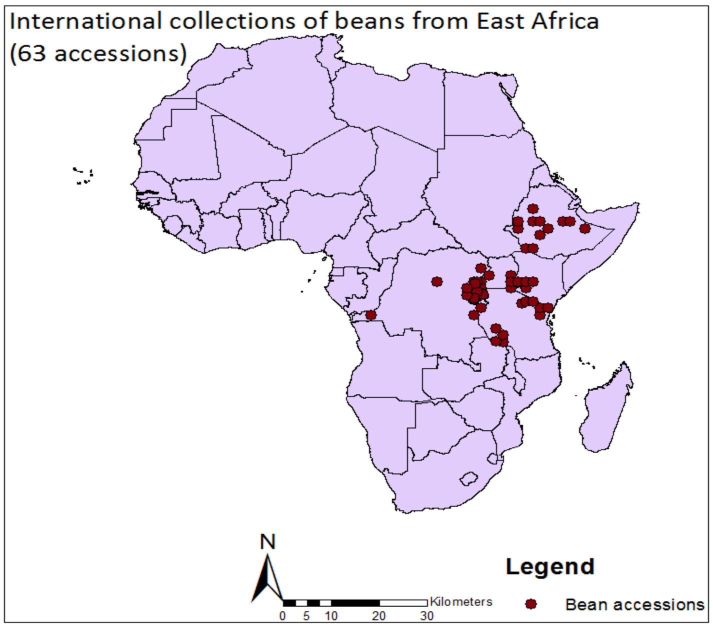
	T. min	T. max	Rain
Jan	16.2	27.2	134
Feb	15.9	27.1	106
Mar	15.9	27.7	122
Apr	15.8	26.9	127
May	15.9	26.1	136
Jun	14.2	27.2	38
Jul	14.7	28.4	26
Aug	15.2	28.3	111
Sep	15.9	27.4	152
Oct	15.9	26.8	134
Nov	15.7	26.7	135
Dec	15.3	26.9	114
Year	15.6	27.2	1335

Source: Worldclim

3.3.2 Accessions selected based on climate and GIS modeling

Based on climate, GIS and crop suitability modeling, accessions for each site were selected from collections originating in East Africa (Figure 7), using the Genesys database. The collections were limited to those in East Africa, mainly due to similarities in weather and soil conditions but also to understand the potential interdependence among East African countries at present and in the future.

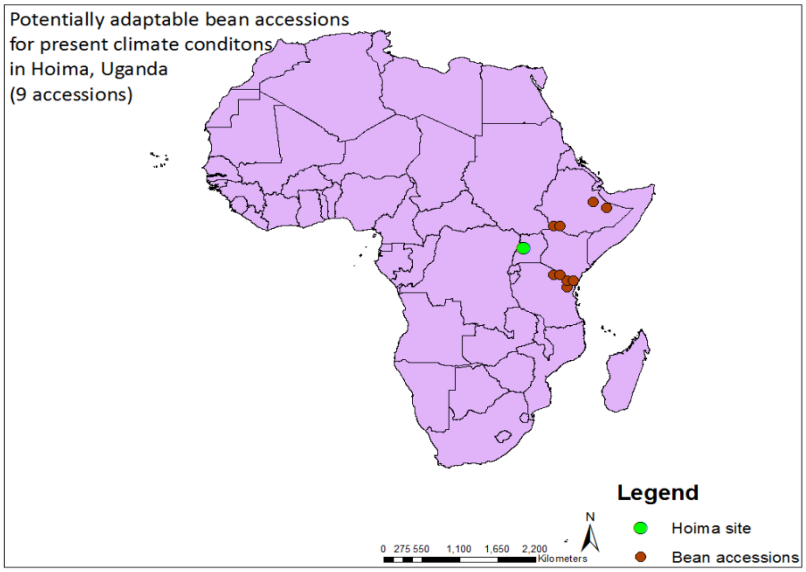
Figure 7: Collections of beans from East Africa



Source: Authors' compilation

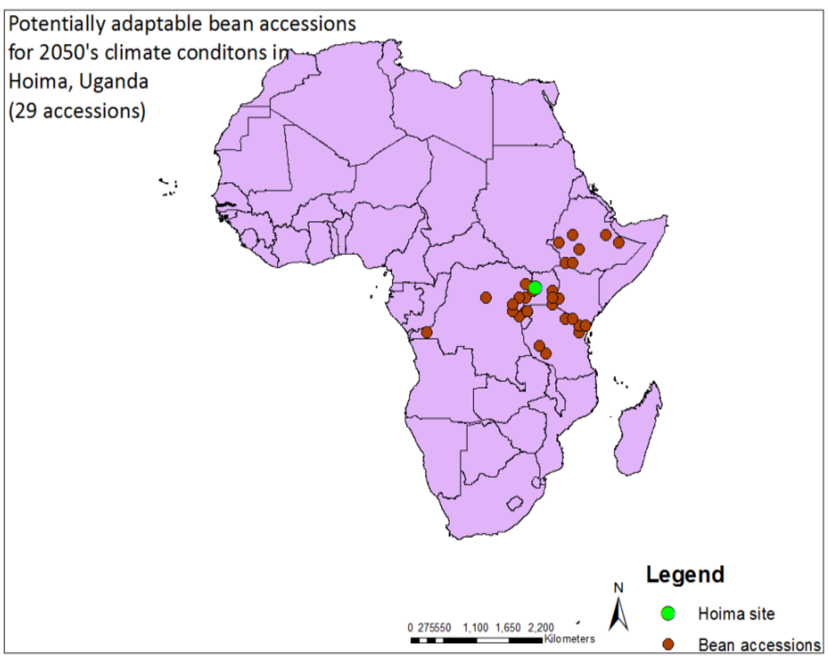
Potentially adaptable collections of beans from East Africa were identified by matching accessions with present and future climatic variables, i.e. temperature, precipitation and 19 bioclimatic variables. The results are illustrated in Figures 8a and 8b below for Hoima, and Figures 9a and 9b for Sheema. Only nine accessions were found to be potentially suitable for present climatic conditions in Hoima. For the predicted future climate of the 2050s, the number of potentially adaptable accessions increased to 29 because the climate in Hoima is expected to be more humid in the 2050s, with higher rainfall and temperatures, which matches some areas in Kenya, Tanzania, Ethiopia, Uganda, Rwanda and DRC. For Sheema, the accessions selected can be found in Ethiopia, Kenya, Uganda, Tanzania and DRC.

Figure 8a: Bean accessions potentially adaptable to present climatic conditions in Hoima



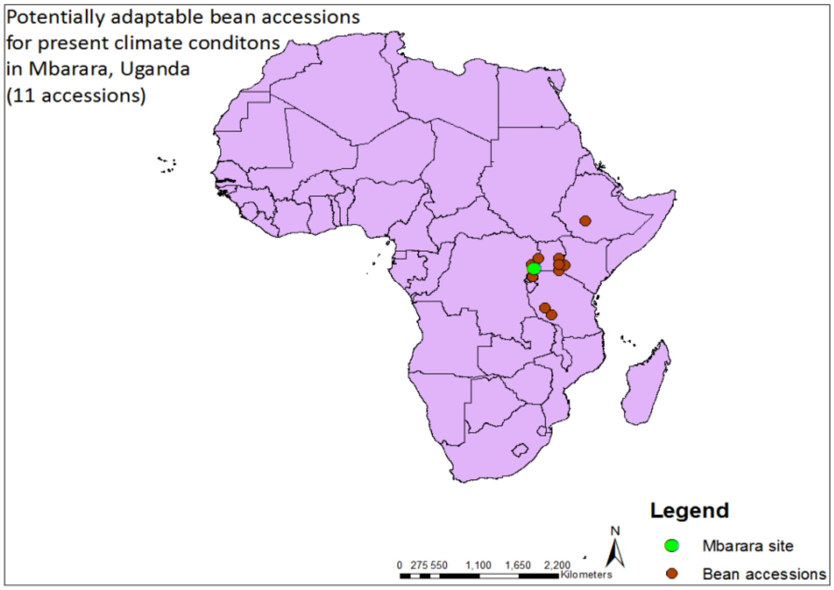
Source: Authors' compilation

Figure 8b: Bean accessions potentially adaptable to future climatic conditions in Hoima



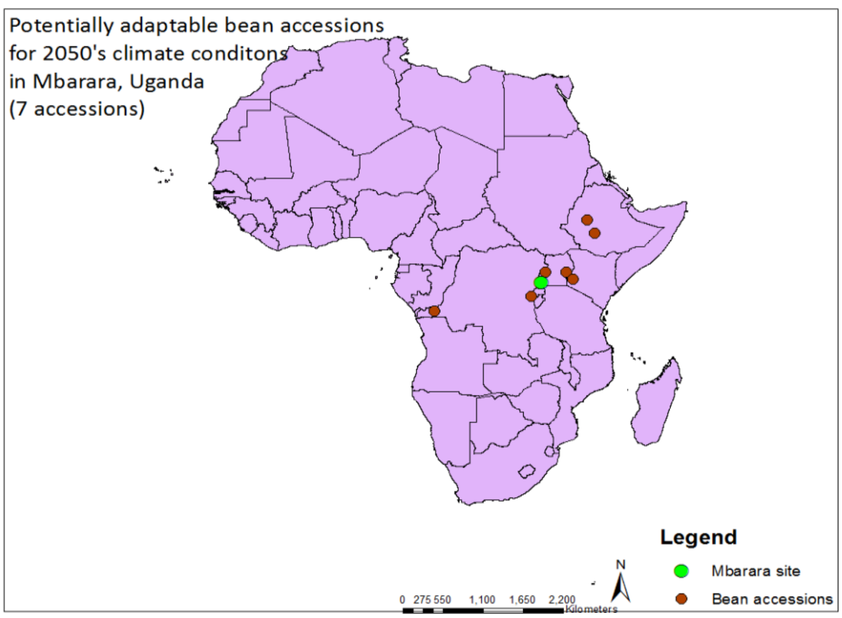
Source: Authors' compilation

Figure 9a: Bean accessions potentially adaptable to present climatic conditions in Sheema



Source: Authors' compilation

Figure 9b: Bean accessions potentially adaptable to future climatic conditions in Sheema



Source: Authors' compilation

3.4 Access to and exchange of genetic resources in Uganda: opportunities and challenges

The exchange of genetic resources in Uganda has presented many opportunities to breeding programmes and farmers. For this study, we were interested in the numerous factors that plant breeders or other stakeholders believed to facilitate the exchange of material. After conducting key informant interviews with seven plant breeders, the following factors were identified: (i) flexibility and cooperation of farmers, especially when disseminating new technologies; (ii) good coordination among stakeholders within the breeding programmes and research institutes, and collaboration between foreign research institutes and NARO in particular; (iii) availability of funds, e.g through a project, which makes it easier to facilitate germplasm exchange; and (iv) the use of an SMTA, which helps to trace movement of germplasm.

The study also identified several challenges that have been faced by plant breeders and other stakeholders in exchanging plant germplasm for food and agriculture; these challenges include: (i) lack of a national policy or regulations and procedures for accessing PGR, as those that exist are still in draft form and have not yet been fully implemented; (ii) lack of national laws on intellectual property rights (IPRs); (iii) climate change; (iv) inadequate human capital, coupled with high resource costs and financial constraints, limits breeding and evaluations; (v) the short lifespan of projects, which leaves little or no time for measuring the impact of improved planting material; and (vii) scenarios where the improved planting material is less successful, for example, when hybrids don't meet a specific need of farmers, such as taste.

3.5 Prevailing policy and legal environment in Uganda and how this affects ABS issues

3.5.1 The ITPGRFA and related legislation in Uganda

Uganda is a party to the ITPGRFA; the Uganda National Council for Science and Technology (UNCST) is its competent authority, and NARO-PGRC its focal point. Accessing PGRFA that are not in the MLS must be carried out under the Nagoya Protocol. In such cases, accessing PGRFA that are in the public domain must be requested through NARO-PGRC and authorized by UNCST. This process makes it difficult to access PGRFA, because there are still no clear institutional mandates for ABS, and even though UNCST is the competent authority for PGRFA and other genetic resources, it does not work closely with the key focal points for the Nagoya Protocol and the ITPGRFA except to authorize access.

Uganda has developed a national policy on genetic resources for food and agriculture but this has not yet been passed into law and still awaits tabling through cabinet for approval. The country is also in the process of developing guidelines for ABS under the ITPGRFA, in harmony with the provisions of the CBD and the Nagoya Protocol. A memorandum of understanding (MoU) between the three key institutions (NEMA, NARO and UNCST) was signed to establish measures and procedures for harmonizing ABS laws under the Nagoya Protocol and the ITPGRFA, and for strengthening institutional arrangements for their implementation (Otieno, Mulumba and Ogwal, 2016).

3.5.2 Uganda's ABS laws under the Nagoya Protocol

Uganda's 2007 guidelines on access and benefit sharing require that before obtaining a permit to access genetic resources, the person, group or association intending to access the genetic resources must obtain prior informed consent (PIC) and an accessory agreement with the resource owners. The applicants then need to acquire a valid access permit from UNCST. In accordance with Ugandan ABS laws, the material transfer agreement (MTA) must provide for benefits to be shared, including expected technology transfer. Article 5.4 of the guidelines determines that mechanisms for sharing benefits must be according to mutually agreed terms (MAT) and concluded with beneficiaries in advance, prior to accessing the genetic resources. The above-mentioned MoU is also important for the operation of ABS laws, as it gives UNCST the institutional mandate to grant access to genetic resources, in consultation with NEMA and NARO-PGRC.

3.5.3 Uganda's Plant Variety Protection Bill and farmers' rights

Enacted in 2010, Uganda's Plant Variety Protection Bill seeks to recognize and safeguard the rights of breeders over plant varieties protected by them. It also promotes the use of appropriate mechanisms for the fair and equitable sharing of benefits arising from the use of plant varieties, knowledge and technologies for the protection of breeders' rights. However, the bill does not have any clauses protecting farmers' rights, indigenous knowledge, or the rights to save, exchange, use and sell farm-saved seed; it is also silent on communities' rights. Thus, by only granting IPRs to breeders, *in situ* conservation and the efforts of CSBs are diminished.

Linking CSBs with national gene banks provides a basis for voluntary inclusions in the MLS. Incentives for this can be in the form of technical support and capacity building for the CSBs; once this material is in the MLS it can then be easily transferred to other users. Linking CSBs to national gene banks can result in mutual benefits of various forms: (i) farmers can voluntarily include materials they have in the national gene-banking systems (thereby including them automatically in the MLS) in exchange for other benefits, allowing for ABS as it is set out by the ITPGRFA, and participation in the MLS and benefit-sharing fund; (ii) national gene banks can hold safety duplicates of farmers' materials in 'black boxes', as they have better equipment and conditions, protecting their sovereignty over seed; (iii) national gene banks may restore farmers' 'lost varieties' within their holdings by reintroducing them to CSBs (Development Fund, 2011), improving diversity, seed and food security; and (iv) farmers may be able to participate in national breeding programmes through participatory plant breeding (PPBs), participatory variety selection (PVS), and participatory variety testing, helping to increase farmers' capacity. All these have been re-emphasized as effective methods of exchanging genetic resources, and ensuring farmers benefit from the exchange of genetic resources (Development Fund, 2011).

4.0 CONCLUSIONS

From the above analysis, we can conclude that with climate changes happening in Uganda, there will be a greater need to access foreign germplasm as a strategy for improving the adaptive capacity of farmers, and providing breeders with the necessary material. Uganda has been very active in the exchange of genetic resources, mainly through CGIAR research centres, breeding programmes and breeders' networks. The most significant movement of materials is through the CGIAR centres for research purposes. Owing to the effects of climate change, at present and in the future, Uganda's PGRFA needs are changing and will continue to change over time, requiring access of PGRFA from further afield. Breeding programmes and research institutes within the country will need to access material they can use for developing new varieties that are climate resilient. Gene bank collections, such as those held by CGIAR centres or the USDA gene bank, are some of the most obvious and important sources of these materials. In addition, national gene banks or even communities, including CSBs, are also important sources of PGRFA for climate change adaptation.

Exchange of materials in the MLS is relatively easy through the SMTA, and is even easier when the holding institutions are the CGIAR centres. However, obtaining PGRFA directly from national gene banks can be difficult if the countries have not implemented the ITPGRFA and do not have ABS laws, and therefore do not have clear processes for accessing PGRFA.

Given the current legal and regulatory frameworks for ABS in Uganda, for materials that are not in the MLS, the process of accessing PGRFA is complicated; for example, for communities wishing to exchange materials across boundaries. Since the materials are not automatically in the MLS, they are subject to communities' consent, and issues of indigenous traditional knowledge (ITK) and farmers' rights come into question; the current legal and regulatory frameworks do not adequately cover these aspects. Furthermore, access agreements in Uganda follow a long process involving communities, local leadership, district leadership, NEMA and UNCST, and the cost and time implications are prohibitive for CSBs or local communities wishing to exchange materials across borders.

In view of the above issues raised, there is a need for the harmonization of any laws related to genetic resources, such as seed laws, laws related to intellectual property rights and ABS laws. The ABS laws in Uganda are currently under revision to ensure mutually supportive implementation of the ITPGRFA and the Nagoya Protocol, by (i) providing guidelines to access PGRFA and the institutional mandates for ABS under the ITPGRFA and Nagoya Protocol, which also includes streamlining and simplifying the ABS processes; (ii) providing incentives for communities to give access to genetic resources and ensure benefits accrued are shared with communities; and (iii) establishing or improving information exchange with respect to inflows and outflows of PGRFA in Uganda, and also between key stakeholders within Uganda such as the National Gene Bank, breeding programmes and local communities.

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6.0 ANNEXES

Annex 1: key Informant questionnaires for ISSD study on ABS and climate change in Uganda (2016)

Name:

Institution:

Recipient or provider (select One) ____

1. **Material received (5-10 years)**

Recipient institution: …………………………………………………………………….

Provider institution	Year	Crop and nature of sample	Number of samples	Qty	Purpose

*Nature of sample – e.g released/commercial variety, advanced breeding lines, populations, hybrid lines, etc

2. **Enter in the table below what kind of agreements were made with what conditions and benefits**

Agreements/contract type	Conditions and benefits

3. **Mention successful story (stories) due to the exchange.**

Annex 2: List of survey respondents

	Contact person	Organization/Institute
1.	Ms. Eva Zaake	Gene bank manager –Plant Genetic Resources Centre (PGRC)
2.	Dr. Jolly M.L. Kabirizi	The East African Agricultural Productivity Programme (EAAPP); National Livestock Resources Research Institute (NaLIRRI)
3.	Dr. George Lukwago	EAAPP
4.	Dr. Benard Yada	National Crops Resources Research Institute (NaCRRI); root crops programme
5.	Ms. Agnes Alajo	NaCRRI; root crops programme
6.	Dr. Titus Alicai	NaCRRI; national cassava programme
7.	Mr. Ssali Tendo	National Agricultural Research Laboratories (NARL); banana programme
8.	Dr. Piet van Asten	International Institute of Tropical Agriculture (IITA)
9.	Yuventino Obong	Ngetta Zonal Agricultural Research and Development Institute (NZARDI)
10.	Dr. Deborah Karamura	Bioversity International (Musa germplasm conservationist)
11.	Dr. Claire Mukankusi	CIAT – bean research programme
12.	Dr. John Wasswa Mulumba	Curator, National Gene Bank – PGRC
13.	Divine Nakede	Senior seed inspector- Seed Inspection and Certification Unit
14.	Francis Ogwal	National Environment Management Authority (NEMA)

Annex 3a: Duplicated materials from the UNGB in Svalbard Global Seed Vault and ICRISAT

Crop	No. of accessions	Date duplicated	Institute	Recipient
Pennisetum glaucum	23	June 2010	ICRISAT, India	Hari Upadhyaya
Sorghum bicolor	64	June 2010	ICRISAT, India	Hari Upadhyaya
Eleusine coracana	429	June 2010	ICRISAT, India	Hari Upadhyaya
Eleusine coracana	262	March 2010	Svalbard Global Seed Vault	Hari Upadhyaya
Eleusine africana	56	June 2011	Svalbard Global Seed Vault	Arni Bragason
Eleusine indica	50	June 2011	Svalbard Global Seed Vault	Arni Bragason
Eleusine jaegeri	3	June 2011	Svalbard Global Seed Vault	Arni Bragason
Eleusine kigeziensis	11	June 2011	Svalbard Global Seed Vault	Arni Bragason
Pennisetum macrourum	9	June 2011	Svalbard Global Seed Vault	Arni Bragason
Pennisetum mezianum	10	June 2011	Svalbard Global Seed Vault	Arni Bragason
Pennisetum procerum	18	June 2011	Svalbard Global Seed Vault	Arni Bragason
Pennisetum thubergii	3	June 2011	Svalbard Global Seed Vault	Arni Bragason
Pennisetum ramosum	26	June 2011	Svalbard Global Seed Vault	Arni Bragason
Pennisetum unisetum	35	June 2011	Svalbard Global Seed Vault	Arni Bragason
Phaseolus vulgaris	90	June 2011	Svalbard Global Seed Vault	Arni Bragason
Sorghum bicolor	180	Sept 2011	Svalbard Global Seed Vault	Arni Bragason
Eleusine coracana	173	Sept 2011	Svalbard Global Seed Vault	
Total	**1,442**			

Source: UNGB, 2015

Annex 3b: Materials distributed from the UNGB

Crop	No. of accessions	Date distributed	Institute
Oryza eichingeri	8	Jan 2012	NaCRRI
Pennisetum glaucum	18	Dec 2011	NaSARRI
Sorghum bicolor	10	Nov 2010	ICRISAT, Kenya
Eleusine coracana	10	Nov 2010	ICRISAT, Kenya
Eleusine indica	1	May 2012	Millennium Seed Bank, Kew
Eleusine jaegeri	1	May 2012	Millennium Seed Bank, Kew
Eleusine africana	1	May 2012	Millennium Seed Bank, Kew
Pennisetum thumbergii	1	May 2012	Millennium Seed Bank, Kew
Pennisetum procerum	1	May 2012	Millennium Seed Bank, Kew
Pennisetum unisetum	1	May 2012	Millennium Seed Bank, Kew
Pennisetum macrourum	1	May 2012	Millennium Seed Bank, Kew
Pennisetum trachyhllum	1	May 2012	Millennium Seed Bank, Kew
Pennisetum mezianum	1	May 2012	Millennium Seed Bank, Kew
Pennisetum glacum	1	May 2012	Millennium Seed Bank, Kew
Pennisetum ramosum	1	May 2012	Millennium Seed Bank, Kew
Eleusine kigeziensis	1	May 2012	Millennium Seed Bank, Kew
Vigna spp.	38	May 2013	NaSARRI
Sorghum bicolor	15	Oct 2014	Agricultural Plant Genetic Resources Conservation and Research Centre –Sudan
Sorghum bicolor	4	May 2013	Norwegian University of Science and technology
Total	**115**		

Source: Key informant survey, 2016

Annex 4: PGRFA received by Ugandan organizations from CGIAR gene banks, 1979-2010

Genus and species	Number of accessions	Percentage of total	CGIAR centre
Arachis – hypogaea	314	23.6	ICRISAT
Cajanus – cajan	676	50.8	ICRISAT
Ipomoea – batatas	239	18.0	CIP
Oryza – sativa	11	0.8	IRRI
Solanum – spp.	31	2.3	CIP
Sorghum – bicolor	50	3.8	ICRISAT
Vigna – unguiculata	10	0.8	IITA
Total	**1331**	**100.0**	**4**

Source: Genesys database, 2014

Annex 5: PGRFA outflows in Uganda, 1979-2010 (distribution according to genus and CGIAR centre)

Genus and species	Number of accessions	Percentage of total	CGIAR centre
Arachis hypogaea	1454	12.2	ICRISAT
Cajanus cajan	68	0.6	ICRISAT
Cicer arietinum	1	0.01	ICRISAT
Eleusine coracana	5,202	43.6	ICRISAT
Pennisetum glaucum	412	3.5	ICRISAT
Pennisetum polystachyon	3	0.03	ICRISAT
Sorghum bicolor	3,920	32.8	ICRISAT
Unknown	1	0.01	ICRISAT
Brachiaria arietinum	23	0.2	CIAT
Brachiaria decumbens	98	0.8	CIAT
Brachiaria ruziziensis	1	0.01	CIAT
Phaseolus vulgaris	62	0.5	CIAT
Glycine Max	2	0.02	IITA
Vigna spp	2	0.02	IITA
Vigna unguiculata	53	0.44	IITA
Leersia hexandra	2	0.02	IRRI
Oryza eichinger	347	2.9	IRRI
Oryza punctata	110	0.9	IRRI
Ipomoea batatas	265	1.4	CIP
Pisum sativum	11	0.1	ICARDA
Total	**11,937**	**100**	**6**

Source: Genesys database, 2014

Annex 6: Distribution of sweet potato germplasm from NaCRRI to various research institutes through EAAPP

Recipient institution	Year	Crop and nature of sample	Number of samples
CIP, Lima	2011	Sweet potato: landraces	192
Kenya Plant Health Inspectorate Service (KEPHIS)	2007 and 2014	Sweet potato: released varieties, Naspot and Ejumula	20
North Carolina	2010	Sweet potato: released varieties – New Kawogo	1
National Resources Institute (NRI), UK	2014	Sweet potato: released varieties	1
Total			**214**

Source: Key informant survey, 2016

Annex 7: Benefits of PGR and technology exchange for breeding programmes

Technology	Year	Provided by	Provided to	Agreement	Comment
Tissue culture	1996	NARO and parental tissue culture labs	Farmers	Sold	
Corm paring	2000	NARO	Farmers	Free	
Kabana 1 and 2	2000	FHIA-NARO collaborator	Kawanda	Collaborative	
Kabana 3 and 4	2000	FHIA-NARO collaborator	Kawanda	Collaborative	
Kabana 5H	2000-2002	Bioversity ITC (Belgium)	Kawanda	Collaborative	
Integrated pest management (IPM) against bacterial wilt	2002	NARO	Farmers	Free	
Kabana 6H	2010	NARO	Farmers	Free	
Kabana 7H	2013	NARO	Farmers	Free	
Genes for Sigatoka resistance in banana	2006	Katholieke University, Leuven		Agreement	
Genes for resistance to banana weevils	2008	University of Leads		MoU	Still under evaluation
Genes for resistance to banana weevil	2008	University of Pretoria		Agreement	Under evaluation
Genes for nematodes resistance	2008	University of California San Diego		Agreement	Under evaluation
Genes for Vitamin A, Iron bio-fortification in bananas	2008	Queensland University of Technology		Agreement	In use
Genes for shortened maturity rate	2008	University of Ghent		Agreement	Gene only enhanced root development but not overall plant development
Genes for nematode resistance and delayed	2009	Rahan Meristem Ltd.		Agreement	Under research

Technology	Year	Provided by	Provided to	Agreement	Comment
ripening of bananas					
Gene silencing tech for Sigatoka, Fusarium and banana weevil	2010	Venganza Inc., North Carolina		Agreement	Under evaluation
Gene for bacterial wilt of bananas	2010	Academia Sinica – Taiwan		Agreement	Field efficacy moving towards variety release
Marker resistance selection of bean diseases – Angular leaf spot (ALS)	2009	CIAT		Agreement	Good
Biological control of ALS in Beans	2010	CIAT		Agreement	Good, still in use and displayed to famers
Tools for protocol for bananas tissue culture and coffee tissue culture	2000		Private sector	Agreement	Good
Transformation tools for protocols	2011		NACCRI	Agreement	Good, in progress

Source: Key informant survey, 2016

Annex 8: Released varieties of bananas in Uganda and their pedigrees

No.	Name of genotype	Released	Year of release	Type of material (hybrid/ landrace/ selection)	Source or breeding programme	Organization/ project undertaking the release of the variety	Year of introduction to Uganda	Year of on-farm evaluation	Pedigree
1	Kabana 1 (FHIA-1)	Yes	2000	Hybrid aaab	FHIA	NARO-NBRP	1990	1991	Dwarf Prata x SH 3142
2	Kabana 2 (FHIA -3)	Yes	2000	Hybrid aaab	FHIA	NARO-NBRP	1990	1991	
3	Kabana 3 (FHIA -17)	Yes	2004	Hybrid aaab	FHIA	NARO-NBRP	1990	1991	Gross Michel x SH 3362 Highgate
4	Kabana 4 (FHIA -23)	Yes	2004	Hybrid aaaa	FHIA	NARO-NBRP	1990	1991	Gross Michel x SH 3362 Highgate
5	Kabana 5 (Yangambi Km5)	Yes	2004	Land race aaa	ITC	NARO-NBRP	1990	1991	Primitive wild local
6	Kabana 6h (M9)	Yes	2010	Hybrid aaa	NBRP-NARO	NARO-NBRP	NA	2005	1201K-1 X SH 3217 (Nakawere x Calcutta 4)
7	M2	No		Hybrid aaa	NBRP	NARO-NBRP	NA	2005	917-2 x 8075-7
8	M17	No		Hybrid aaa	NBRP/IITA	NARO-NBRP	NA	2005	401K-1 x 9128-3
9	M14	No		Hybrid aaa	NBRP/IITA	NARO-NBRP	NA	2005	917K-2 x SH 3217
10	FHIA -25	No		Hybrid aaaa	FHIA	NARO-NBRP	1990	1991	SH 3648 X SH 3142

No.	Name of genotype	Released	Year of release	Type of material (hybrid/ landrace/ selection)	Source or breeding programme	Organization/ project undertaking the release of the variety	Year of introduction to Uganda	Year of on-farm evaluation	Pedigree
11	Williams	No		Hybrid AAA	ITC	NARO-NBRP	1990	1991	Dwarf Cavendish mutant
12	CRBP-39	No		Hybrid AAAB	IITA	NARO-NBRP	2002	2003	French Clair x M 53 (4)
13	Pisang Ceylan	No		Hybrid AA	ITC	NARO-NBRP	2002	2003	Primitive wild local
14	FHIA -21	No		Hybrid AAAA	FHIA	NARO-NBRP	2002	2003	AVP-67 x SH 3142
15	FHIA -18	No		Hybrid AAAA	FHIA	NARO-NBRP	2002	2003	Prata x Ana x SH 3142
16	660-K	No		Hybrid AAAA	NBRP	NARO-NBRP	2002	2003	TMH x 660-1 and TMH 917K-2
17	SH-3439-9	No		Hybrid AAAA	ITC	NARO-NBRP	2002	2003	Soma clonal variant of SH 3436 (Highgate x SH 3142)
18	Buro Cemsa	No		Hybrid ABB	ITC	NARO-NBRP	2002	2003	Bluggoe sub-group
19	Saba	No		Hybrid ABB	ITC	NARO-NBRP	2002	2003	Bluggoe sub-group
20	SH-3640	No		Hybrid AAAB	ITC	NARO-NBRP	2002	2003	Dwarf Prata x SH 3393
21	GCTC-119	No		Hybrid AA	ITC	NARO-NBRP	2002	2003	Giant tissue culture variant 119

No.	Name of genotype	Released	Year of release	Type of material (hybrid/ landrace/ selection)	Source or breeding programme	Organization/ project undertaking the release of the variety	Year of introduction to Uganda	Year of on-farm evaluation	Pedigree
22	TMPX 5511/2 (PITA 3)	No		Hybrid AAAB	IITA	IITA/NBRP	1995	1995/6	Obino l'Ewai x Calcutta 4
23	TMPX 548/9 (PITA 2)	No		Hybrid AAAB	IITA	IITA/NBRP	1995	1995/6	Obino l'Ewai x Calcutta 4
24	TMBX 1378 (BITA 2)	No		Hybrid AAAB	IITA	IITA/NBRP	1996	1998	Fougamou x Balbisiana
25	TMBX 15108-6 (BITA 16)	No		Hybrid AAAB	IITA	IITA/NBRP	1998	1999	TMP x 4479-1 X SH 3362
26	TMBX 5295-1 (BITA 3)	No		Hybrid AAAB	IITA	IITA/NBRP	1996	1998	Laknau x Tjau Lagada
27	TMPX 7152-1 (PITA 14)	No		Hybrid AAAB	IITA	IITA/NBRP	1996	1998	Obino l'Ewai x Calcutta 4
28	TMPX 582/4 (PITA 4)	No		Hybrid AAAB	IITA	IITA/NBRP	1995	1995/6	Obino l'Ewai x Calcutta 4
29	TMPX 548/4 (PITA 1)	No		Hybrid AAAB	IITA	IITA/NBRP	1995	1995/6	Obino l'Ewai x Calcutta 4
30	TMPX 7002-1 (PITA 8)	No		Hybrid AAAB	IITA	IITA/NBRP	1995	1995/6	Obino l'Ewai x Calcutta 4
31	TMPX 4479-1 (PITA 17)	No		Hybrid AAAB	IITA	IITA/NBRP	1995	1995/6	Bobby Tannap x Calcutta 4

Source: Bioversity International

Annex 9: Summary of selected reference sites

Site	District	Altitude (masl)			Rainfall			Soil	Farming characteristics
		Min	Avg	Max	Min	Avg	Max		
Kabwohe	Sheema	1100	1443	1600	800	1125	1400	Loamy sandy	Average amounts of rainfall with short dry spells; two growing seasons. The site has a community gene bank with a wide range of bean diversity
Hoima	Hoima	700	1120	1380	400	1000	1000	Loamy	Drier area with two planting seasons and warmer temperatures

Source: Authors' compilation