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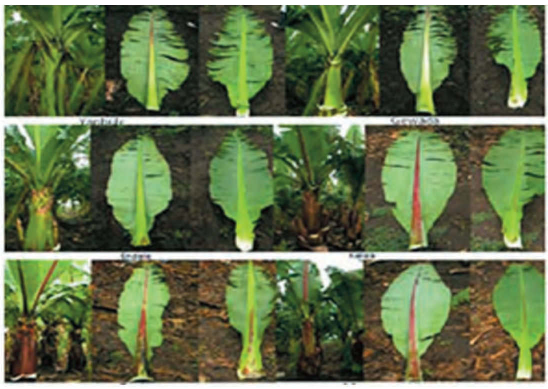
SEMI-ARID FOOD GRAIN RESEARCH AND DEVELOPMENT

AU-SAFGRAD

Climate Change and Agricultural Input Use in East Africa with Special Emphasis on Drought Tolerant Varieties:

Case Study of Ethiopia and Uganda



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List of Acronyms and Abbreviations

AMS	:	Africa Maize Stress Project
ARARI	:	Amhara Regional Agricultural Research Center
ASARECA	:	Association for Strengthening Agricultural Research in East and Central Africa
AU-SAFGRAD	:	African Union Semi-Arid Food Grain Research And Development
BARC	:	Bako Agricultural Research Center
CBO	:	Community Based Organization
CIMMYT	:	International Wheat and Maize Improvement Research Center
CSA	:	Central Statistical Authority (Ethiopia)
C3P	:	Crop Crisis Control Project
EAAFRO	:	East African Agriculture and Forestry Research Organization
EARRNET	:	Eastern Africa Root Crops Research Network
ECA	:	East and Central Africa
EIAR	:	Ethiopian Agricultural Research Institute
FAO	:	Food and Agricultural Organization of the United Nations
FEWSNET	:	Famine Early Warning System Network
ICIPE	:	International Center for Insect Physiology and Ecology
ICPAC	:	Intergovernmental Climate Prediction and Applications Centre
ICRISAT	:	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	:	International Food Policy Research Institute
IGAD	:	Inter-Governmental Authority on Development
IITA	:	International Institute for Tropical Agriculture

ILRI	:	International Livestock Research Institute
IPCC	:	Inter-Governmental Panel on Climate Change
MARC	:	Melkassa Agricultural Research Center
MFPED	:	Ministry of Finance, Planning and Economic Development
MOA	:	Ministry of Agriculture (Ethiopia)
MOARD	:	Ministry of Agriculture and Rural Development (Ethiopia)
MU	:	Mekelle University
NAADS	:	National Agricultural Advisory Services
NARO	:	National Agricultural Research Organization (Uganda)
NARS	:	National Agricultural Research Systems
NaSARRI	:	National Semi-Arid Research Institute (Uganda)
NEMA	:	National Environment Management Authority
NMSA	:	National Meteorological Service Agency
OARI	:	Oromia Regional Agricultural Research Center
PET	:	Potential-evapotranspiration
PRAPACE	:	Regional Potato and Sweet Potato Improvement Network in Eastern and Central Africa
SARC	:	Serere Agricultural Research Center
SARI	:	Southern Agricultural Research Institute
SSA	:	Sub Sahara Africa
TARI	:	Tigray Agricultural Research Institute
UBOS	:	Uganda Bureau of Statistics
UNDP	:	United Nations Development Program
USAID	:	United States International Development
WARC	:	Werer Agricultural Research Center
WFP	:	World Food Program

Acknowledgement

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Foreword

Recurring drought condition is a principal challenge of crop production in Africa drylands. Over the last few decades, the continent has suffered some major drought episodes, in particular, In the Horn of Africa. As a way of mitigating the adverse effect of the recurring dry spell, researchers have successfully developed varieties of major food crops that are drought tolerant or early maturing. Adopting these varieties for cultivation will not only increase crops yield but it will benefit farmers and consumers from increased income and lower food costs respectively. In terms of the transformation gains, the use of the varieties will go a long way in the institution of resilient livelihoods in the drylands of Africa for sustainable development the study on Climate Change and Agriculture inputs use in East Africa with Special emphasis on drought tolerant varieties, was conducted by African Union-SAFGRAD, a specialized technical office of The African Union Commission, in collaboration with GIZ. Ethiopia and Uganda were selected as case studies due to the relatively developed and the population of stakeholders in the agricultural sector compared to other countries in the horn of Africa.

Against the backdrop of high climatic variability, the quality of agricultural input use in modern agriculture is key determinant of households' and national development fortune. It is my sincere hope that the findings of this study will not only contribute to the knowledge pool of inputs use in modern agriculture, but will also facilitate the adoption of climate smart agriculture through use of resistant varieties. The practical value is in increasing the awareness of available agricultural technologies to mitigate climate variability in the drylands in the sub-Sahara region of Africa.

Dr. Ahmed Elmekass

Coordinator, AU-SAFGRAD

Executive Summary

The effects of climate change such as rising temperatures and changes in precipitation are undeniably clear with impacts already affecting ecosystems, biodiversity and people. In both developed and developing countries, climate impacts are reverberating through the economy. One region of the world where the effects of climate change are particularly heavy is Africa. Due to the lack of economic development, and institutional capacity, African countries are likely among the most vulnerable to the impacts of climate change. The long-term impact of climate change on food security and environmental sustainability are continuously gaining attention in Sub-Saharan Africa, because there is a strong link between climate variables and livelihoods. East Africa depends heavily on rain-fed agriculture making rural livelihoods and food security highly vulnerable to climate variability such as shifts in growing season conditions.

The main purpose of this assessment study was to develop a better understanding of the current status of climate change impacts on one of the most vulnerable parts of Africa, East Africa, taking Ethiopia and Uganda as case study and assess how these countries are trying to cope with the problem through wider use of drought tolerant/resistant crop varieties. The specific objectives were:1. assess the impact of climate change on agricultural input use in the region, particularly Ethiopia and Uganda; and 2. identify and analyze the contribution of improved drought tolerant crop varieties in the context of climate change. The findings have un-equivocally shown that climate change is indeed causing considerable impact on agriculture and other economic sectors of the countries in East Africa, specially Ethiopia and Uganda. Climate predictions demonstrated the likelihood of increased temperatures (> 1°C between 2000 and 2050), greater uncertainties in the amount, duration and distribution of rainfall in Ethiopia and Uganda in the years ahead; where in most of the places, on average 50 – 100 mm reduction in total rainfall is predicted. Evidences indicate that more than the amount, the anticipated huge variability in distribution and duration of rainfall will potentially have far reaching consequences on agricultural production and livelihoods.

The study further revealed Climate change is demanding whole review of agricultural input use in the small scale, subsistence farming dominated agriculture of East Africa. Farmers are changing their farming practices in an effort to minimize the impact of the recurring frequent droughts and irregular weather patterns. On the other hand, research and development agencies are responding by developing and promoting drought tolerant crop cultivars and integrated approaches involving moisture conservation and water harvesting. As the central component of the integrated and holistic interventions being promoted in the region drought tolerant/resistant crop varieties are receiving due emphasis in the region. Over the years, the National Agricultural Research Systems (NARS) have developed, released and promoted outstanding cereal crop varieties including sorghum, maize, rice, wheat, barley, tef (Ethiopia); legumes - mungbean, cowpea, pigeon pea, common bean varieties; oil seeds such as sesame, safflower, groundnuts; and roots and tubers – cassava and sweet potato. There are also certain crops that are peculiar to a specific country such as the enset (false banana) in Ethiopia. The tuber is the edible part in this crop, and with limited moisture.The crop produces substantial biomass which can stay in the farm field without being spoiled to sustain families and see them through difficult times, and it is nick named “hunger averter” in parts of southern Ethiopia. During the study, it was learned that the production of the climate resilient root and tuber crops (e.g. cassava, sweet potato, enset) will trend upwards in the coming years as a climate change mitigation strategy. Such crops coupled with appropriate cultural and agronomic practices are believed to help sustain production during the increasingly unreliable climatic conditions.As part of an integrated approach moisture harvesting and conservation measuresare also being promoted and these include - tied ridges, farm pond and Zai pits. These methods allow conserving and harvesting the occasionally occurring torrential rains to sustaincrops.

In conclusion the study proposes few fundamental approaches to be implemented as effective climate change adaptation strategy, including:

- Increased use of drought tolerant varieties i.e. shifting to cultivation of crops that are more tolerant to drought or early maturing

- Promoting crop diversification - integration of different varieties of crops, both food and cash crops. Crop diversification in a subsistence farming system provides an alternative means of income generation for smallholder farmers, the majority of whom are vulnerable to climate change.
- Implementing integrated drought management methods involving drought tolerant varieties, and a combination of cultural practices and effective water conservation methods.
- Implementation of comprehensive policies e.g. mainstreaming climate change in sectorial plans, aligning seed trade policies within the East African region and beyond to facilitate trade and exchange of seeds. The key areas that deserve focus within the seed sector include variety evaluation, release and registration; seed certification; phytosanitary regulations; plant variety protection and seed laws and regulations (import and export).

Climate change predictions for East Africa point to decreased rainfall and a rise in temperatures. Rainfall is also predicted to be more erratic and violent, further disrupting predominantly rain-fed agricultural production systems in the region. The predicted future climate will affect the productive infrastructure and exacerbate the constraints on the other livelihood systems. The climate change consequences of this state of affairs are adverse in the sense that east Africa still has a large number of poor people dependent on agriculture with poverty constrained climate change adaptation, resilience and mitigation options.

Introduction

1. Climate change impact on African agriculture

The effects of climate change such as rising temperatures and changes in precipitation are undeniably clear with impacts already affecting ecosystems, biodiversity and people. In both developed and developing countries, climate impacts are reverberating through the economy, from threatening water availability and to causing extreme weather impacts. In some countries, climate impacts affect the ecosystem services that communities are largely dependent upon, threatening development and economic stability. Future impacts are projected to worsen as the temperature continues to rise and as precipitation becomes more unpredictable.

One region of the world where the effects of climate change are being felt particularly hard is Africa. Because of the lack of economic, development, and institutional capacity; African countries are likely among the most vulnerable to the impacts of climate change (IPCC, 2001). Climate change impacts have the potential to undermine and even, undo progress made in improving the socio-economic well-being of Africans. The negative impacts associated with climate change are also compounded by many factors, including widespread poverty, human diseases, and high population density, which is estimated to double the demand for food, water, and livestock forage within the next 30 years (Davidson et al., 2003).New studies re-confirmed that Africa is one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptive capacity (IPCC, 2007). And agricultural production – including access to food – in many African countries and regions is already being severely affected. The Fourth Assessment Report of the IPCC highlighted the vulnerability of African agriculture and all who depend on it for food security and livelihoods (IPCC, 2007). Agriculture will be affected by reduced growing seasons and higher temperatures. The IPCC study (IPCC, 2007) predicted that rain-fed crop yields in some countries will decrease by as much as 50 percent by 2020. With only about 6 percent of African crop lands irrigated, the impacts on smallholders could be catastrophic. According to FAO (2007), agricultural production and the biophysical, political and social systems that determine food security in Africa are expected to be placed under considerable additional stress by climate change. It is anticipated that adverse impacts on agriculture sector will exacerbate the incidence of rural poverty (Dinar et al. 2008). Studies show that many are already being affected in the continent because temperature has increased and precipitation has decreased in some areas. For example, from 1996 to 2003, there has been a decline in rainfall in the range of 50-150 mm per season (March to May) and corresponding decline in long-cycle crops (e.g., slowly maturing varieties of sorghum and maize) (Funk et al., 2005). Long-cycle crops depend upon rain during the typically wet season and progressive moisture deficit results in low crop yields, thereby impacting the available food supply. Increased variability (i.e., deviation from the mean) of crop production is also a major concern of farmers in Africa (Patt et al., 2005). For example, a glance at Fig. 1 below generated by IFPRI (Bashaasha et al., 2011) using global circulation model shows that the variable impacts of climate change on rainfall patterns across regions, clearly indicating that many of the countries will get drier with time. Given the fact these areas are already moisture deficient, additional reduction could have a huge impact on agriculture and related activities. Similarly, Fig. 2,demonstrates the predictions of very high temperature increases for most of Africa. The models predict greater than 1 0C and in the worst of cases above 2-3 0C again for much of Africa and these is expected to trigger a chain effect on local climate and agriculture. Further climate studies also reconfirm that the continent will most likely become more arid with time. Aridity across Africa is projected to increase strongly, mainly driven by temperature increases that raise the evapotranspiration “demand” of plants, not compensated by a sufficient increase in precipitation, or even amplified by a projected decline in precipitation (Schellnhuber et al., 2013).

2. Climate change impact on East African agriculture

The long-term impact of climate change on food security and environmental sustainability are continuously gaining attention, particularly in Sub-Saharan Africa (Maccarthy and Vlek, 2012). In this region, agriculture accounts for about 32% of the GDP, and therefore increasing agricultural productivity remains top priority. However, the high hopes for achieving food security in the region have

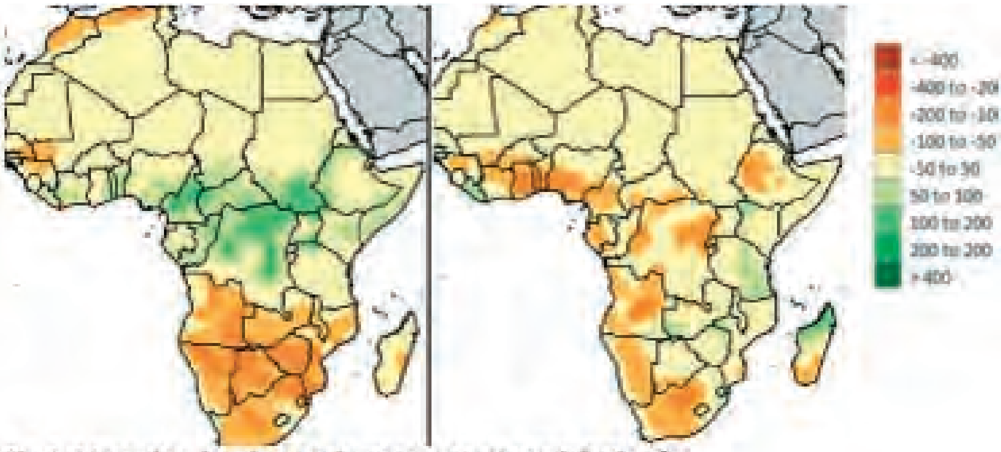


Fig. 1: Maps showing changes in mean annual precipitation for Sub-Saharan Africa between 2000 and 2050
Source: IFPRI as cited by Bashaasha et al., 2011

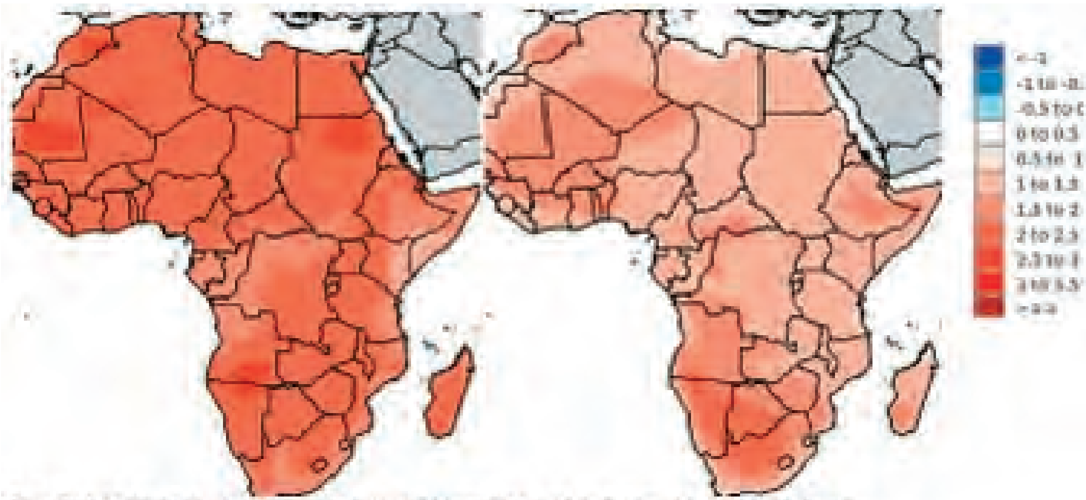


Fig. 2: Maps showing changes in normal annual maximum temperature for Sub-Saharan Africa between 2000 and 2050
Source: IFPRI as cited by Bashaasha et al., 2011

become even more elusive than ever before because of climate change. The climate change impact is exacerbated by many other factors that are prevalent in this part of the world, including the current low levels of agricultural productivity due to agronomic, environmental, institutional, social and economic factors; and low input use, including total fertilizer input.

There is a strong link between climate change and East African livelihoods. East Africa depends heavily on rain-fed agriculture making rural livelihoods and food security highly vulnerable to climate variability such as shifts in growing season conditions (IPCC, 2001). East African rainfall is bimodal but is characterized by uncertainty both in spatial and temporal relations. The 1998 El Niño produced an estimated five-fold increase in rainfall (Galvin et al., 2001). On the other hand, 1997 was a drought year, and the 1999 drought was estimated to be one of the worst on record (WFP, 2000). Climate analyses results further suggest that there will be highly differential impacts of climate change in East Africa to the middle of the twenty-first century (Thomton et al. 2002). Parts of East Africa will become drier, with considerable reduction in the length of the growing season. Such changes surely will make fundamental changes to ecosystem structure and function. These in turn will affect human land-use and livelihoods and have the potential to make these populations more vulnerable. Crop production in SSA is based on rain-fed agriculture and largely at a subsistence level. Hence, deterioration in weather patterns, particularly rainfall amounts and distribution, could be devastating to food production. Furthermore, research on a range of crops has unequivocally shown how rising temperatures and rising carbon dioxide (CO2) levels due to climate change could change production dynamics and crop yields. Yields of grains and other crops could decrease substantially and some crops (e.g. maize) could be discontinued in some areas. A report by the International Food Policy Research Institute (IFPRI) warns that unchecked climate change will have major negative effects on agricultural productivity, with yield declines for the most important crops and additional price increases for the staples (Nelson et al., 2009). As a consequence of these impacts, climate change is likely to further entrench food insecurity. Therefore, climate change mitigation strategies have to be developed and widely promoted to avoid the devastating long term impacts of the phenomenon. Thus, this study was proposed to analyze the level of input use with special emphasis to drought resistant crops, and assess measures put in place to sustain and enhance agricultural productivity and avert the negative impacts of climate variability. Developing a very good understanding of existing drought resistant crops can lead to broadening the knowledge on source of variability in crops and provide genetic material that could be used to breed cultivated crops with improved vigor and yield and environmental resilience.

Objectives

- To assess the impact of climate change on agricultural input use in East Africa considering Ethiopia and Uganda as case studies
- To identify and analyze the contribution of improved drought tolerant crop varieties in the context of climate change

Purpose, Scope and Methodology

The main purpose of this assessment is to develop a better understanding of the current status of the impact of climate change on one of the most vulnerable parts of Africa, East Africa, taking Ethiopia and Uganda as case study and assess how these countries are trying to cope with the problem through for e.g.wider use of drought tolerant/resistant crop varieties. These two countries face different rate of drought incidence and aridity problems and thus vulnerability to climate change related consequences. In other words they represent different case scenarios and category of vulnerability to climate change. Ethiopia is a highly populated (over 80 million) country with over 66% of its land exposed to drought and degradation. Uganda, a less populated country, with fairly intact agro-ecologies but, yet, facing a growing threat from increased frequency of drought incidences and climate irregularities. It is believed that by analyzing the situation in these two countries, representing varying case scenarios a fairly complete picture of the impact of climate change in the region can be generated.

During the study attempts were made to learn about best bet practices that can be shared and scaled up in other countries to fight the scourge of climate change in the region. As stated above the scope of the study was limited to conducting a detailed investigation of the two countries in East Africa and review the impact of climate change on agriculture thus far. To achieve this, the study reviewed currently used crop varieties, to assure food security, and their nutrient, water, climatic and agronomic management requirements; and their adaptation potential to prevailing climatic patterns wasalso, carefully analyzed and synthesized. Different methods were used to collect data and information, including: 1. Extensive consultation and review of existing literature (printed and electronic) and all available secondary data. 2. Discussions with key scientists, experts and R & D managers (individually and in group) in relevant research and development institutions (Governmental and Non Governmental Organizations). 3. Further information were collected through personal observation during visits to research and farm fields, and targeted exchange of views with farmers. 4. Formal (questionnaire) and informal interview methods were employed to ensure focused discussions. Attempt was made to cover the whole East Africa region with the study but more in depth investigation was undertaken in the two selected countries, significant parts of which fall within the dry lands category. Quite a number of regional and global research and development institutions including CIMMYT, ICRISAT and ASARECA which have their headquarters in these countries were visited, and those organizations served as very good source of relevant data and information.

During the study period particular attention was given to assessing among others:

- Important crops and varieties primarily cultivated in arid and semi-arid areas and their peculiar attributes, and adaptation potential to varying climate and drought.
- The nutrient, water, soil and climatic requirements of those crops and varieties
- Information on the economic use of inputs (chemical and organic) for enhancing productivity, with special emphasis to those crops and varieties
- Production constraints (biotic and abiotic) and the response of those crops and varieties to those stresses
- Agricultural best practices implemented to combat drought and climate variability

Case Studies

1. Ethiopia

1.1. Background

Ethiopia is situated in the Horn of Africa between 3-150 North latitude 33-480East longitude, and covers a total surface area of 1.113 million km^2 (CSA, 2002). The agricultural sector, which is dominated by small-scale, subsistencefarming, forms the foundation of the national economy andconstitutes the primary source of livelihood for the overwhelming majority of the population. The sector employs more than 80 percent of the labor force and contributes 45 percent toGDP and 85 percent of total export revenues (CSA, 2004). Ethiopian agriculture is almost,exclusively, dependent on rainfall, given that irrigated agriculture accounts for less than 1 percent of the country's total cultivated land.Thus, the amount and temporal distribution of rainfall and otherclimatic factors are key determinants of crop yields and food security situation.

Ethiopia is susceptible to frequent climate extremes such as disastrous droughts and floods. These disastrous climatic events, which have caused significant adverse effects on the country's economy and society, are expected to become more pronounced in the future because of climate change. Climate extremes have already significantly affected economic development in the country in the past. During the coming decades, climate conditions are expected to worsen, rendering Ethiopia's population particularly vulnerable.

A vulnerability and poverty mapping exercise on climate change revealed that, Ethiopia is one ofthe most vulnerable countries given its low adaptive capacity (Deressa, 2006).The study investigated vulnerability to climate change as the net effect of sensitivity, exposure, and adaptive capacity and indicated that certain regions in the country will be more vulnerable than others. Furthermore, vulnerability was attributed to the low level of rural service provision and infrastructure development; and also to frequencies of droughts and floods, lower access to technology, fewer institutions, and lack of infrastructure. Lower vulnerability of some of the regions was associated with relatively greater access to technology and markets, larger irrigation potential, and higher literacy rate.

Like in much of Africa, climate change impacts are already being felt in Ethiopia. Temperature has become warmer over the past century. According to the UNDP Climate Change Profile for Ethiopia (Oxford, 2008), the mean annual temperature in Ethiopia has increased by 1.3°C between 1960 and 2006, at an average rate of 0.28°C per decade. More recent predictions (MARC, 2011) show the likelihood of increased temperatures

Fig. 3 - Predictions showing rising temperatures due to climate change (left-T Max, Right-T ***Source :*** *MARC (2011)*

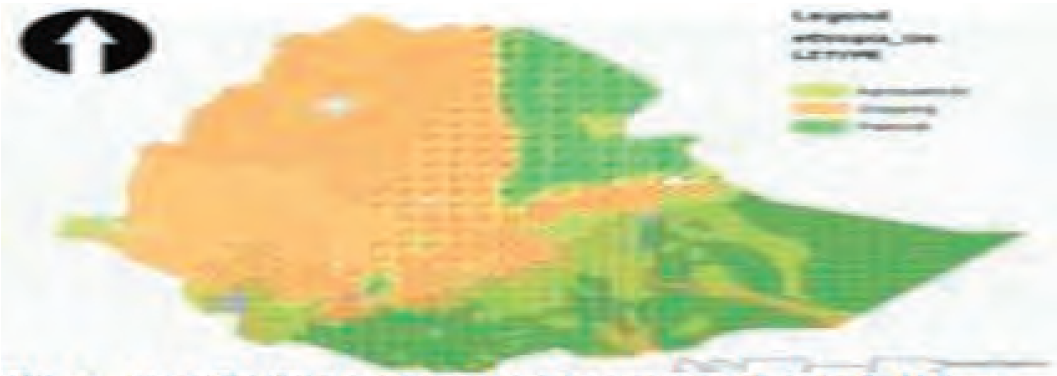


Fig. 4 - Predictions showing in increased rainfall but hugely varying distribution and duration
Source : *MARC (2011)*

due to climatic influences (Fig. 3). Similarly, this source further revealed the total amount of rainfall received may increase but the distribution and duration is going to be seriously affected (Fig. 4).

Reports by IGAD/ICPAC (2007) indicated that the recent trends in Ethiopia show that climate change has already put pressure on the Ethiopian livelihoods. The natural resource base has been depleted due to intensive human interference,mismanagement and utilization without proper precautions; causing deforestation, degradation of arable lands through soil erosion and loss of fertile soils. The pasture lands and wetlands have been diminished due to human interventions being accelerated by climate change (Kidane et al, 2010; Dawit and Habtamu, 2011). During the last four decades, observed climate change related impacts in Ethiopia included drought, floods, heavy rains, strong winds, frosts, high temperature (heat waves), lightening and siltation (Kidane, et, al. 2010). The climatic hazard particularly, drought and flood occurrence has increased both in frequency and intensity in recent years. The country has suffered recurrent droughts of varying intensities in the past. Droughts of 1992, 1994, 2000 and 2003 in particular, which have caused loss of millions of lives, are recent memories. The challenges with diminishing water resources have been aggravated by ensuing climate change, with serious implications on socio-economic development. Water resources are fast declining due to prolonged drought, shrinking of lakes and drying of rivers and wetlands and sinking water tablesare believed to be the impacts of climate change (Kidane et al, 2010).

Arecent study which analyzed the potential challenges that climate change presents to Ethiopia's economy considering the influence of three major factors—water constraints, flood losses, and CO2 fertilization—showed that the major impact of climate change on the economy is shown to be related to more frequent extreme hydrologic events, which cause losses in both the agricultural and nonagricultural sectors (IFPRI, 2010). The impact on agriculture particularly is a source of major concern for an agrarian country like Ethiopia. Information generated using crop modeling on six crops in rain-fed and irrigated systems under current and predicted temperature and precipitation regimes suggested substantial reduction in wheat yields presumably owing to heat stress. The results further revealed that substantial maize land will be marginalized and be completely unsuitable for crop production (Habtamu et al., 2012).

Generally, the part of Ethiopia that is going to suffer the brunt of climate change and climate variability will be the dry arid and semiarid area which covers over 66% of the total landmass of the country (NRMRD MoA, 1998). Ecologically arid, semi-arid and dry sub-humid parts of the country are the most vulnerable to drought (Dawit and Habtamu, 2011).Those areas often receive low and poorly distributed rainfall, which adversely affects crops production. And, at times the rainfall is torrential, erratic, variable, and unreliable in nature. In the typical semi-arid areas the long-term annual average rainfall ranges from 50 mm to more than 800 mm, with high coefficient of variability (usually > 30%) with regard to quantum, onset and cessation of rainfall. In addition, the rainfall is so unpredictable that water stress can occur at any time during the life cycle of the crop (Hailu and Kidane, 1991). There is also high annual evapotranspiration rates ranging from 1400 to 2900 mm, owing to high temperature, normally > 25oC. Monthly potential-evapotranspiration (PET) rates usually exceed rainfall in most parts of the dryland areas except during the peak rainy season months of July and August. Thus, the atmospheric demand for water in the dry areas is high. The water holding capacity of soils in these areas is generally low because soils are often shallow in depth and mostly light textured with low organic matter content. These conditions generally lead to short growing periods. As a result, the length of the growing period is generally of short duration, ranging from 1-60 and 60-120 days (NRMRD MoA, 1998). The dry arid and semi-arid areas are mainly found in the north, eastern, the central, south and southeastern parts of the country (Fig.5).

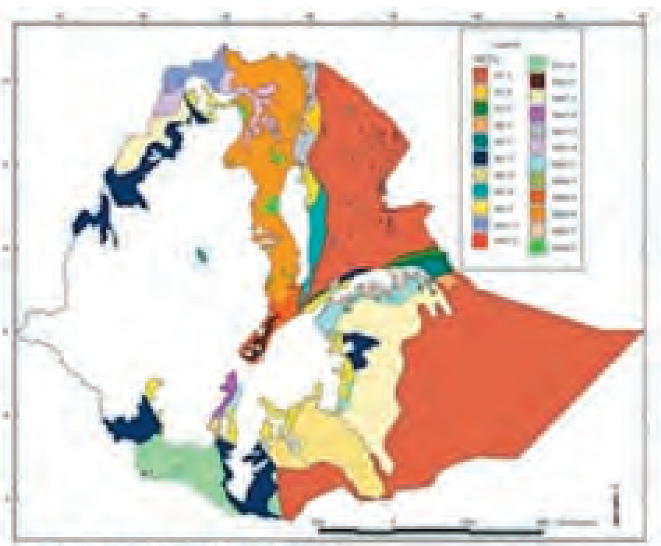


Fig. 5 - Dry and zones of Ethiopia
Source : *NRMRD MCA (1995)*

1.2. Climate change impact on input use in Ethiopia

Climate change is demanding whole review of agricultural input use both biological performance and cost effectiveness especially in developing regions dominated by small scale, subsistence agriculture. This trend is particularly happening in the dryland areas where response of crop varieties to fertilizer application is largely dependent on availability of sufficient soil moisture. One of the limited researches done in those areas investigated the economics of maize production and the profitability of new varieties and management practices over existing practices (local varieties, and farmer's practices) in the Rift Valley (Bedru et al, 2009). Maize production input costs were used for economic profitability analysis in the study. The results indicated that growing the improved maize variety,Melkassa-2 was more profitable under the prevailing conditions. This suggested that farmers can earn more income by investing on the improved maize packages i.e. use of improved maize varieties, appropriate fertilizer application and other management practices in the Rift Valley area, prone to drought and weather irregularities. And, the study concluded that moisture conservation practices have to be employed as part of the integrated package for maximum effectiveness.Other field studies from southern Ethiopia indicated that farmers were very keen on fertilizer use, but not at the recommended rates. The high recommended rates were considered no longer effective by farmers under the prevailing environmental conditions, prompting them to opt for lower amount, spot application of fertilizers.Such tendencies were also observed in other parts of the country (Croppendstedt and Mamo, 1996).

The major feature of dryland areas is that they are areas with low and unevenly distributed rainfall, which adversely affects crop growth.In the dryland areas of Ethiopia, poor distribution of rainfall is the most serious determining factor than the amount. Moisture stress can occur at any time during the crop growth period and this is being exacerbated by the effect of climate change. Thus, to improve and sustain productivity in these fragile environments emphasis must be given to generating technologies that would help address the overriding constraint of low moisture stress. Therefore, the primary strategy for improving agricultural production in the dryland areas should focus in developing early maturing crop varieties that could match the length of growth period, integrated with water conservation and harvesting techniques to enable efficient use of the limited available water. Information regarding the water requirements of early maturing varieties thus far is lacking, however, the improved crop varieties seemed to perform relatively well compared to the traditional varieties. This has been particularly true for sorghum, maize, wheat and barley. The early and extra early varieties of tef (*Eragrostis tef*) and haricot bean mature well before water stress occurs during the growing season. Sesame, mung bean and cowpea are very well adapted to the dryland areas of Ethiopia, and under rainfed conditions their water requirements is known to be low and are able to mature and yield earlier than other crops.

Limited attempts have been made to study the impact of climate change on Ethiopian agriculture (NMSA, 2001). The very few research efforts so far done, unequivocally, demonstrate that climate change is influencing farmers' decisions on input use in their attempt to mitigate the damaging effect of the phenomenon. A recent study by Habtamu et al., 2012 revealed that in response to perceived long-term changes, farmersimplement a number of adaptation measures, includingchanging crop varieties, adopting soil and water conservationmeasures, harvesting water, planting trees, and changing planting and harvesting periods. Further studies confirmed that adaptation measuressubstantially mitigated the effect of climate change on crop yields. As expected, the integrated use of improved seeds, fertilizers, especially animal manure,and additional labor tended to increase food production, although significant differences in yields were observed across agro-ecological zones. The results of the study indicate that farmers' decisions to adopt yield-enhancing adaptation strategies are influenced by informaland formal institutional support, the availability of information on future climate changes, the amount of rainfall, and the agro-ecological setting, as well as household specific characteristics of size and age and literacy levels of thehousehold head.

The professionals who responded to the questionnaire distributed as part of the study have all agreed that crop calendar in the dry land, climate change prone areas has been in continuous change due to variability in onset and secession of rainfall period. One respondent informed that in 2013 all the farmers in the northwest, traditional sesame belt of Ethiopia were forced to shift to sorghum due to late onset of rainfall, and this is becoming a rather frequent occurrence in the area. On the other hand experts from the southern region stressed, the bimodal rainfall system which allowed the cultivation of long season and productive varieties is becoming less dependable, prompting farmers to increase their demand for short cycle varieties or heat and drought tolerant roots and tubers such as taro, cassava and sweet potato. Unfortunately, according to the respondents, available drought tolerant varieties often lack some of the good traits valued by farmers as they are low yielders with short stalk and some of them lack desirable culinary quality. The majority of the experts consulted confirmed that increasing number of farmers are considering inorganic fertilizer use as a risky venture, due to recurring moisture stress, even though they are aware that this trend could negatively impact productivity.

The above reviews clearly demonstrate that achieving food security in the face of the impending climate change might become a major challenge in Ethiopia, and the promotion of adaptation strategies including integrated package of technologies involving drought tolerant crop varieties as the most feasible option for the small scale farming should be given priority consideration.

1.3. Drought tolerant/resistant crops/varieties

Ethiopia is the center of origin and diversity of many cultivated crops. It is a very important center of genetic diversity and Vavilov classified Ethiopia as one of the 12 genetic centers. It is the sole or the most important center for Arabica coffee (*Coffee arabica*), tef (*Eragrostis tef*), enset (*Enset ventricosum)* and anchote (*Coccinia abyssinica*). It is also the center of diversity for noug (*Guizotia abyssinca*) and Ethiopian rape (*Brassica carinata*). It is one of the main centers of diversity for sorghum, finger millet, field peas, chickpea, cow pea, perennial cotton, safflower, castor bean, and sesame. Almost all of these crop species are grown in the dry arid and semi-arid areas of Ethiopia. But all this genetic wealth is seriously threatened by climate change and the recurrent and more frequentdrought occurrence, which is the manifestation of the phenomenon. A number of studies conducted over the recent past clearly reveal that climate changeis already an overriding issue to be reckoned with, and research and development institutions in the country are responding by developing and releasing drought tolerant or resistant crops and varieties. Considering the predominantly subsistence nature of the small scale farming system in sub Saharan Africa use of well adapted and resilient crop varieties can provide a more feasible option in countries like Ethiopia rich with wealth of diverse genetic resources.The major drought tolerant/resistant food crop varieties currently in use to mitigate the effect of climate change and the recurrent droughts and rainfall variability are described below.

1.3.1. Cereals

? **Sorghum**

Even though sorghum is produced in broad ecological range of 400 to 3000m.above sea level (Reddy and Kidane, 1993), it is known for its drought resistance and it is major staple crop and source of livelihood in the dry areas most affected by climate change and environmental vagaries. There are about twenty varieties released by research (Table 1, Fig. 6 and 7)but the major ones for the semi arid and arid zones are the following:

- Gambela-1107 (released in 1978), a variety with good emergence capacity, fit for sorghum production in the dryland areas. It has good seed quality, white seed with very good local bread making quality and is preferred by farmers. It fits well the moist semi-arid areas.

- Seredois released specifically for bird (Queleaquelea) resistance in the Rift Valley and similar areas. The seed quality is not good for bread making because of the sour taste due to its high tannin content. However, it is widely used for making local beverages.
- 76-T1-No 23 is very early maturing (60-70 days to anthesis) and fits well to the dry semi-arid areas with short growing period. It has good quality seed, white in color highlypreferred by consumers. It is widely adapted to many dry land agro ecologies.
- Meko-1 (released in 1998) is early drought resistant, white seed with acceptable bread making quality. Relatively tall with high biomass production. This variety fits well for dry semi-arid areas with short growing season.
- Gubiyeis an early drought resistant variety, with goodstriga resistance ability, white seeded with good bread making quality, relatively tall with substantial biomass production. This variety fits well for dry semi-arid areas with short growing season.
- Abshir is a more recently released variety with good potential yield (2.5-4.5 ha-1) and earliness. It is tall with good biomass production potential, also drought resistant, and it is specifically bred for striga resistance. It fits well areas with short growing period.

There are five, less known drought tolerant sorghum varieties namely Wediarba, Arfae'gedem, Megud, Korokora, and Chemureybeing grown as break or rotation crops in the sesame belt of northwestern Ethiopia. Those varieties are mostly of Sudanese origin and widely grown in the bordering parts of the two countries.

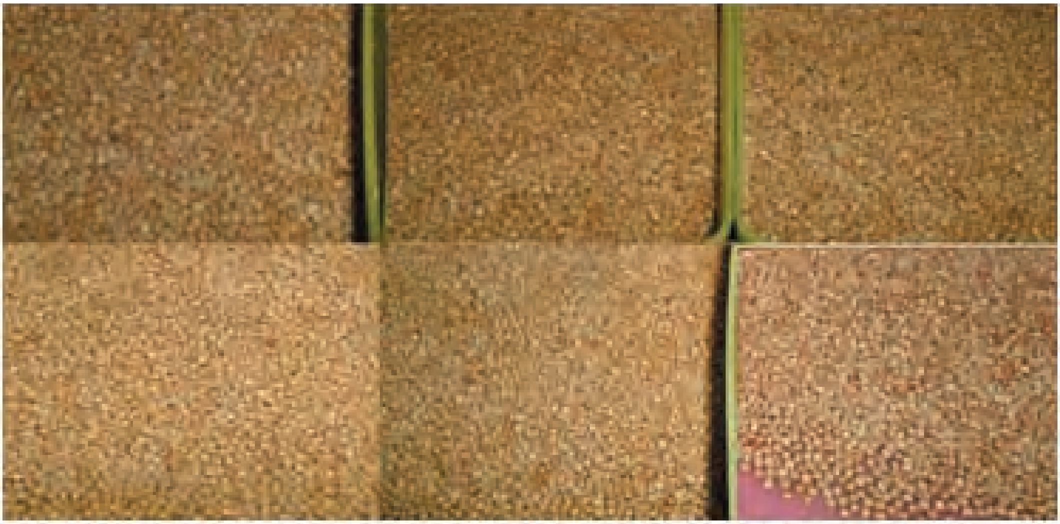


Fig. 6. Clockwise from top left: Gambella 1107, Melkam, Teshale, Abshir, Gobiye and 76 T1 N23
Source: MARC (2013)

Fig. 7. Clockwise from top left: Gobiye, Meko, Teshale, Abshir, 76 T1 N23 and Melkam
Source: MARC (2013)

Table 1: Improved Sorghum varieties released for moisture stress and in lowland areas

No.	Varieties	Year of release	Maturity Group/days	Days to flowering	Plant height (cm)	Yield (q/ha) Research	Farmer	Seed color	Releasing Center	Special merits
1	Gambella 1107	1976	Medium	80-90	150-200	30-50	25	White	Melkassa	
2	76T1# 23	1976	Early	60-70	120-140	25-45	17	White	Melkassa	
3	Seredo	1986	Early	65-75	110-140	20-40	17	Brown	Melkassa	Bird resistant
4	Meko-1	1998	Early	61-92	157-177	22-33	17	White	Melkassa	High grain quality
5	Teshale	2002	Early	65-76	170-210	26-52		White	Melkassa	
6	Abshir	2000	100-120	83	110-140	15-25			Melkassa	Striga resistant
7	Gobye	2000	100-120	80	110-140	19-27			Melkassa	Striga resistant
8	Macia	2007	113-130	55-60	135-150	42-44	23-30	White	Melkassa	Malt
9	Red Swazi	2007	Early/ 106-112	55-60	120-153	30-33	20-21	Red	Melkassa	Malt
10	Raya	2007	129	82	185.7	37.68	22.77	White	Sirinka	
11	Misikir	2007	126	76	123-191	40.73	37	White	Sirinka	
12	GIRANA-1	2007	122	75	135-305	40.86	38.7	White	Sirinka	
13	Yeju	2002	Early	68	172	50.9		White	Sirinka	
14	Birhan	2002	Early						Sirinka	Striga resistant
15	Abuare	2003	Early						Sirinka	
16	Hormat	2005	Early	71	161-171	23.3	16-22	White	Sirinka	Striga resistant
17	Gedo	2007	Early	75	116-138	34	27-36	white	Melkassa	
18	Melkam	2009	118	76-82	126-163	37-58	35-43	White	Melkassa	
*19	ESH-1 (Hybrid)	2009	118	71-78	160-243	50-55	35-45	White	Melkassa	Hybrid variety
*20	ESH-2 (Hybrid)	2009	120	61-75	150-192	42-60	35-43	White	Melkassa	Hybrid variety

Source: Crop variety registry, Ministry of Agriculture and Rural Development, Crop Development Department, 2002, 2003, 2005, 2007 and 2009 Ethiopian sorghum improvement project, Melkassa Agricultural Research, EIAR, 1976, 1998 and 2000. *Hybrid varieties

? Maize

Maize is one the major cereal crops grown in Ethiopia. It ranks first in total production and yield per hectare. It is well adapted to almost all agro-ecological zones of the country. Maize used to be a less accepted crop in the dry low lands of Ethiopia where drought and low and erratic rainfall are very common and the length of growing period rarely exceeds 80 – 100 days. But this seems to be changing over the recent past as number of short cycle, drought tolerant varieties are developed and promoted by R & D institutions. The consumption of green maize is growing rapidly across the country particularly amongst the urban poor, because of the rising prices of traditionally used cereals such as tef. An increasing number of urban poor population and farmer households gets by consuming green or processed maize, and the crop is considered hunger alleviating crop, providing food source before harvest of the other crops.

Recent breeding strategies have focused on early (70 to 90 day maturity period) and extra early (40 to 60 days maturity period). There has also been some innovative work on drought tolerance. There are 11 varieties including the Melkassa series varieties (Melkassa 2 through 7) (Fig. 8) developed for the dry climates (Dagne, Personal communication). There is also the extra early yellow endosperm maize, Melkassa 1, which has enjoyed wider acceptance in moisture stress areas (Fig. 9).Most of these varieties inherently have high moisture stress tolerance and escape capability because of the drought tolerant gene they contain. A more recent research effort has led to the development of more nutritionally enhanced versions of those varieties with high quality protein content (open pollinated Melkassa 1Q and 6Q, and hybrid - Melkassa 138Q). Gibe 1 and Gibe 2, released from Bako Research Center, which are drought tolerant, open pollinated varieties are also in wide use in moisture stress areas. A summary of the maize varieties with their altitudinal and rainfall requirements and agronomic characteristics is presented in Table 2 (cf. p. 16).

Fig.8. Recently Released drought tolerant varieties. From left to right: Melkassa 2,4,5 and 6. Source: MARC (2013)

Fig. 9.Melkassa 1.Drought tolerant maize variety.Source: Marc (2013)

Table 2: Improved Maize varieties released for moisture stressed agro-ecologies (Drought tolerant varieties)

Variety	Adaptation areas		Fertilizer use		Phenology			Crop pest reaction	Grain yield (t/ha)		Year of release	Rel. center
	Altitude (m.a.s.l)	Rainfall (mm)	P2O5 (kg/ha)	N (kg/ha)	Days to anthesis	Days to silking	Days to maturity		On-station	On-Farmer		
Melkasa 1	1000-1750	450-750	46	64	48	49	90	Resistant to rust and blight	3.0-4.5	2.5-3.5	2000	EIAR/ MARC
Melkasa-1Q	1000-1750	450-750	46	64	49	50	90	Resistant to rust and blight	3.0-4.5	2.5-3.5	2013	EIAR/ MARC
Melkasa-2	1200-1700	600-800	46	64	66	67	130	Resistant to rust and blight	5.5-6.5	4.5-5.0	2004	EIAR/ MARC
Melkasa-3	1200-1700	600-800	46	64	62	64	125	Resistant to rust and blight	5.0-6.0	4.5-5.0	2004	EIAR/ MARC
Melkasa-4	1000-1600	500-700	46	64	53	55	105	Resistant to rust and leaf blight	3.0-3.5	3.5-4.0	2006	EIAR/ MARC
Melkasa - V	1000-1700	600-800	46	64	60	62	125	Resistant to rust and leaf blight	3.5-4.5	3.0-3.5	2008	EIAR/ MARC
Melkasa 6Q	1000-1750	500-800	46	64	58	60	120	Resistant to rust and blight	4.5-5.5	3.0-4.0	2008	EIAR/ MARC
Melkasa 7	1000-1750	500-800	46	64	55	57	115	Resistant to rust and blight	4.5-5.5	3.0-4.0	2008	EIAR/ MARC

Table 2: *(continued)*

MHQ138	1000-1800	500-1000	46	64	71	72	140	Resistant to rust and blight	7.5-8.0	5.5-6.5	2012	EIAR/ MARC
MH130	1000-1750	500-800	46	64	64	65	120	Resistant to rust and blight	6.0-7.0	4.2-5.2	2012	EIAR/ MARC
MH140	1000-1800	500-1000	46	64	69	70	140	Resistant to rust and blight	8.0-9.0	6.0-7.0	2013	EIAR/ MARC
SC-403	1000-1750	500-800	46	64	67	68	130	Resistant to rust and blight	6.0-7.0	5.0-6.0	2012	Seedco

Source: Crop variety registry, Ministry of Agriculture and Rural development, Crop Development Department 2000, 2004, 2006, 2008, 2012 and 2013

* Maize improvement for moisture stress areas, Melkassa Agricultural Research Center (MARC), EIAR

? Millets

There are two types of millet, the pearl and finger millets widely cultivated in dryland regions of Ethiopia. Pearl millet is largely produced in the north east and the southern fringes of the country. The crop is highly tolerant to drought but very little research effort has gone into it, and there is only one variety (Kola-1) (Table 3. Fig. 10) officially released for production by the Ethiopian Institute of Agricultural Research. The variety is suitable for the dry lowlands but performs best in areas with 500 – 1600 meters elevation, 500 – 870 mm rainfall. The variety can mature within 80 – 85 days and produce 3.0 – 4.2 t ha-1 (MOARD, 2007). Finger millet is more widely used and cultivated compared to pearl millet in Ethiopia. There are two released varieties – Tadesse and Padet. Tadesse variety (Fig. 10 and 11), again released by the EIAR in the late 1990s shows considerable ecological elasticity and it is being grown successfully from the central highlands all the way to the southern dry lowlands of the country. The variety has multiple uses and it is drought tolerant and productive (2.8 t ha-1 under farmers condition, 3.1 t ha-1 under research). PADET is also a fairly productive variety (2.8 t ha-1 under farmers condition) and drought tolerant.

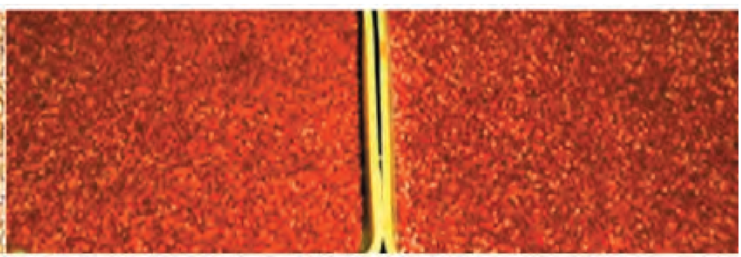


Fig.10. From left to right: Seed of Kolla1 (pearl millet) **Fig. 11.**Tadesse and PADET (Finger millet).

Source: MARC (2013)

Table 3. Improved pearl millet variety released for moisture stress and lowland areas

No.	Name of Varieties	Year of release	Altitude	Rainfall	Days to flowering	Days to maturity	Plant heigh t (cm)	Yield (ton/ha)		Relea-sing Center
								Research	Farmer	
1	Kola-1	2007	500-1600	500-870	55	80-85	182	3.0-4.2	2.2-3.0	MARC

Source: Crop Variety Registry, Ministry of Agriculture and Rural Development, Crop Development Department: 2007

? Tef

Tef is the major staple, indigenous cereal crop grown in Ethiopia and its production exceeds that of most other cereals. Every year, the area allocated for tef production is estimated to be 1.4 million hectares and the production could reach about 0.9 million tons of grain or about one quarter of Ethiopia's total cereal production.Tef is grown either as regular or as emergency crop. Normally, it is sown late and harvested during the dry season. Often, during dry seasons or late onset of rains the tef area increases, and this happens when the main coarse grain cereals, maize and sorghum, show signs of total failure and are replaced by tef as an emergency crop.Sixteen tefvarieties are developed and released by the research system (Table 4). However, the varieties most known for their earliness and drought tolerance are Tseday (DZ-Cr-37), a 30 year old variety but still very popular; and Bosset (DZ-Cr-409), a highly promising variety, released in 2012 (Fig. 12). These varieties are extra early, maturing in 46 to 60 days, fit for the increasingly unreliable weather patterns and short cropping cycle. The varieties are capable of producing a substantial crop output with a meager 300 – 500 mm of rainfall.What makes tef stand out as a most preferred crop by growers is the fact it is extremely resilient, being capable of withstanding a host of stress factors encountered in arid and semi-arid environments. Unlike other crops, the pests of tef are not many but could inflict substantial damage. These include Wello Bush Cricket, shoot-fly and weeds. Because of its low competitive behavior tef is particularly sensitive to weed competition, which often necessitates repeated weeding. The tiny seed also requires a fine seed bed, free of clods for optimum germination and emergence.


Fig.12. From left to right:Bosset and Tsedeytef varieties. Source: MARC (2013)

Table 4. Improved tef varieties released for moisture stressed areas

Variety name	Common name	Year of re-lease	Altitude (m.a.s.l)	Rainfall (mm)	Fertiliser		Days to heading	Days to mature	Plant height (cm)	Grain yield (ton /ha-1)		Breeder/ Maintainer
					P2O5 (kg/ha)	N (kg/ha)				On-station	On-farm	
DZ-01-99	Asgori	1970	1400-2400	300-700				80-130	53-100	2.2-2.8	1.8-2.2	DZARC /EIAR
DZ-01-354	Enatit	1970	1600-2400	300-700				85-100	53-115	2.4-3.2	2.0-2.4	DZARC/ EIAR
DZ-01-196	Magna	1978						80-113	50-117	1.8-2.4	1.6-2.0	DZARC/ EIAR
DZ-Cr-44	Menagesha	1982	1800-2400	300-700				95-140	85-110	1.8-2.4	1.8-2.2	DZARC/ EIAR
DZ-Cr-37	Tsedey	1983	1600-2000	300-700	46	41		82-90	67-92	1.8-2.5	1.4-2.2	DZARC/ EIAR
DZ-01-1681	Key Tena	2002	1600-2000	300-500				84-93	74-85	1.7-2.4	1.6-2.2	DZARC/ EIAR
DZ-Cr-387	Quncho	2006	1800-2500	800-1200	60	60	41-71	86-151	72-104	2.5-2.7	1.6-2.0	DZARC/ EIAR
Ho-Cr-136	Amarech	2006	1600-1700	500-850	60	40	29-41	63-87	67-81	1.3	1.2	DZARC/ EIAR
DZ-Cr-385	Simada	2009	Low altitude	300-700	40	60	48	88	65-80	1.6	1.0	DZARC/ EIAR
DZ-Cr-387	Gemechis	2007	1450-1700	600-1950	40	60	36.3	62-83	86.6	1.3-2.0	1.4	MARC/ EIAR
DZ-Cr-409	Boset	2012	1500-1750	500-900	60	40	26-35	75-86	75-90	1.8-2.0	1.4-1.8	DZARC/ EIAR
Acc. 205953	MECHARE	2007	1450-1850	660-1025	46	41	43	79	88	2.1	1.8	SRARC/ ARARI

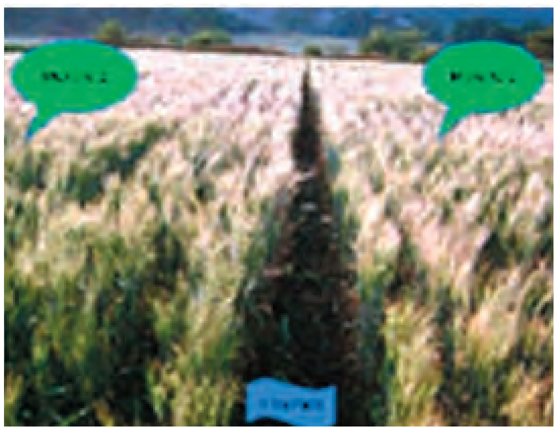
Table 4. *(continued)*

RIL 273	Lakech	2009	1450-1850	660-1025	46	41	52	90	102	2.24	1.3-1.8	SRARC/ ARARI
DZ-01-2054	Gola	2003	1450-1850	660-1025	46	41	35-50	60-100	72-106	1.0-2.2	1.6	SRARC/ ARARI
DZ-01-146	Genete	2005	1450-1850	660-1025	46	41	42-46	80-90	42-46	2.17	1.55	SRARC/ ARARI
DZ-01-1821	Zobel	2005	1450-1850	660-1025	46	41	43-48	78-85	85-97	2.1	1.5	SRARC/ ARARI

Source: Crop variety registry, Ministry of Agriculture and Rural Development, Crop Development Department, 2002, 2003, 2005, 2006, 2007 and 2009.

? **Wheat**

Wheat is the second most important crop next to tef in terms of area coverage in Ethiopia but most of the production is concentrated in the highland plateaus of Ethiopia. However, in recent times drought tolerant wheat varieties are being developed and promoted by federal and regional research establishments in the country. There are currently three varieties making the recommendation list vis. Jefferson released by Oromia Regional Research Institute, Ogolocho and Picaflor developed at Kulumsa Research Center of the Ethiopian Agricultural Research Institute, respectively. Tigray Regional Research Institute recently released two out standing wheat varieties for moisture stress areas in northern Ethiopia. Those varieties named Mekelle 1 and 2 (fig. 13) can grow well within the rainfall range of 400 – 800 mm, mature between 90 to 115 days producing 2.0 to 3.7 t/ha. Jefferson is resistant to stripe rust although it is susceptible to leaf rust;



Picaflor Mekelle 1 Mekelle 2

Fig. 13.Improved drought tolerant wheat varieties.Source: EIAR (2013), MARC (2013)

Ogolcho is resistant to major rusts; while Mekelle 3 is resistant to yellow rust but moderately susceptible to stem rust (Table 5)

Table 5: Improved bread wheat varieties released for moisture stress areas

Variety name	Bree-der/Maintainer	Year of release	Altitude (m.a.s.l)	Rainfall (mm)	Days to heading	Days to mature	Plant height (cm)	Fertilizer use		Pest reaction	Grain yield (ton /ha-1)	
								P2O5 (kg/ha)	N (kg/ha)		On-station	On-farm
Jeffer-son	OARI/Fedis)/MOR-RELL	2012	1200-1900	500	60	90	90	46	64	Resistant to stripe rust susceptible to leaf rust	?	2.0-3.0
Ogolcho	KARC/EIAR	2012	1600-2100	400-500	60	102	70	46	41	Resistant to major rusts	2.8-4.0	2.2-3.5
Mekelle-03)	Me-kelle&Alamata (TARI)	2012	2200-2500	650-800	60	106-115	75	46	41	Moderately resistant to yellow rust & Moderately susceptible to stem rust	4.0-4.5	3.3-3.7

Source: Crop Variety Registry, Ministry of Agriculture and Rural Development, Crop Development Department, 2012

? **Barley**

The research focus on barley improvement for much of the time was targeted for the highlands, high rainfall agro-ecologies. However, of late,an increasing number oflow input and drought tolerant varieties are being used. The Ethiopian Agricultural Research Institute has two recently released varieties (Bentu and Desta) for moisture stress areas (Table 6). Those varieties require 500 mm to make it to maturity, and they are early maturing type capable of completing their growth in just over 70 days, tolerating scald and net blotch diseases. The varieties have fairly substantial productivity range of 1.2 to 2.4 t ha-1 under farmer's condition, and 2.4 to 5.9 t ha-1in experimental stations.

Table 6: Improved food barley varieties released for moisture stress areas

Variety name	Bree-der/Maintainer	Year of release	Altitude (m.a.s.l)	Rainfall (mm)	Days to heading	Days to mature	Plant height (cm)	Fertilizer use		Pest reaction	Grain yield (ton /ha-1)	
								P_2O_5 (kg/ha)	N (kg/ha)		On-station	On-farm
BENTU	KARC/EIAR	2006	1700-2300	>500	41-59	71-99	71	18	46	Tolerant to scald and net blotch	2.4-5.9	1.2-2.4
DESTA	KARC/EIAR	2006	1700-2300	>500	46-61	73-104	63	18	46	Tolerant to scald and net blotch	2.5-5.4	1.3-2.1

Source: Crop Variety Registry, Ministry of Agriculture and Rural Development, Crop Development Department, 2006

Three more varieties released by Mekelle University are in the recommendation list for the dry lands of northern Ethiopia. Those varieties are climate resilient and they are receiving wide acceptance by farmers (Fetien, Personal communication). Felamit variety developed through participatory selection with farmers can yield up to 5.2 t ha-1, withstanding the prevailing biotic and abiotic constraints. Fetina is a two-rowed, white seeded, extra early varietywith high zinc, iron and beta-gluten content and with productivity potential of 3.0 to 5.0 t ha-1. For areas with slightly better rainfall conditions the third six row, white seeded variety called Hiriti is recommended and this variety can produce greater than 5.0 t ha-1 (Fig. 14)

Fig. 14. Felamit, Fetina and Hiriti seeds; and Felamit and Hiriti panicles.

Source: MU (2013)

1.3.2. Pulses

Haricot bean

Haricot bean *(Phaseolus vulgaris L.)* is one of the most important grain legumes grown in the dry lowlands of Ethiopia, particularly in the Rift Valley. In these areas farmers grow white, canning quality bean varieties such as Awash Melka, Argene and Mexican 142 (Fig.

15) mainly for export purposes. Haricot bean is also a principal food crop, particularly the brown seeded, in southern and eastern part of Ethiopia. Therefore, the varieties with white seed color are mainly used for export, while the red and yellow varieties are used for local food consumption (there are 24 white and colored varieties in the recommendation list at present, Table 7). The colored haricot bean is a cheapest source of plant protein for farmers in the dry areas. Furthermore, the crop plays an important role in various cropping systems. The crop has wide adaptation, growing well between 1400-2000 m.a.s.l, with an optimum temperature range of 18-230C, and rainfall of350-700 mm. Common beans can be successfully grown on light and heavy clay soils, with pH range of 5 and above. However, the soils should be well drained, because beans are very sensitive to waterlogging. There are a number of constraints, which limit bean production including moisture stress, low yielding potentials, pests and diseases (rust, anthracnose, and common blight) and weeds (MARC, 2004).

Fig. 15. Partial view of release drought tolerant common bean varieties.

Source: Marc (2013)

Table 7. Improved Common bean varieties released for moisture stress areas

Variety name	Year of re-lease	Altitude (m.a.s.i.)	Rainfall (mm)	Fertillizer (kg/ha)		Days to flowering	Days to mature	Grain yield (ton/ha-1)		Breeder / Maintainer
				P2O5	N			On-station	On-farm	
GLP-2	2011	1000-1950	400-750	46	41-46	38-50	85-90	2.0-3.3	1.8-2.6	MARC/ EIAR
Morka (ECAB-0056)	2011	1300-2200	400-1100	46	41-46	41-55	84-115	2.0-3.5	1.8-2.6	MARC/ EIAR
SARI-1	2011	1400-2250	350-1500	100 DAP	-	53	90	3.0	2.0	AwARC/ SAR
Lehode	2010	<1850	350-700	-	-	48	88	1.7-2.4	1.6-1.8	SARC/ ARARI
Batu	2008	1300-1650	400-750	46	23-46	35-39	75-85	1.8-2.5	1.6-2.0	MARC/ EIAR
Deme	2008	1400-2000	400-1100	46	23-46	45-55	90-115	2.0-3.0	1.8-2.2	MARC/ EIAR
Kufanzik	2008	1300-2100	600-1200	46	18	43-48	90-95	2.5-4.0	1.9=3.5	H. University
Melkadima	2006	1300-1850	400-1100	46	41-46	39-54	79-102	2.3	1.8	MARC/ EIAR
DOR-554 (Dimtu)	2003	1200-1800	350-1000	46	41-46	45-47	91-93	2.14	2.2	MARC/ EIAR
Awash melka	1998/99	Semi-arid Lowland		46	18-36		95-100	2.2-3.2		MARC/ EIAR
Awash-1	1990	1400-1800	350-700	100	100	-	75-90	2.0-2.4	-	MARC/ EIAR

.../...

Table 7. *(continued)*

Roba	1990	1400-1800	350-700	100	50-100	-	75-95	2.0-2.4	-	MARC/ EIAR
Mexican-142	1973	1500-1800	350-700	100	100	-	95-110	1.6-2.0	-	MARC/ EIAR
Chore (STTT-165-92)	2006	1300-1950	400-1100	46	41-46	51-59	87-109	2.0-2.3	1.9	MARC /EIAR
RWR-719 (Omo-95)	2003	1400-2250	350-500	46	18	55-60	90-120	1.73-3.2	1.9-2.6	AARC/ SARI
Nazareth-2 (TAO4JI)	2005	1300-1800	350-1000	46	41-46	50-60	90-95	2.2-2.5	-	MARC/ EIAR
Fedis	2012	1500-2200	500-1200	100 DAP	-	47	93	2.3-3.6	1.0-2.2	H. University
Dicta-105 (Nasir)	2003	1200-1800	350-1000	46	41-46	86-88	42-45	2.03	2.3	MARC/ EIAR
Atndaba	1997	1400-1900	380-700	-	-	-	91	2.3	-	MARC/ EIAR
Ayenew	1996	1700-2000	500-1200	100	23	-	100	2.0-3.5	1.5-2.5	H. University
Gofta	1996	1700-2000	500-1200	-	--		110	2.0-3.5	1.5-2.5	H. University
MAM-41 (Wedo)	2003	1450-1850	660-1025	-	-	40-42	74-84	1.2-2.2	0.9-1.4	SRARC/ARARI
Hirna (ECAB0203)	2012	1500-2200	500-1200	100 DAP	-	48	92	2.3-3.4	1.6-3.0	H. University

.../...

Table 7. *(continued)*

Babile (ECAB 0247)	2012	1500-2200	500-1200	100 DAP	-	48	91	2.4-3.5	1.5-3.0	H. University
Hundane (k-132)	2012	1500-2200	500-1200	100 DAP	-	46	91	2.2-3.0	1.5-2.0	H. University
Tinike (RXR-10)	2012	1500-2200	500-1200	100 DAP	-	47	91	2.0-3.0	1.5-2.5	H. University
CRAN-SCOPE	2007	1300-1950	400-1100	46	41	48-52	90-98	1.93-2.7	1.6	MARC/ EIAR
MONT-CAM/ACOS RED	2007	1300-1950	400-1100	46	41	35-40	75-82	1.98-2.2	1.6	MARC/ EIAR
Bobe Red (XAN-310)	2006	1400-1850	400-1100	46	41-46	51-59	82-102	2.5	2.0	MARC/ EIAR
Dursitu (DOR-811)	2008	1500-2100	600-1200	46	18	50-55	100-105	.0-3.52	1.5-3.0	H. University
AFR-722 (ibbado)	2003	1400-2250	350-500	46	18	49	90-120	2.0-2.9	1.5-2.0	SARI/AARC

Source: MARC (2013)

? Cowpea

Cowpea is an important food legume and a valuable component of the traditional cropping systems in the semi-arid parts of Ethiopia. Being a drought tolerant crop, cowpea is well-adapted to the semi-arid regions where other food legumes do not perform well (Mesele and Belay, 1999; Reddy and Kidane, 1993). There is much variability within the species in terms of growth habit. The different cowpea accessions can show wide variation in reproductive development. Some may start flowering 30 days after sowing and are ready for harvest 25 days later; others may take more than 90 days to flower, and 210-240 days to mature (Teshale Assefa, personal communication). Cowpea crop yields about 300-500 kg/ha under traditional farming system. However, improved varieties can yield 1500- 2000 kg/ha under rain fed condition (MARC, 2004). Under research,even higher cowpea yields ranging from 3940 to 5000 kg/ha have been registered (MARC, 2004). Experiments carried out on varietal screening, sowing dates and intercropping with sorghum indicate that the crop has great potential for arid and semi-arid of Ethiopia (Kidaneet al, 2003). Table 8 depicts the list of released varieties (Fig. 16) and agronomic recommendations.

Cowpea has a wide range of adaptation and grows from sea level up to 300 to 1500 m.a.s.l and precipitation range of 650-2,000 mm. However, it is very susceptible to frost and only grows well in warm seasons at an optimum temperature range of 25-35°C. The crop is moderately tolerant to drought but excessive soil moisture is harmful, reducing growth and favoring fungal infection. Extended water logging or poor drainage should be avoided. Cowpea is adapted to a wide range of soils from sands to heavy, well-drained clays, with a preference for lighter soils that allow good rooting. The crop tolerates a wide range of PH including very acid (pH 4), and low-fertility. It is better adapted to strongly acid soils than either Lablab or *Mucuna Pruriens* (MARC, 2004). The crop grows well also on heavy textured strongly alkaline soils but does not tolerate extended flooding or salinity. It responds well to nitrogen, phosphorous and potassium as well as sulfur fertilizers. However, the crop's response to nutrients is affected by soil moisture, temperature, placement, tillage and crop. Where there is suitable soil conditions, it is recommended to apply 46 kg P2O5/ha during planting. When the plants are deficient in nitrogen they show leaf yellowing, at this moment, 41-46 kg N could be applied as top dressing before flowering (MOA, 2006).

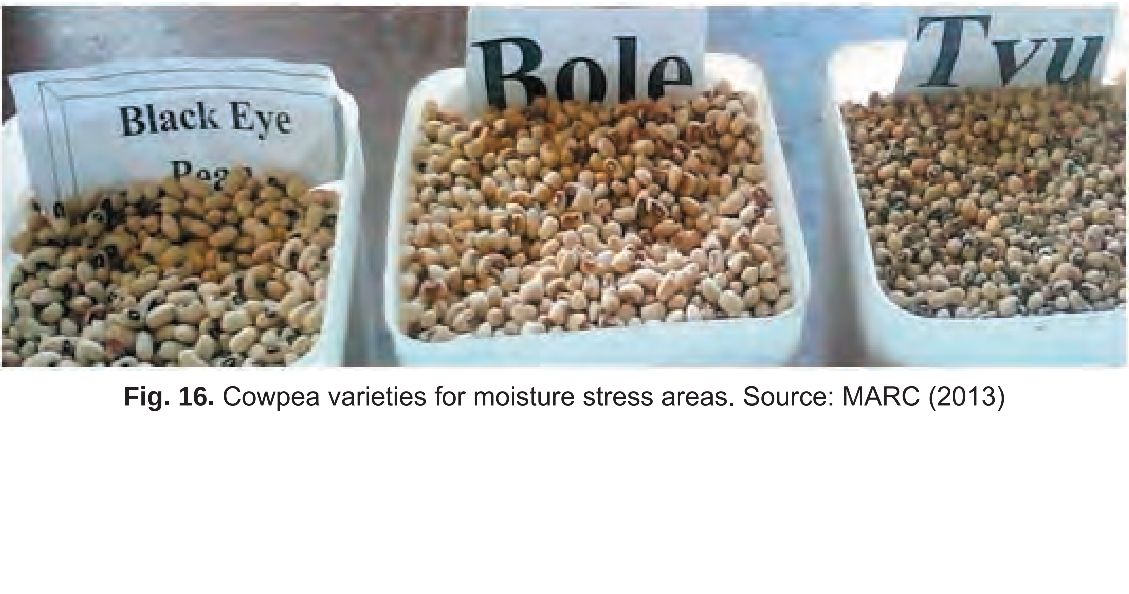


Fig. 16. Cowpea varieties for moisture stress areas. Source: MARC (2013)

Table 8. Improved cowpea varieties released for moisture stress areas

Variety name	Year of release	Altitude (m.a.s.i.)	Rainfall (mm)	Fertillizer (kg/ha)		Days to flowering	Days to mature	Grain yield (ton/ha-1)		Breeder / Maintai-ner
				P2O5	N			On-station	On-farm	
Keti (IT99K-1122)	2012	1000-1850	350-1100	46	41- 46	46 - 53	72-81	2.2-3.2	1.7-2.1	MARC/ EIAR
Asebot (82D-889)	2008	1300-1650	350-750	46	23 - 46	48 - 58	75-85	1.8-2.6	1.7-2.0	MARC/ EIAR
Bole (85D-3517-2)	2006	1300-1850	350-1100	46	41- 46	58 - 66	86-95	19	17	MARC/ EIAR
Asrat (ITS92KD -279-3)	2001	1450-1850	660-1025	-	-	55 - 65	95-100	2.0-2.25	1.66	SRARC/ ARARI
Bekur (838 689 4)	2001	1450-1850	660-1025	-	-		95.4	1.9-2.1	1.96	SRARC/ ARARI

Source: MARC (2013)

? Pigeon pea (*Cajanus caja)*

Pigeon pea is one of the major grain legumes crops of the tropics and sub-tropics. Eastern Africa produces about 10% of the total world production; Kenya (with over 200,000 ha) and Uganda (50,000 ha) are the principal producers; with small production areas in Burundi, Ethiopia and Sudan (ICRISAT, 1992). The most commonly grown pigeon pea varieties (Fig. 17, Table 9) are photo-sensitive, long duration which are often intercropped with cereals (maize, sorghum, or pearl millet) and short-duration legumes. In Ethiopia, the crop is grown as field crop in southern Ethiopia, where it covers large area. In north western and eastern parts of the country, pigeon pea is planted for agro-forestry and erosion control. In the east, it is used as garden crop (Westphal, 1974). It is an important intercrop and rotation crop in cereal based cropping systems, especially in some parts of southern Ethiopia. In fact one of the promising intercrops with cereals particularly sorghum and maize is the late maturing pigeon pea (Kidane et al, 2003). Even though early growth of the legume is reduced when intercropped with maize or sorghum, pigeon pea compensates for through continued growth after maize harvest and producing substantial biomass of about 3 t ha-1 of dry matter from leaf litter and flowers (Kidane et al., 2003). As a multi-purpose crop pigeon pea is well known but ought to be promoted especially in more semi-arid regions, for which the crop is well suited due to its tolerance to drought and low soil fertility and its ability to recover after environmental or biotic stress. Its large seed-yield potential offers promise in more favorable environments. Pigeon pea fits well in agro-forestry, in smallholder garden cropping and in hedge cultivation, and is suitable for improved short-duration fallows.

Fig. 17. Pigeon pea variety for moisture stress areas.

Source: MARC (2013)

Table 9. Improved pigeon pea varieties released for moisture stress areas

Variety name	Days to mature	Grain yield (ton /ha-1)		Breeder/ Maintainer
		On-station	On-farm	
ICEAP 87091	110-120	1.0-1.5	-	MARC/EIAR
ICP 7732	120-130	1.0-1.5	-	MARC/EIAR

Source:MARC (2013)

? Mungbean

Mungbean also known as green gram or golden gra-mis an early maturing crop, tolerant to drought with a great potential for semi-arid areas. In Ethiopia the crop is grown in north, south and south-western parts of the country. Its special feature is good yield, better nutritive value, earliness (65 days from sowing to maturity), an attribute that enables the crop to escape drought.In the past, different set of mung bean accession and varie-ties were mainly introduced to Ethiopia. Among the in-troduced varieties tested - M-1134, M-409, M-109, M-76, M61 and M-140 ex Gode(Fig. 18, Table 10) were found to be suitable for the dryland areas. Awassa agri-cultural research center has released Borda-1 in 2007 for the southern region.

Mungbean is a warm season crop requiring 65–120 days of frost-free conditions from planting to maturity (depending on variety). Adequate rainfall is required from flowering to late pod filling in order to ensure good yield but it can also substantial produce during short rain season. High humidity and excess rainfall late in the season can result in disease problems and harves-ting losses due to delayed maturity. Mungbean does best on fertile sandy, loam soils with good internal drainage. They do poorly on heavy clay soils with poor drainage. Performance is best on soils with a pH between 6.2 and 7.2 and plants can show severe iron chlorosis symptoms and certain micronutrient deficiencies on more alkaline soils. Mungbean has phosphorus, potassium, calcium, magnesium and sulfur requirements which must be met by fertilizer additions if the soil is deficient in these elements (MARC, 2004). As a legume that fixes its own nitrogen, mungbean does not need much nitrogen fertilizer. Nitrogen and phosphorous needs have not been studied for mungbean in Ethiopia. If other crops like common bean respond to phosphorous in the area apply around 50-100kg DAP/ha during planting. The small amount of nitrogen will help the plants to get a good start. When the plants are deficient in nitrogen they show leaf yellowing, at this moment, 50-100kg urea/ha could be applied as top dressing before flowering. Mungbeans require phosphorus, potassium and certain micronutrients at levels similar to other field beans. The amount fertilizer to be added should be based on soil test results.

Fig.18. Drought tolerant mung bean. Source: MARC (2013)

Table 10. Improved mung bean varieties released for moisture stress areas

Variety name	Year of release	Altitude (m.a.s.i.)	Rainfall (mm)	Fertillizer (kg/ha)		Days to flowering	Days to mature	Grain yield (ton/ha-1)		Breeder / Maintai-ner
				P2O5	N			On-station	On-farm	
Rasa (N-26)	2011	900-1670	350-550	46	41-46	30-37	65-80	0.8-1.5	0.5-1.0	MARC/ EIAR
Borda (MH-97-6)	2008	1100-1750	>500	100	-	-	-	1.35		SRARC/ ARARI

Source : MARC (2013)

1.3.3. Oil crops

There is limited number of oil crops that is suitable to the harsh conditions in the dry areas prone to climate variability. However, there are some economically important crops widely grown in the arid and semi-arid areas of Ethiopia.

? **Sesame**

Sesame is one of the oldest crops cultivated for its oil in Ethiopia. It is mostly grown as a rain-fed crop in the Semi-arid regions. Sesame has high heat and light requirements and is sensitive to low temperature. This oil crop has high commercial value in northern Ethiopia. It is drought resistant and very intolerant to water logged soils, it can be grown in pure stand mainly in the north-west private commercial farms, but it usually is intercropped with sorghum or maize or millets by small farmers. Because of the very good market price it commands, it is often used as a cash crop, especially the white seeded varieties. There are six varieties

(Table 11) under production at present which can fit to areas with 560 – 1650 m.a.s.l. elevation, 400 – 1100 mm of rainfall, with a maturity period of 80 to 142 days. However, the productivity of those varieties is low and ranges between 0.5 to 1.0 t.ha-1 under farmers condition.Setit 1 and Humera 1 are the two most popular varieties in the major sesame belt of north western Ethiopia not only because of their white seed, which is in great demand by the export market but also relatively superior productivity (45 – 60% higher yield than the locals) despite the environmental challenges often associated with drought and erratic weather patterns.Abasena (Fig. 19) is also another productive sesame variety with good drought tolerance trait.

Fig. 19. Abassena, drought tolerant sesame. **Source**: MARC (2013)

Table 11. List of improved sesame varieties

Variety name	Year of release	Altitude (m.a.s.i.)	Rainfall (mm)	Fertillizer (kg/ha)		Days to flowering	Days to mature	Grain yield (ton/ha-1)		Breeder / Maintai-ner
				P2O5	N			On-station	On-farm	
Setit-1 (cols el p#1)	2011	560-1130	400-650	-	-	45-55	80-90	0.62-1.0	0.55-0.9	Humera/ TARI
Humera-1 (ACC.038 sel.1)	2011	760-1130	550-750	-	-	50-60	90-100	0.59-0.9	0.5-0.8	Humera/ TARI
Obsa (EW004)	2010	1250-1650	700-1100	-	-	62-75	120-137	1.06	0.87	BARC? OARI
Dicho (EW015)	2010	1250-1650	700-1100	-	50 Urea	65-78	131-142	1.06	0.81	BARC? OARI
AHADU (Kelafo 74XC-22sel4)	2007	1400-1600	750-950	-	-	50-65	104-115	0.8-1.3	0.7-1.0	SRARC/ ARARI
BOR-KENA (Pungun Yongae)	2007	1400-1600	750-950	-	-	49-65	105-117	0.8-1.2	0.6-1.0	SRARC/ ARARI

Safflower

The other important oil crop, which deserves a special attention for the low rainfall areas with marginal soils, is safflower. Ethiopia is the major producing country in Africa and produces almost all the safflower crop in the continent(about 34,000 t/year). The plant is very drought resistant and it is well adapted to the Semi-arid highlands, particularly being an important crop in northern Ethiopia. Safflower is well suited to soils with marginal fertility and under dryland conditions has a similar degree of resistance to salinity. It is usually planted in mixture with tef. Besides its use as local food, it has a good potential for quality of edible oil. The oil yield of the available varieties is 29%. The oil is of good quality and the cake has 16% protein.

The promising varieties include Natt-11 and Kulumsa selection. These are both spineless and this makes handling and threshing easier. Natt-11 is relatively high yielder. It takes about 97 days to flower and 144 days to mature. The crop is planted at 45 x 20 cm spacing and a seed rate of 20-50 kg ha-1. For reliable emergence, seeds should not be buried deeper than 5 cm.An early weeding is necessary at 20-25 days after emergence, because the crop is slow starter and susceptible to weed competition at early growth stage.

? **Groundnut**

Groundnut is exotic to Ethiopia, but it is a widely grown crop in the warm lowland areas of the country. It is mainly produced in in the eastern lowlands but many areas in the south and south west are also identified as potential areas (WARC, 1991).Groundnut is very important cash crop for the smallholder dryland farmer in particular and the country in general. Ten varieties are released between 2004 and 2011 for marginal rainfall areas of the country (Table 12). Those varieties can be successfully grown in areas with elevation range of 740 – 1850 m.a.s.l., and rainfall range of 350 – 1370 mm. They have a maturity period of 96 – 157 days. However, the yield potential of these varieties is often low (1 – 2 t ha-1), although Werer-961 and Werer-962 can yield up to 4.5 t ha-1 under favorable conditions.The major production constraints to groundnut include disease and insect pests, lack of improved varieties, drought, and lack of harvesting technologies.

Table 12. List of improved groundnut varieties

Variety name	Year of release	Altitude (m.a.s.i.)	Rainfall (mm)	Fertillizer (kg/ha)		Days to flowering	Days to mature	Grain yield (ton/ha-1)		Breeder / Maintai-ner
				P2O5	N			On-station	On-farm	
Eta (ICGV-96395)	2010	1450-1850	350-700	-	-	32-40	123-135	2.2	2.0*	SARC/ ARARI
Fenta	2010	1450-1850	350-700	-	-	32-40	127-140	2.1	1.8*	SARC/ ARARI
Fetene (ICGV-93370)	2009	750-1650	569-740	-	-	27-35	115.96	-	1.8 *	MWARC/ EIAR
ICGV-94205	2008	740-1650	740-1370	-	-	28-40	144-156	2.34	1.02*	MWARC/ EIAR
ICGV-94222	2008	740-1650	740-1370	-	-	31-40	146-157	2.0	1.2*	MWARC/ EIAR
ICGV-93164	2008	740-1650	740-1370	-	-	29-49	130-155	1.96-	0.82*	MWARC/ EIAR
Werer-961 (ICGV-87108)	2004	750-1650	569-1100	-	-	34	127	2.6-4.5	-	MWARC/ EIAR
Werer-962(ICGV-86928)	2004	750-1650	569-1100	-	-	44	130	2.9-3.9	-	MWARC/ EIAR
Werer-963(ICGV-86644)	2004	1400-1650	569-686	-	-	46	129	2.16	-	MWARC/ EIAR
Werer-964(ICGV-86635)	2004	1400-1650	569-686	-	-	44	128	2.15	-	MWARC/ EIAR

1.3.4. Root and tubers

? **Enset**

Enset (*Enset escitamineae*) also known as “false banana” due to its striking resemblance to the banana plant, is a traditional staple crop in the south and southwestern Ethiopia with uneven and erratic rainfall. Its high moisture carrying capacity and resulting durability means it could help to ensure food security in drought prone areas. Although it is a protein poor crop, its deep roots give it a greater resilience to drought than other cereal crops and consequently, a greater degree of food security to those who grow it. Evidences show that famine has been averted at times of drought in areas where the Enset crop have been grown and processed by rural communities (Jacob, 2004).

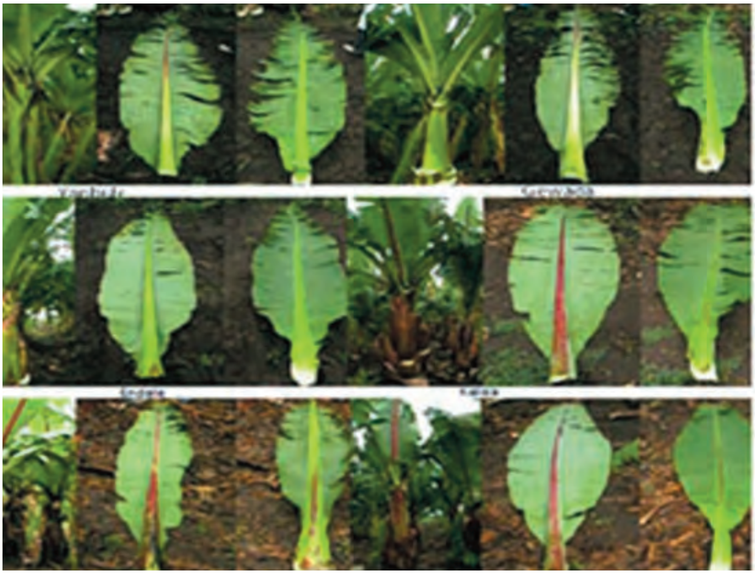


Fig. 20. *Major Enset varieties released by SARI. Source: SARI (2013)*

The Southern Regional Agricultural Research Institute is taking the lead in developing productive, adapted and drought tolerant varieties (Fig. 20) for wider use in the region and other enset producing areas of the country. Currently, six varieties are in the recommendation list and being widely used by farmers

? **Cassava**

Cassava used to be traditionally grown for food only in certain parts of southern Ethiopia. But because the food security challenges associated with recurrent drought and climate change, this highly resilient, drought tolerant and productive crop is being widely promoted throughout the country. Two varieties (Kello red and Qulle) are recommended for use (Table 13) by Southern Region Agricultural Research Institute. Those varieties were released in 2005 for mid altitude areas (1200 – 1800 m.a.s.l.) with a rainfall range of 980 – 1398 mm. The crop matures in 16 – 18 months producing very high tuber yield of 24 – 28 t ha-1 (Daniel Belachew, personal communication).

Table 13. Improved drought tolerant cassava varieties

Variety name	Year of release	Altitude (m.a.s.i.)	Rainfall (mm)	Fertillizer (kg/ha)		Days to flowering	Days to mature	Grain yield (ton/ha-1)		Breeder / Maintai-ner
				P2O5	N			On-station	On-farm	
Kello red (44/72)	2005	980-1398	1200-1800	Blanket appl.	Blanket appl.	16-18	205	28.1	27.1	AwARC/SRARI
Qulle (104/72Nigerian red)	2005	980-1398	1200-1800	Blanket appl.	Blanket appl.	16-18	185	27.2	24.1	AwARC/SRARI

? **Sweet potato**

Sweet potato is more broadly utilized as a food crop in many parts of the country, especially the dry lowlands of the south and the south east. The crop is suited to moisture stress areas and quite substantial research effort has gone into it. Three regional agricultural research institutes (Amhara Regional Agricultural Research Institute, Oromia Regional Agricultural Research Institute and South Regional Agricultural Research Institute) have so far released 15 varieties

Table 14. Improved drought tolerant sweet potato varieties

Name of Variety	Year of release	Altitude (m.a.s.i.)	Rainfall (mm)	Fertillizer (kg/ha)		Days to maturty	Plant height (cm)	Tuber yield (t/hac)		Breeder / Maintai-ner
				DAP	Urea			On-station	On-farm	
Jari (CN-2059-1)	2008	1650-1850	950-1204	-	-	133	91.9	19.22	16.52	SARC/ ARARI
Birtukanie (Saluboro)	2008	1650-1850	950-1204	-	-	150	137.4	19.9	11.4	SARC/ ARAR
Dimitu	2005	1400-1800	980-1559	100	100	120	156	26.7	12.8	BARC/ ORARI
Kuflo (Lo-323)	2005	1200-2200	980-1398	--	-	150	75-150	27.0	25.6	AwARS/ SRARI
Tulla (CIP420027)	2005	1200-2200	980-1398	-	-	150	75-150	28.5	25.5	AwARC/ SRARI
Kero (TIS 8250)	2005	1200-2200	980-1398	-	-	150	35.4	26.6		AwARC/ SRARI
Ordollo (192009)	2005	1200-2200	980-1398	-	-	150	75-150	17.3	13.4	AwARC/ SRARI
Temesegen (192009 VIII)	2004	1200-2200	980-1398	-	-	120	151-250	17.43	15.0	SARC/ ARARI
Awasa-83	1997/98	Mid & high altitude	850-100	-	-	150	-	2.07	-	AwARC/ SRARI
TIS-444	1997	650-850	-	-	-	Early	-	2.17	-	AwARC/ SRARI
TIS3107 (2)	1997	650-850	-	-	-	Early	75-150	1.67	-	AwARC/ SRARI
TIS 1499	1997	650-850	-	-	-	Early	75-150	2.4	-	AwARC/ SRARI

.../...

Table 14. *(continued)*

Guralolow	1997	Mid-altitude	750-900	-	-	120-135	151-250	3.07	-	AwARC/ SRARI
Var 375	1997	Mid-altitude	750-900	-	-	120-135	75-150	2.96	-	AwARC/ SRARI
AIOC-1	1997	Mid-altitude	750-900	-	-	120-135	75-150	3.54	-	AwARC/ SRARI

for areas with an altitude range of 650 - 1850 m.a.s.l. The varieties take up to 150 days to mature, yielding 26 t ha-1 (Table 14).

1.4. Major constraints of drought tolerant varieties in Ethiopia

The drought tolerant crop varieties are faced with a host of biotic and abiotic constraints to mention but few –

1. Poor emergence,caused by inappropriate seedbed preparation, depth and method (broadcasting) of planting, poor quality of seed,is significant problem particularly for the grain crops. To overcome the problem the crops should be planted at appropriate depth. And proper land preparation and early planting, and use of high quality seed are also considered crucial.

2. Water stress due to low and erratic rains, high potential evapo-transpiration resulted by high temperature and strong winds, shallow soil depth and low soil organic matter with poor water retention capacity is a common problem in the dry lands of Ethiopia prone to climate change and climate variability. Use of appropriate water harvesting technique (ponds, zai pits etc.), moisture conservation mea-

sures (tied ridges), appropriate cropping systemsapproches, timely land preparation and planting, use of mulches and green manure, weed control are the measures recommended to alleviate the problem.

3. Low soil fertility, which occurs due to complete removal of organic residues, lack of plant cover, low or no inorganic fertilizer application, intensive cultivation of unsuitable areas with steep slopes, and over grazing is addressed through use of organic and inorganic fertilizers, green manuring, cereal-legume rotation, and cropping systems approaches (inter, relay and strip cropping).

4. The other major constraint to dry land crops is weed infestation particularly the parasitic weed, striga, a problem often aggravated by water stress, poor fertility, mono-cropping of susceptible cereal crop, and land degradation.Use of the striga resistant varieties mentioned in the list above i.e. Gobiye, Abshir and Berhan; and improving soil fertility particularly N supply, crop rotation, intercropping in integration with improved soil moisture conservation methods can help to manage the parasitic weed.

5. Insect pests especially stalk borer inflicts heavy damage in the dry semiarid and arid areas. The pest incidence is increasing due to erratic rainfall and late onset of the rainy season. In hot spot areas, removing alternative hosts and crop residues is advisable to deny the pest a breeding ground. Furthermore, early planting and, in the worst of cases, application of pesticides should be considered although access to those kind of inputs is often not easy due to limited supply.

6. Birds especially *Quelea quelea* are a serious menace in the Rift Valley of the country on cereals, especially sorghum. Where this is a major problem, use of the high tannin varieties such as Seredo can provide respite in the case of sorghum. In the absence of such varieties use of uniform maturing cultivars for spreading the risk and bird scaring are alternative methods worth considering.

2. Uganda

2.1. Background

Uganda is located between 4° N and 1° S latitude and 29.5° W to 35.5° E longitude. It has a total area of 241,040 Km^2, and it is a country with equatorial climate having moderately humid and hot climatic conditions throughout the year; even though this is modified by the elevation. The altitude ranges between 620 and 5110 m, with a mean of 1200 m above sea level. The country receives uni-modal (northern part) and bi-modal (central, western and eastern parts) types of rainfall. The long rains fall between March and May, while the light/short rains fall between September and November (State of the Environment Report for Uganda, 1996). The dry seasons occur between June and August and December and February when temperatures are highest. Annual rainfall and temperature range from 500 mm to 2500 mm; and 2oC to 26 oC, respectively (McSweeney, 2008).

Sub-Saharan Africa in general and Uganda in particular are vulnerable to the adverse impacts of climate change and variability because their economies are tightly bound to climate (Houghton et al., 2001; IPCC, 2007; Lukwiya, 2009). In Uganda, minimum temperatures have been rising faster than maximum temperatures (Oxfam, 2008). According to this source, temperatures rose from about 1960 to 1982 then declined before rising again since the 1990s. The trend is reported to have been steadily upward to about 1oC higher. Climate change models for Uganda and IPCC (2007) also point to an increase in temperature of between 0.7 oC and 1.5 oC by the year 2020. Future forecast using modeling confirmed that the average daily maximum and minimum temperature will continue showing increasing trend over a 50-year period (Bashaasha et al., 2011). However, the lower limits of the ranges of the daily maximum and minimum temperatures will be increasing faster than the upper limits (Fig. 21). The implication of this finding is that the day and night temperatures will become warmer.

A growing number of assessment studies predict a likely increase in the variability of rainfall. In fact, vulnerability assessments for Uganda identified precipitation as the most important climate change related variable (NEMA, 2006/2007). According to NEMA (2008), the average long-term annual rainfall for Uganda is about 1,318 mm but the main concern for Uganda is not with the total amount of rain but with the distribution of rain through the season and the type of rain. The onset and cessation of rains are increasingly erratic and when the rain does come it is heavier and more violent. Further information generated on seasonal rainfall characteristics revealed the onset of rains in the March–May season in Uganda is delayed for as many as 30 days, with rains starting in mid-April instead of mid- March. However, the timing of rainfall cessation has more or less stayed the same, regardless of the time of onset of rainfall. Consequently, even when rains start late, withdrawal is timely, thus making the growing season shorter (Bashaasha et al., 2011) (Fig. 22). On a monthly scale, there seems to be a decreasing trend in the number of rainy days during the critical months of crop growth in the March–May season, making crops grown in this season prone to climatic risks and therefore in need of adaptation measures. According to NEMA (2008), the average long-term annual rainfall for Uganda is about 1,318mm but the main concern for Uganda is not with the total amount of rain but with the distribution of rain through the season and the type of rain. The onset and cessation of rains are increasingly erratic and when the rain does come it is heavier and more violent. Comparison of the 2008 monthly cumulative rainfall with the long term means show that for Tororo to the East, Entebbe in the Central and Mbarara to the South-West, the actual cumulative monthly rainfall is higher than the long term mean for the month for all the 12 months in 2008 (NEMA, 2008). This is however, not the case with Gulu to the North and Kotido to the North East.

Agriculture is the backbone of Uganda's economy and contributes 23.7% tothe GDP (MFPED, 2010). Uganda's agricultural sector is climate-dependent, and thus particularly sensitive to climate variability and change. Notably, the variations in climate and extreme events have increased with more frequent droughts and floods in different parts of the country (Goulden, 2006). The agriculture is predominantly rain-fed; and any slight variability in rainfall may therefore be reflected in the productivity of agricultural systems and pronounced variability may result in adverse physical, environmental and socio-economic impacts. Because of the different rainfall patterns between the south and

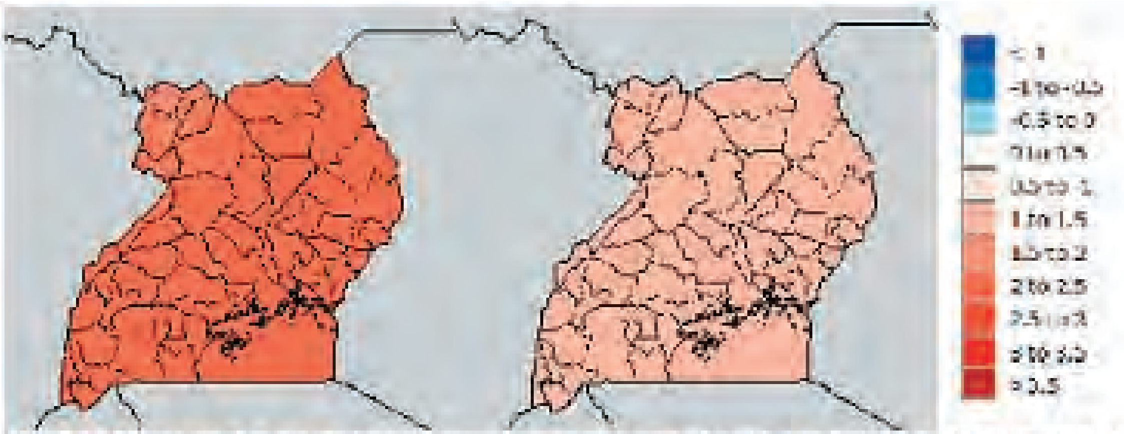


Fig. 21. Changes in annual maximum temperature for Uganda (year 2000 – 2050)
Source: IFPRI (2011)

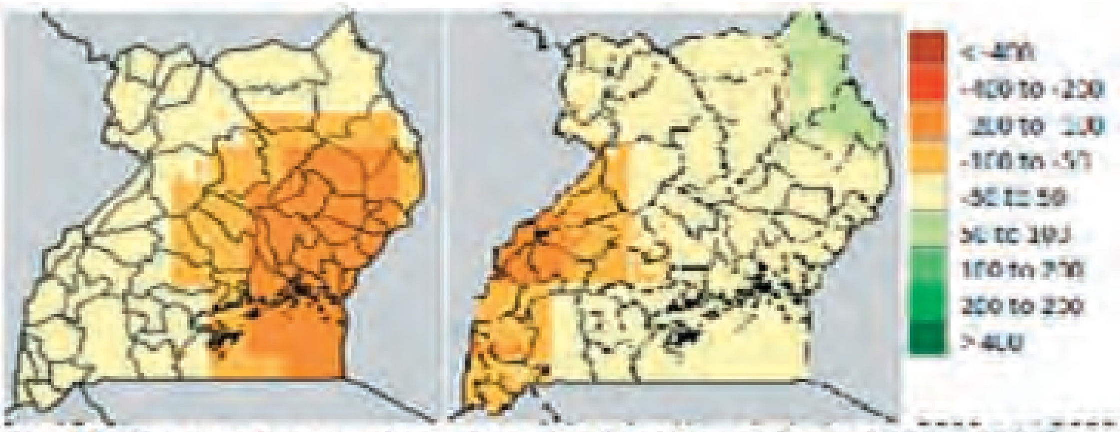


Fig. 22. Changes in annual precipitation for Uganda (year 2000 – 2050)
Source: IFPRI (2011)

the north (above latitude 3°N), the cropping systems and the dominant crops also differ. In the north, where the rainfall pattern is uni-modal annual crops such as millet, sorghum, groundnuts and sesame are major crops. Whereas, in the south, where the rainfall pattern is bimodal, perennial crops such as banana and coffee predominate. Maize, beans, cassava and cooking banana (plantain) are the most widely grown crops in Uganda in terms of hectarage devoted to the commodity and proportion of households cultivating the crop. Cooking banana (plantains) is the first in area coverage followed by beans, maize and sweet potato. According to the UBOS (2006), these were grown by at least by 3 million households out of the estimated number of agricultural households of 4.2 million. Other important crops are sweet potato and coffee. However, in the Northern region of Uganda, sorghum and sesame are more important than sweet potato and coffee. At regional level, cassava and sweet potato are mainly grown in the Central Region; maize is mainly grown in the eastern region while sorghum is mainly grown in the Northern Region. Meanwhile, finger millet, beans and cooking banana are predominant in the Western region of Uganda. However, some changes in the farming and cropping system are already taking place because of changing climate and increasingly un-predictable weather patterns.

2.2. Climate change impact and input use in Uganda

Farming systems in Uganda comprise a diversity of crops such as cereals, root and tuber crops, leguminous and oil crops. Notably, the vast majority of farming systems in Uganda is rain-fed and only a small area is irrigated. The country exhibits considerable climatic and topographic variability, and much spatial and temporal variation exists in the performance and response of the different crops grown. The impacts of climate change on the agricultural sector accordingly vary depending on the existing agro-ecological zones. Accordingly, climate change is set to hit the agricultural sector the most and cause substantial suffering particularly for all categories of smallholder farmers and is also set to bring about drastic change in the agricultural landscape of the country.

A very limited research information is available from Uganda on the impact of climate change on agriculture in general and input use in particular. A study by Bashaasha *et al.*, (2011) using different crop models to compute yields under current temperature and precipitation regimes inputting soil data, assumptions about fertilizer use and planting month, and additional climate data such as days of sunlight revealed that in the Karamoja areas of Uganda that were previously not producing maize would begin to produce the crop with maize production in the rest of country remaining fairly stable. Recent events seem to suggest this being the case, especially for the Karamoja region. A recent study reports above average rainfall for the region that it attributes to moderate La Nino weather conditions (USAID and FEWSNET, 2010). The future scenario is likely to be characterized by crop expansion into areas that previously did not grow them. This trend, observed for maize, is likely to pertain for the majority of the crop commodities and livestock.

The production and yield of cassava and other roots and tubers in Uganda are likely to trend upwards (ASARECA, 2009). The pessimistic scenario characterized by low GDP and a high population consistently shows a higher median beyond 2035. This is probably so largely because root and tubers are predominantly consumed in the rural areas and by the urban poor so that these items will remain important food sources in a population that is assumed to remain largely rural in the foreseeable future. Harvested area will trend downwards owing to increased land pressure in the traditional root and tuber growing areas so that output will increase on account of increased yield. Uganda has recently been selected as the center of excellence in cassava production and this will spur technology development, dissemination and adoption further contributing to the yield of cassava. Sweet potato and Irish potato are already benefiting from intensive research in collaboration with the International Potato Centre and this is likely to continue in the foreseeable future. Furthermore, roots and tubers are known to do well in various environments and to be reasonably drought tolerant so that their production might be least affected by climate change.

Other research reportsand the information gathered through questionnaire interview with key agricultural professionals during this study indicate that smallholder farmers have observed changes in the amount and distribution of precipitation and they are responding by increased use of short season drought-resistant crops, water harvesting and moisture conservation measure(Fig. 23), irrigation, adjusting planting dates and tree planting. Respondents further highlighted that although the potential to invest in irrigation in Ugandaand in much of Africa as a whole is high, poor performance of large-scale irrigation schemes and competition for diminishing water resources suggest that smallholder irrigation is preferable and should be promoted more aggressively. It was also noted that conservation agriculture should be recognized as one of the 'climate smart agriculture' strategies as it provides for a relief in the changing climate. Among other benefits, if well managed, conservation agriculture helps foster agro-biodiversity and other essential environmental services, which improve agro-ecosystem resilience, helping farmers to better face risks and uncertainties as a result of climate change.Furthermore, raising livestock on dry lands through seasonal migration was noted as an efficient way to makeuse of lands that are unsuitable for other forms of agriculture. Rangeland resources are typically heterogeneous and dispersed, with their variation tied to seasonal patterns and variable climaticconditions. Many researchers studying pastoral systems have concluded that extensive livestock production on communal land is the most appropriate use of semi arid lands in Africa (ASARECA, 2013).

Fig. 23. Recommended moisture conservation and water harvesting methods
Source: NaSARRI (2013)

2.3. Drought tolerant/resistant crops/varieties

2.3.1. Cereals

? **Sorghum**

In Uganda, sorghum breeding started in 1958 under the East African Agriculture and Forestry Research

Organization (EAAFRO), (NaCRRI, 2010). The breeding programme has been geared towards increased yield, resistance to insect pests, Striga drought tolerance, high grain quality. NaSARRI in collaboration with stakeholders and partners including farmers and private seed companies has so far developed and promoted high yielding cultivars. These include Sekedo and Epuripur (1995), SESO 1W, SESO 2W and SESO 3B (2011).SESO1 and SESO 2W (Fig.24)

Fig. 24. The popular drought tolerant sorghum varieties
Source: NaSARRI (2013)

- Sekedo (released in 1995) is a brown seeded sorghum variety, matures in 100 days with yield potential of 3000 Kg/ha, tolerant to drought suitable for the semi arid regions of Eastern and Northern regions of Uganda. Good for bread and local alcoholic beverages eg Local potent gin. The variety has been replaced by SESE3B which is more drought tolerant.

- Epuripur(released in 1995) - white seeded sorghum variety, matures in 110 days with yield potential of 1,800 Kg/ha, tolerant to drought and shoot fly suitable for the semi arid regions of Eastern and Northern regions of Uganda. Used for Commercial Lager beer brewing (Eagle and Senator beer brands); by cottage industries for making composite flours, bread and cakes, popped sorghum. The variety has got adulterated through mechanical mixing and out crossing hence leading for the search of new drought tolerant sorghum lines for varied end uses.
- SESO 1W (released in 2011) - white seeded sweet sorghum variety, matures in 100 days with yield potential of 2,000Kg /ha, tolerant to drought and Striga and suitable for the semi arid regions of Eastern and Northern regions of Uganda.Used for Commercial Lager beer brewing (Eagle and Senator beer brands), by cottage industries for making composite flours, bread and cakes, popped sorghum etc. Most preferred by farmers for its tolerance to drought and earliness.
- SESO 2W(released in 2011) - white seeded sweet sorghum variety, matures in 90 days with yield potential of 2,200 Kg /ha, tolerant to drought and Striga, suitable for the semi arid regions of Eastern and Northern regions of Uganda.Used for Commercial Lager beer brewing (Eagle and Senator beer brands), by cottage industries for making composite flours, bread and cakes, popped sorghum etc. preferred by farmers for its earliness and drought tolerance.
- SESO 3B(released in 2011) - brown seeded sorghum variety, matures in 85 days with yield potential

of 2,400 Kg /ha, tolerant to drought and Striga, suitable for the semi arid regions of Eastern and Northern regions of Uganda. Good for bread and local alcoholic beverages e.g.local potent gin. Exceptionally early maturing and tolerant to drought and preferred by most farmers for smooth sweet local bread when mixed with cassava.

? **Maize**

Over 80% of the farmers in Eastern and Central Africa (ECA) depend on rainfedAgriculture (ASARECA, 2009). Maize is a staple crop in the sub-region, grown mainly under rainfedconditions. This makes drought one of the major constraints affecting its production. Maize production is also affected by low levels of soil fertility, especially due tonitrogen deficiency. Three categories of maize varieties—early maturing; extra-early maturing; and drought and low nitrogen tolerant varieties were released by the framework of the Africa Maize Stress (AMS) project, a joint project between the International Maizeand Wheat Improvement Center (CIMMYT) and other stakeholders in the Eastern andCentral Africa region. Some of these varietiesbeing promoted in Uganda include ECAVL1, ECAVL2, ECAVL16 STRS, ZM621, ZM521 and Espoir. CIMMYT in collaboration with IITA, advanced research institutions, private sector seed companies, NGOs, CBOs and 11 national agricultural research institutes have developed fifty new maize hybrids and open-pollinated maize varieties and provided to seed companies and NGOs for dissemination, and several of them have reached Ugandan farmers' fields. These drought-tolerant maize varieties produce 20-50 percent higher yields than other maize varieties under drought conditions.

? **Rice**

Recent initiatives in the development and improvement of upland rice varieties have renewed the optimism of rice farmers. The varieties, known as New Rice arieties for Africa (NERICA), are moderately tolerant of multiple stress conditions,yield well and have the potential to improve farmer livelihoods. They include NERICA-1, NERICA-10 and NERICA-4 (Fig.25). In Uganda, the varieties were developed by researchers at the National Crops Resources Research Institute (Na-CRRI) working in collaboration with rice farmers, seed companies, the National Agricultural Advisory Services (NAADS) and agro-input dealers.NERICA-4 is the most widely preferred variety with an estimated market share of about 70%. Among the reasons for the high uptake are its high yield, tolerance to multiple stress conditions and its semi-aromatic trait. Uptake of NERICA-1 and NERICA-10 has not been substantiated yet but there is potential for their wider use in the country (ASARECA, 2009).

Fig. 25. High yielding, stress tolerant rice varieties
Source: ASARECA (2009)

2.3.2. Pulses

? **Cowpea**

A number of cowpea varieties are developed and released by Serere Agricultural Research Center in Uganda. Those varieties are under production in the moisture stress areas of the country. They include SECOW-1T, SECOW-2W and SECOW-3B.

- SECOW 1T (released in 2002) - brown seeded, matures in 90 dayswith yield potential of 1,200 kg/ha.The grain is nutritious with high protein content and the leaves are used as the main source of vegetables at household level.It is preferred by farmers for its high yield, tolerance to drought and dual purpose uses. It is well suited to drought prone areas of Eastern and Northern regions of Uganda with low annual rainfall regime.
- SECOW 2W (released in 2002) - White seeded, matures in 85 days with yield potential of 1,000 kg/ha under good management.The grain has attractive white skin color and it is nutritious with high protein content and the leaves are used as the main source of vegetables at household level.It is preferred by farmers for its high yield, tolerance to drought and dual purpose uses. It is well suited to drought prone areas of Eastern and Northern regions of Uganda with low annual rainfall regime.
- SECOW 3B (released in 2002) - black seeded, matures in 70 dayswith yield potential of 2,500 kg/ha under good management.The grain is nutritious with high protein content and the leaves are used as the main source of vegetables at household level.It is preferred by farmers for its high yield, tolerance to drought and dual purpose uses. It is well suited to

drought prone areas of Eastern and Northern regions of Uganda with low annual rainfall regime.

? **Pigeonpea**

SEPI 1 and SEPI 2 drought tolerant varieties recommended for the northern and eastern parts of Uganda.

- SEPI 1 is drought tolerant grown mainly in Eastern and Northern drought prone regions of Uganda. It has a yields range of 850 to 1000 Kg/ha and matures in 140 days.The grain has high protein content.
- SEPI 2 is drought tolerant grown mainly in Eastern and Northern regions of Uganda. It has a yield range of 850 to 1000 Kg/ha and matures in 110 days.The grain has high protein contents and it is used as source of food at household level.

2.3.3. Roots and Tubers

? **Cassava**

Cassava offers a cheap source of food to a multicultural population in sub-Saharan Africa. It is a source of food security for many rural households. However, in thelate 1990s, its production in the sub-region came under serious threat from the cassava mosaic disease (CMD). Through research, the Eastern Africa Root Crops Research Network (EARRNET) developed and released several cassava varieties resistant to CMD in different countries (Fig. 26). The varieties being promoted in Uganda include TMS60142 (NASE 1),TMS30337, TMS30572, SS4, SS5, TMS(2)1425, CE85, CE98, 30555-17, 95/NA-00063, 92/NA-2-TC1, MH95/0414, MH2961 and 00067 (Fig. 20); EARRNET in collaboration with national agricultural research systems (NARS), non-governmental organizations (NGOs), farmer groups/organizations and other stakeholders multiplied and distributed the varieties through the Crop Crisis Control Project (C3P). By mid-2000, the varieties werebeing used by about 80% of the small-scale farmers in Uganda (ASARECA, 2009).

Fig. 26. One of the newly promoted cassava varieties
Source: ASARECA (2009)

? **Sweet potato**

Up to 50 million children in sub-Saharan Africa could benefit from the new orange fleshed sweet potato (OFSP) varieties. Adoption of these varieties could alleviate vitamin A deficiency for 85–95% of the children, in addition to the benefits forchild-bearing women (ASARECA, 2009). Varieties being promoted by the Regional Potato and Sweet Potato Improvement Network in Eastern and Central Africa (PRAPACE) include Kakamega, Kemb 10, Zapallo, Serura, Muganda and Yanshu. High adoption rates of over 84% have been registered, with households increasing the area of land allocated to OFSP by 75–100%. Productivity gains in terms of increase in yield are between 56% and 103%. While the OFSP varieties mature early, their main benefit is their richness in pro-vitamin A. The varieties contain 20–30 times more ß-carotene than Golden rice, providing richer vitamin A source. Kemb 10 is the most widely adopted variety. Besides the economic gains, Kemb 10 is widely adaptableacross environments and has high yields (Fig. 27). The technology is currently being used in the districts of Kumi, Soroti, Katakwi, Mbale, Kamuli, Mpigi, Wakiso, Mukono, Kiboga and Luweero districts in Uganda.

Fig. 27. Kemb 10, orange fleshed sweet potato
Source: ASARECA (2009)

Improved non-orange fleshed sweet potato (NOFSP) varieties (Fig. 28) developed throughregional efforts with stakeholders are helping to combat hunger in sub-Saharan Africa,including ECA. Compared with traditional varieties, improved NOFSP have a shortergrowing cycle (3 months), yield 3–4 times higher than other varieties and can fetchover USD 300 per hectare (ASARECA, 2009). The varieties include Muganda, Kemb 10, Wagabolige,Yanshu, Kakamega and Zapallo. Muganda, Kemb 10and Kakamega were the three most widely adopted varieties with adoption rates of between 60% and 70%. This is because of their high yield, early maturity, good taste, adaptability to different environments, longevity of storage in soil, potential utilization in processing (especially in production of animal feeds) and market demand.

Productivity has improved by between 56% and 103%, while consumption of sweet potato per week has increased by 50–100%. The varieties are currently being widely produced in the districts of Kumi, Soroti, Katakwi, Mbale, Kamuli, Mpigi, Wakiso, Mukono, Kiboga and Luweero districts in Uganda.

Fig. 28. Non orange fleshed sweet potato
Source: ASARECA (2009)

2.4 Major constraints of the drought tolerant varieties

Rice yields are affected by the Rice Yellow Mottle Virus Disease withreported crop losses of 50–100% and reduction in average production to 1.5 t/ha.Although resistant varieties have been developed, resistance alone has not provedsufficient and effective control measure for the disease. An integrated approach that incorporates the useof resistance with other agronomic practices including manipulation of plantingdate and pesticide use is being implemented to manage the disease. The other major constraint on cereals is the parasitic weed, Striga.

Yield losses of over 80% have been attributed to Striga. As a result,some farmers abandoned their fields or switched to production of other crops suchas cassava and sweet potato. Striga thrives well in depleted soils, a scenario prevalentin many cereal producing areas.In rice producing areas, NERICA varieties integrated with agronomic management strategies were developed and made available to farmers to reduce the effects of Striga. The integrated package includes use ofthe new NERICA varieties, which are high yielding, drought tolerant, and early maturing. In addition, the farmers use green manure from Crotolaria spp. And plant pigeon peas in rotation with rice.

The practice has proved effective in reducingStriga infestation, improving soil fertility and subsequently boosting rice yields. Key benefits of the technology include an improvement in soilfertility because of the use of organic manure, reduction in Striga intensity in thefields, and the output from the pulses such as pigeon peas used at rotation crops.In sorghum and millet producing areas, the management package includes use of new tolerant sorghum or millet varieties in combination with well defined agronomic practices.

A number of varieties that are tolerant to Striga have been released and tested includingthe varieties released in neighboring Tanzania - Wahi andHakika, but also Seredo originally released locally in Uganda. The agronomicpractices used in combination with these varieties are moisture conservation,fertility management techniques, intercropping and weed management.

Summary and Conclusion

Most of this century's growth in world population will occur in low income countries. For example, Africa's population is projected to double from just over a billion in 2010 to about 2 billion by 2050, and most of this increase is believed to come from sub-Sahara Africa. More people means more total food demand. Projections suggest that demand for cereals will increase by 70% by 2050, and will double in many low income countries in Africa, however attaining this target might prove elusive because of climate change. For low income populations, food insecurity negatively affects future livelihoods through the forced sale of assets that are difficult to rebuild, and through reduced expenditure on education.

Agriculture in east Africa is highly sensitive to climate, both in terms of long term trends in the average conditions of rainfall and temperature, which determine the distribution of food crops, but also interms of inter-annual variability and the occurrence of droughts, floods, heat waves, frosts and other extremes. One of the expected results of climate change is increasing climate variability; for example even where mean rainfall is not projected to change, there are likely to be more significant droughts and more significant precipitation events. A changing climate is associated with increased threats to food safety, post-harvest losses and pressure from invasive species, pests and diseases.Extreme weather events and climate change will exacerbate the fragility of food production systems and the natural resource base – particularly in environments prone to degradation and desertification, in areas of widespread and intense water stress, and wherever poverty undermines the capacity of rural people to take the needed preventive steps.

Farmers can no longer rely on historical averages of temperature and rainfall, making it harder for them to plan and manage production when planting seasons and weather patterns are shifting. Rainfed agriculture is particularly vulnerable to climatic vulnerability. Modest climate change (at the levels that now seem near-inevitable, indexed by global mean temperature rise of around 2° C) is expected to lead to decreases in agricultural production in the hot and dry arid and semi-arid areas. As climate change amplifies the environmental and socio-economic drivers of food insecurity, it is imperative to prioritize where, how and when to act. The threats posed by climate change to food supplies and livelihoods are likely to vary geographically; therefore global hotspots where the threats are greatest will need to be identified, and specific, practical interventions developed to boost resilience in these areas. In east Africa the major challenge is the pronounced gaps between actual and potential crop yields and the shrinking per capita land base.In east Africa, low crop yields result from degraded lands, inherent low soil fertility, nutrient depleted soils, unreliable rainfall and inadequate water supply related to climate-change and variability. Given that shorter rainy seasons and increasing rainfall variability are predicted, it is prudent to consider specific strategies for climate changeadaptation for different farming systems. There are few fundamental approaches to implement effective climate change adaptation strategy, and those include:

1. Increased use of drought tolerant crops

Shifting to cultivation of crops that are more tolerant of droughts or shorter rainy seasons, such as switching from maize to sorghum, either as a long term change or as climate prediction information might suggest the likelihood of drier seasons. Increasing number drought-tolerant varietiesare being developed and made available by R & D institutions. These varieties can be used when fore casts suggests that there is high probability of less precipitation in the coming rainyseason. Many research institutions have developed various crop varieties suitable for specific climatic zones. For instance, new rice varieties with acceptable grain quality and yield and shorter growing duration need to be introduced into rice-growing areas. The drought olerant maize for Africa initiative has come up with drought tolerant varieties of broad adaptation, Greater efforts must be made to share those technologies across countries affected by climate related challenges such as weather irregularities.

Advanced science is being harnessed to develop climate resilient and heat and drought tolerant varieties in developed countries, and such varieties have to be introduced and used in East Africa. Case in point new bean germplasm lines containing heat, drought and disease tolerance are released by Agricultural Research Service (ARS) of the United States Department of Agriculture in US. ARS in collaboration with Tropical Agricultural Research Station in Puerto Rico, has recently released two new kidney bean germplasm lines, named TARS HT-1 and TARS HT-2, that are tolerant to high temperature conditions (Yao, 2010). TARS HT-1 yields well under high day and high night temperature stress, and TARS HT-2 performs well under high day and moderate night temperature stress. It is claimed that these lines can improve yields for farmers in regions prone to high temperature stress.On the other hand, Texas A & M University has released and tested new stress-resilient cowpea varieties combining extra-early maturity (60-70 day), high protein and high yield potential with resistance to major diseases and aphids, as well as high levels of tolerance to heat and drought (Anonymous, 2013). Again, efforsts must be made to introduce and use these varieties in areas prone to drought and environmental stress in East Africa.

2. Promoting crop diversification

- Shift to growing cash crops with existing irrigation-technologies which will earn more income and enable farmer to invest in upgrading irrigation systems among other agriculture water management interventions. Crop diversification alsoincludes integration of different varieties of crops, both food and cash crops. Crop diversification in a subsistence farming system provides an alternative means of income generation for smallholder farmers, the majority of whom are vulnerable to climate change. Because of changing rainfall patterns and water resources depletion, the existing cropping pattern is becoming less productive. Thus crop intensification, through mixed cropping and integration of high-value crops such as horticultural production, is gaining prominence as a climate change adaptation strategy. Due to shrinking natural resources and ever-increasing demand for food and raw materials, agricultural intensification is the main course of future growth of agriculture. Many agree that it is time to critically redesign alternative cropping patterns based on agro-climatic zones, and to demonstrate them in farmers' fields. Hence the need for crop diversification from:

- o low-value to high-value crops (resulting in a price-risk benefit);
- o Low-yielding to high-yielding crops (resulting in a yield-risk benefit);
- o High water-use crops to water-saving crops;
- o Single cropping to multiple or mixed cropping;
- o Crop alone to crop with crop-livestock-fish-apiculture;
- o Subsistence food crop to market-oriented crop;
- o Raw material production to processing and value addition.

- Non-food crops such as bio-fuels present opportunities for crop diversification and increased income should also be considered, albeit with caution since they compete with food crops for land, nutrients and water. Bio-fuels produce low green housegas emissions by recycling carbon dioxide extracted from the atmosphere. Besides mitigating the impacts of climate change, bio-fuels have the economic and strategic advantage of replacing fossil fuels. Due to their high economic returns with minimum investment, bio-fuels are seen by smallholder farmers as a viable alternative to labor-intensive and low-yielding cereals. Plants such as jatropha are becoming popular among small holder farmers in eastern Africa (e.g., Ethiopia). However, little information on the productivity of bio-fuels inwater-stressed conditions is available, and more research is needed.

- There is a wide variety of edible plant species in use around the world, yet research and development in east Africa has been directed to only a very few of the possible crop species suitable for agriculture, most of them cereals. Many understudied edible species compare very favorably with major grains on a production per growing time basis for protein and calories and have more favorable nutritional properties and cocking requirements. Some of these advantages may be offset by post-harvest losses, although estimated loss rates are difficult to determine, especially where the crops are used for subsistence. Many of these species can be left to be harvested as needed, or can slot into very short cropping windows, further highlighting the role they can play in agricultural systems that are more resilient and better manage the risks of climate change and extreme weather. Some species such as cassava and amaranth have been shown to thrive under hot and dry growing conditions.

3. Drought management

The national agricultural systems in east Africa region have developed technologiesthat can help farmers deal with the problem of drought in the production of crops. The technologies include:

- Improved, drought tolerant varieties, and a combination of cultural practices for improved plant growth.This combination includes conservation tillage, soil amendments, timely plantingand weed management.
- Use oftied ridges, where crops are planted on ridge tops, along ridge sides or in thefurrow. This effective

water conservation method should be promoted more aggressively to alleviate increasing moisture stress problem in the region. Compared to the flat or open ridged fields,tied ridges have been shown to result in yield increases of about 40% in maize-trials with improved varieties. Grain yield increases of about 63% and 37% wereobserved with maize varieties ACV-6 and Melkassa-1 in Ethiopia.

- ‘Push-pull’, a novel farming system developed jointly by the International Center for Insect Physiology and Ecology (ICIPE), Roth Amsted Research (UK) and national partners in East Africa, simultaneously addresses the major constraints of cereal-based farming system, including poor soil fertility. The strategy involves intercropping cereals with a repellent legume plant such as *Desmodium unicinatum*, and planting an attractive trap plant, such as Napier grass, as a border crop around this intercrop.Stem-borers are repelled or deterred away from the target food crop (push) while, at the same time, they are attracted to the trap crop (pull), leaving the food crop protected. In addition, *Desmodium* stimulates the germination of Striga seeds and inhibits their growth after germination.The technology also provides high quality animal fodder. Furthermore, since both companion plant species are perennial, ‘push–pull’ conserves soil moisture and improves soil health and beneficial biodiversity. With the ADOPT project, working on the next phase of the project, new combination of crops involving a more drought tolerant Desmodium species (D. intortum) and Brachiaria spp. The participation of ASARECA on the project can ensure that the benefits are up-scaled to other member countries not participating on this project and create wider regional impact.

4. Policy

- The commercial seed sector in most of sub-Saharan Africa accounts for less than2% of the estimated levels of the global seed trade. The seed sector in the east African region ischaracterized by high costs, with a narrow range of crops and market differencesin seed policies, laws and regulations. The result of these factors is inefficient seedsystems with low effective demand for seed and low agricultural productivity.Agricultural research, and varietal development, release and dissemination havebeen constrained by the existing laws and regulations in the different countries.These differences are a challenge to the free movement of germplasm and seed tradein the sub-region. A study commissioned by ASARECA on rationalization and harmonization seed policies, laws and regulations in selected countries has identified that key areas that deserve focus include variety evaluation, release and registration; seed certification; phytosanitary regulations; plant variety protection and seed laws and regulations (import and export). The outputs were draft agreements broadly categorized as proceduraland legal. Procedural agreements required no alteration in legislation and offeredpotential for immediate implementation. Legal agreements, however, requiredchanges in legislation and approval by law makers (Parliament) or fast track actionfrom attorneys general. Therefore, a follow up action is required to make member countries consider those legal recommendations and ultimately ratify them for implementation.
- Although the East African countries have developed policies and established institutions/structures for environmental management and climate change is-

sues, there are still a number of gaps pertaining to mainstreaming climate change matters in sectorial plans and programs, and as such the last three decades climate change issues were not key issues in the development agenda.

- Most of the policies and strategies in the East African region, especially those produced prior to 2000s and before the production of national action programs do not directly link to climate change matters. Even though they articulate matters that may contribute to climate change adaptation and mitigation, they have to be reviewed or implemented in the context of the changing climate which has significant implications for sustainable natural resources management, sustainable development and community livelihoods. This is largely attributed to the fact that climate change is an evolving and cross-sectoral concern, which requires proactive, collective and gender response adaptation measures among interrelated sectors.

In conclusion, climate change predictions for east Africa point to decreased rainfall and a rise in temperatures. Rainfall is also predicted to be more erratic and violent, further disrupting predominantly rain fed agricultural production system. The predicted future climate will also affect the productive infrastructure and exacerbate the constraints on the other livelihood systems. The climate change consequences of this state of affairs are adverse in the sense that east Africa still has a large number of poor people dependent on agriculture with poverty constrained climate change adaptation, resilience and mitigation options. At a regional level the incidence of poverty remains highest in east Africa with implications for regional integration and networking, emphasizing the need for focusing climate change interventions on most affected locations. Going forward there are significant regional/zonal differences in vulnerability and capacity to respond that have to be taken into consideration.

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Annex 1.

Questionnaire used to interview relevant professional from Ethiopia and Uganda

Climate Change and Agricultural Input Use in Semi Arid East Africa with Special Emphasis onDrought Tolerant Varieties

Survey questionnaire

1. How do you assess the impact of climate change on agriculture in the semi-arid zones of East Africa?

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   ....

2. How is climate change affecting input use (varieties and fertilizer) in the semi arid zones?

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   ....

3. Is climate change leading to drought being a more frequent phenomenon in those areas?

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   ....

   ....

4. What are our best bet options to combat climate change and drought?

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5. What is your impression about the drought tolerant crops/varieties we have at hand i.e. their role in combating drought? Are they adequate? What can be done to strengthen R & D in this area?

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6. What is your impression about the agronomic, soil and water management methods we have at hand to combat drought and climate change? Are they adequate? What can be done to strengthen R & D in this area?

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....

7. What are the policy/strategy related gaps in the ongoing effort to combat drought and climate change (especially in relation to wide dissemination and use of drought resistant crop varieties within and between countries)?

....

....

....

Name and title of respondent:__________________________________

Affiliation: ____

NB: Please include a list of drought tolerant/resistant crops/varieties from your area and pictures of those crops/varieties.

Annex. 2. Contacted persons

ETHIOPIA

1 **Dr. Nigussie Dana**
Director General- Southern Region Agricultural Research Institute (SARI)
negussiedana@yahoo.com

2 **Dr. WoldeyesusSinebo**
Ex Director, Crops Research (SARI)
wsinebo@hotmail.com

3 **Dr. EyasuAbraha**
Director General - Tigray Region Agricultural Research Institute (TARI)
Eyasu_abraha@yahoo.com

4 **Dr. Tesfay Belay**
Director, Crops Research - TARI
belayreda@ethionet.et

5 **Dr. YigzawDesalegn**
Ex Director, Crops Research - Amhara Region Agricultural Research Institute (ARARI)
yigzawdessalegn@yahoo.com

6 **Dr. FentahunMengistu**
Director General - Ethiopian Agricultural Research Institute (EIAR)
Dg@eiar.gov.et

7 **Dr. AsnakeFikre** - Director, Crops Research EIAR fikreasnake@yahoo.com

8 **Dr. AsefaTaa**
D/Director General - Oromia Region Agricultural Research Institute (OARI)
taaasefa@yahoo.com

9 **Dr. GezahegnBogale**
Senior Maize Breedern- Ethiopian Agricultural Research Institute (EIAR)

Gezahegnbogale2004@gmail.com

10 **Tolera Keno**
Maize breeder - EIAR
tolekenop@yahoo.com

11 **Dr. Kiros Meles** - Senior Plant Protection Expert - Mekelle University (MU)
Kirosm62@yahoo.com

12 **Dr. Frew Mekbib -** Associate Professor - Haramaya University (HU)
Firew.mekbib@gmail.com

13 **Dr. KetemaBelete**
Associate Professor - Haramaya University (HU)
ktmbelete@yahoo.com

14 **Dr. Mohammed Yusuf**
Senior Researcher (Plant Protection) - EIAR - mahanarc@yahoo.com

15 **Dr. HabtamuAdmasu**
Senior Agronomist - EIAR
Habtamu.admassu@gmail.com

16 **Dr. Girma Mamo**
Senior Agro-Meteorologist - EIAR
Mamo_girma@yahoo.com

17 **Mezgebu Getinet**
Agro-Meteorologist - EIAR
mezgebe@yahoo.com

18 **Dr. Asfaw Adugna** - Senior Sorghum Breede - EIAR asfawadugna@yahoo.com

19 **Kassaye Negash**
Legume Crop Breeder - EIAR
kasanegash@yahoo.com

20 **Dr. Lemma Desalegn**
Senior Researcher (Vegetable research) - Seed Producers Association
lemades@yahoo.com

21` **Dr. Mandefro Nigussie**
Director Oxfam America (Ethiopia)- mnigussie@oxfamamerica.org

22 **Dr. BergaLemaga**
Director, Research and Extension - Agricultural Transformation Agency (ATA)
Berga.Lemaga@ata.gov.et

23 **Dr. TarekeBerhe**
Director, Tef and Rice Value Chains ATA -
Tareke.Berhe@ata.gov.et

24 **Dr. Marco Quinones** Senior Director, Geographic Implementation ATA-
Marco.Qionones@ata.gov.et

25 **Dr. Tsegay Woldegeorgis**
Senior Advisor, Climate and Environment - ATA
Tsegay.Woldegeorgis@ata.gov.et

26 **Dr. Habtemariam Abate**
Senior Advisor, Geographic Implementation - ATA
Habtemariam.Abate@ata.gov.et

27 **Dr. GeremewTerefe**
SBN Coordinator - SBN
geremew.sbncoordinator@gmail.com

28 **DestaGebre**
Rice breeder - EIAR
destagebrebanje@gmail.com

29 **Dr. AbuhayTakele**
Senior Researcher, Agronomy - EIAR
Kidumet04@gmail.com

30 **Dr. FetienAbay**
Associate Professor - Mekelle University
fetien.abay@yahoo.com

31 **Prof. Mohammed Abdella**
Senior Sorghum Breeder - ICRISAT (Ethiopia)
A.H.Moahamed@cgiar.org

32 Dr. Dagne Wagari
Senior Maize Breeder - CIMMYT (Ethiopia)

33 Dr. AdefrisTeklewold
Breeder CIMMYT (Ethiopia)

UGANDA

34 Dr. Robert Anguzu
Senior Development Communication Officer - National Agricultural Research Organization (NARO)
anguzurob@gmail.com

35 Dr. Komutunga Everline
Agro-Metiorologist - National Agricultural Research Laboratories (NARO)
Komutungae@gmail.com

36 Dr. Asea Godfrey
Maize Breeder Namulunge Research Center (NARO)
grasea9@gmail.com,
g.rasea@gmail.com

37 Dr. Beatrice O. Akello
Director Serere Agricultural Research Center (Nasarri, NARO)
ibakello@yahoo.com

38 Dr. Olupot Robert
Leader, Legume and Oil crops Research - Nasarri, NARO
olupotrobert@hotmail.co.uk

39 Dr. JohnieEbiyau
Leader, Cereals Research - Nasarri, NARO
johnebiyau@yahoo.com

40 Dr. WanyeraNelson
Millet Breeder - Nasarri, NARO
mwanyera@gmail.com
mwanyera@hotmail.com

41 **Yeshi Chiche**
Head, Gender Mainstreaming - Association for Strengthening Agricultural Research in East and Central Africa (ASARECA)
c.yeshi@asareca.org

42 **Dr. HezronMogaka**
Program Manager, NRM & Biodiversity - ASARECA
h.mogaka@asareca.org

43 **Brian Esabriye**
Program Associate, Staples Program - ASARECA
brianisabirye@yahoo.com/ brianisabirye@gmail.com

44 **Dr. Ivan Ruwomushana**
Program Manager, Staples Program - ASARECA
i.rwomushana@asareca.org]

AFRICAN UNION SAFGRAD

261, Rue de la culture
01 BP 1783 Ouagadougou 01, Burkina Faso
TEL. + 226 25 31 15 98/ + 226 25 30 60 71
Website: http://www.ua-safgrad.org