SEED SYSTEMS GROUP

FEASIBILITY STUDY FOR THE DEVELOPMENT OF PUBLIC-PRIVATE SEED DELIVERY SYSTEMS IN ERITREA

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FEASIBILITY STUDIES FOR THE DEVELOPMENT OF PUBLIC-PRIVATE SEED DELIVERY SYSTEMS IN ERITREA

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ACRONYMS

AED	Agricultural Extension Department
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
CGIAR	Consultative Group for International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
DANIDA	Danish Foreign Aid Agency
DUS	Distinction, Uniformity and Stability
ECARSAM	Eastern Central Africa Research Sorghum and Millet network
FYM	Farm Yard Manure
HAC	Hamelmalo Agriculture College
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICARDA	International Center for Agricultural Research in the Dry Areas
IFS	Integrated Farming System
IHE	Institution of Higher Education
GoSE	Government o the State of Eritrea
INTSORMIL	International Sorghum and Millet Collaborative Research Support Program
MoA	Ministry of Agriculture
MoLWE	Ministry of Land, Water and Environment
NARI	National Agricultural Research Institute
NVRC	National Variety Release Committee
NSC	National Seed Committee
QDS	Quality Declared Seed
RSD	Regulatory Services Department
UPOV	International Union for the Protection of New Varieties of Plants
VCU	Value for Cultivation and Use

ERITREA'S SEED SYSTEMS DEVELOPMENT

1.0 Introduction

Eritrea is located in the Horn of Africa, lies north of the equator between latitudes 12^0 22′ and $18^0$02′ North and the longitudes $36^0$26′ and $43^0$13′ East. Eritrea is bordered on the east by the Red Sea, the south by Djibouti and Ethiopia, and the north and west by Sudan. The country covers a total area of 124,320 km^2 and has a long and pristine coastline of about 1900Km. Its territorial waters are around 120,000km^2 and has around 350 off shore islands, the biggest being the Dahlak Archipelago.

The population of Eritrea is estimated to be about 3.5 million (Eritrean Department of National Statistics, 2015) of which 70-80% live in the rural areas and derive their livelihood from agricultural activities both crop and livestock production. The country has an estimated annual population growth rate of 2.6% (World Bank, 2013). The population is unevenly distributed with 65% of them living in the Central Highlands. The population consists of nine ethnic groups: Tigrigna, Tigre, Saho, Afar, Hidareb, Bilen, Kunama, Nara, and Rashaida, each with its own language and cultural diversity. Eritrea is divided into 6 administration regions called "zoba". Administration region Gash Barka is the bread basket for the country where majority of the field crops are grown where as the regions Northern and Sothern Red Sea are the coastal desert area with less amount of rainfall (figure 1). Crop cultivation in these two regions is minimal; however spate irrigation where floods flow from the Central highlands that diverted to cropping area is a common practice.

Eritrea is in the Sahelian rainfall zone, with rainfall provided by the south-western monsoons. In normal years, rainfall varies from an annual average of 400 mm to 600 mm in the highlands and from 300 to 400 mm in the lowlands. The annual temperature and relative humidity are 15-21 and 60% in the highlands and 21-29 and40% in the lowlands respectively. The soils are dominated by Cambisols, Lithosols, Fluvisols, Regosols, Salonchak with light and medium textured and Vertisols with heavy textured soils. Climate, rainfall and topography are highly varied. The country is periodically subject to severe droughts which result in extreme food deficit for years.

1.1 Agricultural crop production systems

Agriculture is the back bone of the Eritrean economy. Over 70% of Eritrea's people are rural and depend for their livelihood on traditional subsistence agriculture including crop farming, mixed agro-pastoralist and pure pastoralist. Average family plot size is 0.75-1 ha in the highlands and2-3 ha in the lowlands. Of the total land area of about 12.4 million ha, 3.2 million hectares is arable and roughly 0.6 million ha is potentials suitable for irrigation. Although up to 2.1 million hectares of land is estimated to have potential for agriculture only about 442,600 ha is currently cultivated under rain fed and the irrigated land area is about 28 000 hectares leaving considerable potential for expansion. Together they make up for about 5% of the total land area (MoA, 2018).

The country has numerous ecological zones due to its topography. Eritrea exhibits a varied topography, rainfall and climate with altitude that ranges from 120 meters below sea level to over 3,000 meters above sea level. The diversity of ecosystems makes the country suited to produce a wide variety of tropical and temperate crops. In Eritrea, Agricultural sector is given priority by the government in order to: increase productivity, generate employment and increase income for the rural population, supply raw materials to domestic agro-industries, earn foreign exchange through high value crops and protect and restore the environment.

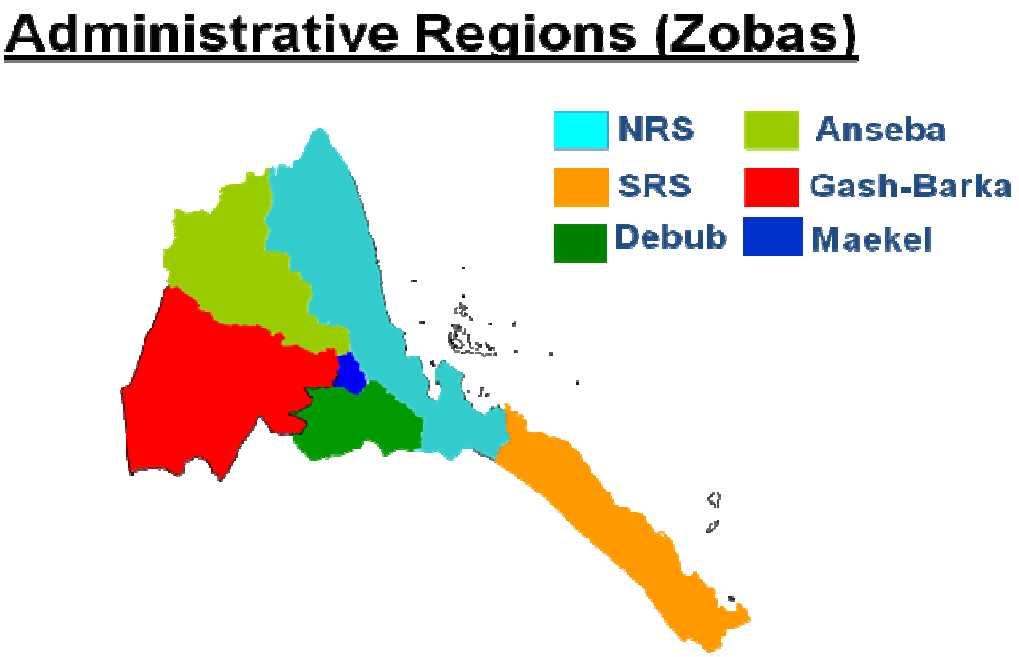

Figure1. Administration regions (zobas) of Eritrea,
Where, NRS and SRS stands for Northern Red Sea and Southern Red Sea respectively, Debub and Maekel in Tigrigna language stands for South and Central regions (zobas) respectively.

Although the majority of the population lives in the rural areas, agricultural contribution to the Gross Domestic Product (GDP) is relatively modest, accounting for only about 11.6 percent in recent years. Among other things, this highlights the low value of agricultural production, reflecting the dominance of rainfed crop production by subsistence farmers and livestock rearing by pastoralists. Yield of crops are very low, varying from 0.2 to 1.5 tonnes/ha depending on rains. Likewise, productivity of livestock is also low and subject to the unpredictable of the climate. In the past few years, poor and erratic rains have lead to frequent droughts, discouraging farmers from adopting modern agricultural practices, thus exacerbating rural poverty. In addition to the drought conditions, the country's soils are seriously eroded, particularly in the highlands, as the result of deforestation, overgrazing and inadequate resource management which is contributing to low agricultural productivity.

Traditional farming system has been widely exercised throughout the country. Therefore, the government has been endeavouring to address the issues related to traditional farming

practices and resource conservation in order to improve agricultural productivity. It launched a major development programme known as the *Integrated Farming System* (IFS) and crop-livestock production packages whose main thrust was to increase agricultural productivity through the use of modern farming practices, namely the provision of fertilizers, seeds, machinery ploughing and harvesting services. The result of IFS showed a significant yield increases in crops especially in the south western lowlands of Eritrea, where soils and rainfall are relatively better.

1.2 Current and recent agricultural development initiatives

The government of Eritrea, immediately after independence has massively invested in Agricultural sector in order to restore, sustain and enhance the productive functions of the country´s natural ecosystem resources that helps to boost agricultural production. Achievement of food-security and nutrition is the prime objective of the Government of the State of Eritrea (GoSE). Strategically, the promotion and development of the agricultural programs and support services, i.e. research and extension in livestock production, field and horticultural crops, soil and water conservation, water harvesting and irrigation development, forestry and wildlife conservation and agro-infrastructure development services, the concomitant promotion and development of the human resources and regulatory aspects of these services are determining factors for the success of the agricultural sector.

There are number of agricultural packages and projects currently the government of Eritrea implementing through the ministry of agriculture and other stakeholders. These agricultural packages include minimum household integrated agricultural package (MHAP), Land Degradation Neutrality (LDN) and soil and water conservation, integrated water harvesting systems and dam constructions. All these efforts are expected to increase agricultural productivity.

To implement the Integrated Crop and Livestock Development, Agricultural Land and Natural Resources Management Programs and Human Resource Development the following divisions and programs are in place.

Crop Development Program: (Field Crops, Horticultural Crops and Home Science)

Livestock Development Program: (Dairy Development, Meat Development, Poultry

Development and Bee-Keeping (Apiculture)

Agricultural Land and Natural Resources Management Program: (Soil and Water

Conservation, Irrigation and Forestry and Wildlife

National Agricultural Research Programs (NARI): (Management of Natural Resources; Development of appropriate knowledge and technologies for sustainable and integrated management of natural resources; Genetic Resources Development: Ensuring efficient and sustainable conservation and utilization of genetic resources; Crop Production and Pest

Management, Improvement of staple and horticultural crop productivity and quality, Generation and release of improved Agricultural pest management technologies; Livestock Development: Development of technologies for sustainable and improved livestock productivity and Agro-Engineering: Improvement of Small and Intermediate Agro-Engineering Technologies.

Besides, there are service offering programs that include Animal Health, Plant Health, Regulatory, National Plant and Animal Health Laboratory, Support.

In addition to the indicated packages and programs there specific projects under implementation that focus problem oriented targets: These include:

- The provision of drought resistant crop varieties and adoption of moisture conserving cultural practices are important in mitigating rainfed crop failures when rainfall is below normal patterns;
- Efforts was also under way to shift rainfed farming towards irrigated agriculture (year round irrigation, supplementary or spate–based) to secure harvests;
- Promotion of rational range management systems for livestock production in order to utilize such resources on a sustainable basis;
- Rehabilitation of the environment for better soil and water conservation was considered as an integral part of agriculture development; and
- The provision of support services that respond to critical problems of the individual farmers and their communities that include supplying improved crop varieties, introduction of improved animal breed and farmers advisory services.

1.3 The challenges and constraints of crop productivity related to rainfall patterns in Eritrea

Eritrea is an arid and semi-arid country and is not endowed with rich water recourses. Furthermore being part of Sahelien Africa it has been the victim of recurrent and devastating droughts. It is also a country predominantly dependent on rain fed agriculture. Worsening the situation rainfall in Eritrea is torrential, has high intensity over a short duration very unpredictable and occurs sporadically that varies greatly from year to year. Average precipitation in the country is about 384mm/year with only 1% of the total area receiving more than 650 mm of annual rainfall (FAO, 2005) (figure 2).

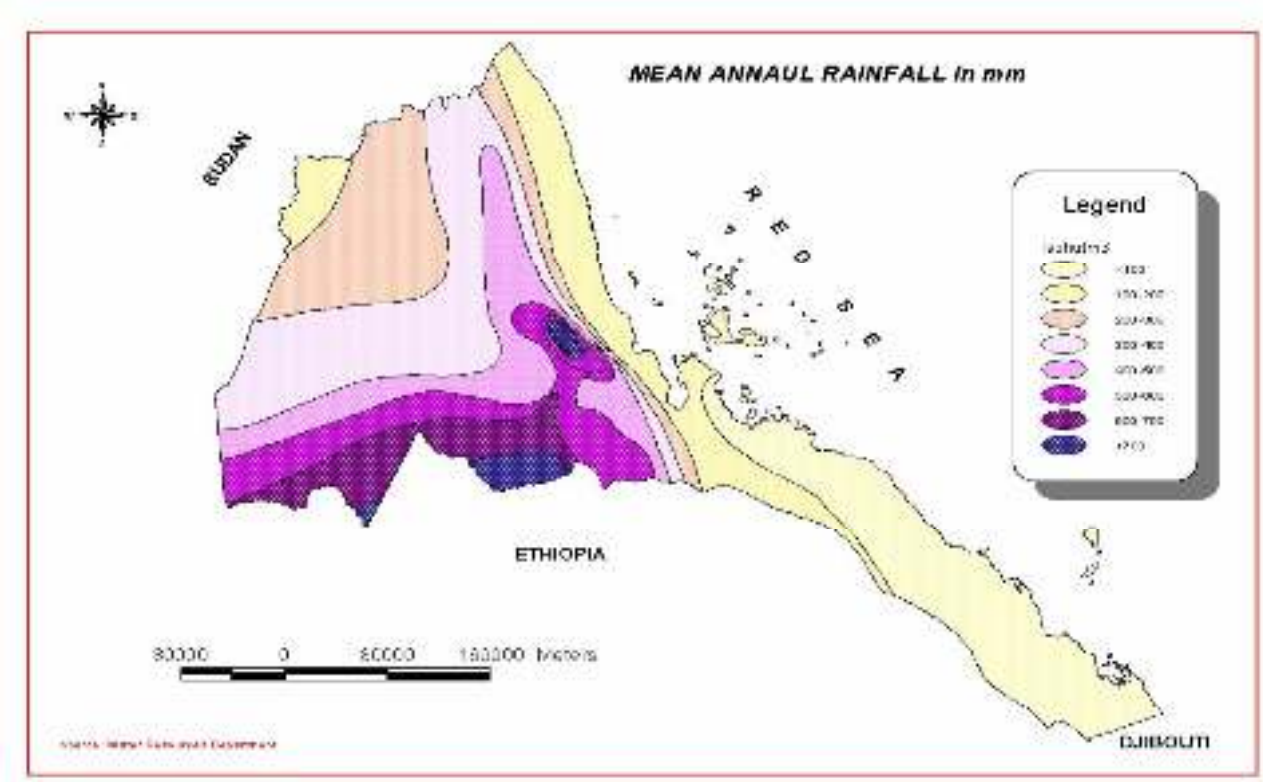

Figure 2 Mean annual rainfall of Eritrea

Seasonal rainfall variability has a direct influence on production volume of the main crops cultivated in Eritrea (Tesfamichael et al., 2018). These can be demonstrated in the following table of the major crop production and productivity by comparing two extreme years in Eritrea. In 2014 the mean annual rainfall was 450 mm while in 2015 the amount of rainfall reduced to 326 mm. The difference of 124 mm rainfall between the two years, it has an implication in making differences in crop production and productivity of major field crops of Eritrea (Table 1). In general, the total area and production is higher in all the field crops in 2014 as compared in 2015. There was a sharp decline of production in the major crops in 2015 such as sorghum in which its production was reduced by 86.9% compared to 2014 and the total area was reduced by 6.8%. It can be noted that rainfed crop production in Eritrea is highly dependent on rainfall situation.

Owing to the rugged nature the high lands (highest rainfall areas), thin soil formations, and new largely forested terrain most of the rain develops in to flash floods. Thus soil-water filtration is very low. In the low lands areas even though there are favourable geological formation, infiltration is also low owing to high evaporation rates and lower intensity rainfall. The Ministry of Agriculture put a strategic plan to focus on the use of drought tolerant crops and varieties along with proper planning date and design of soil, water conservation structures and adopt proper water use in the unpredicted rainfall patterns for improved rainfed crop production under moisture stresses conditions. In the lowland areas, water harvesting system to supplement rainfed agriculture starting from the source and divert to agricultural

lands can optimize yield of field crops. Similarly the Ministry of Land Water and Environment focuses on water harvesting system (MoLWE, 2005).

Table 1. Comparison of Cultivation Area (ha) and Crop Production (ton) of field crops in 2014 and 2015 in Eritrea

Crop type	2014			2015		
	Area (ha)	Yield (ton/ha)	Production (ton)	Area (ha)	Yield (ton/ha)	Production (ton)
Sorghum	234,254	1.0	244,345	218,233	0.2	32,091
Pearl .millet	65,856	0.5	44,772	56,920	0.2	10,348
Maize	27,343	1.0	28,424	25,636	0.7	34,019
Finger millet	24,925	1.2	30,079	23,004	0.3	7,064
Barley	34,196	1.2	42,134	34,343	0.4	12,209
Wheat	22,035	1.4	30,661	22,271	0.4	8,495
Taff	33,578	0.9	30,094	32,987	0.3	10,744
Hanfez	11,166	1.3	14,610	10,556	0.3	2,923
Total	**453,353**	**---**	**465,119**	**423,950**	**---**	**117,893**
Field peas	2,779	0.7	2,025	2,605	0.2	604
Chick peas	10,187	1.0	9,854	9,683	0.4	4,013
Vetch	5,327	1.0	5,154	5,284	0.4	2,086
Horse-bean	4,829	1.2	5,964	5,389	0.4	1,990
Lentils	1,375	0.5	725	1,549	0.2	242
Total	**24497**	**---**	**23722**	**24,510**	**---**	**8,935**
Linseed	1,736	0.5	941	1,677	0.2	373
Sesame	22,200	0.6	14,011	8,290	0.1	1,061
Ground-nut	3,514	1.4	4,775	3,305	0.1	355
Total	**27450**	**---**	**19727**	**13272**	**---**	**1789**
Grand Total	**525,300**	**---**	**508,568**	**471,732**	**---**	**128,617**

Source: Ministry of Agriculture, Division of Crop production, 2018, Asmara

1.4 The scope of development for agricultural crop production

The agricultural crop production in Eritrea is steadily growing. The cultivation area and production of the major food crops such as sorghum, wheat, barley and pearl millet are increasing from year to year. From the total 442,600 hectares of land the proportion of cereals, pulses and oil crops covered 90%, 6% and 3% respectively. This figure indicates the domination of cereals over pulses and oil crops, a situation that causes soil fertility deterioration, low productivity as well as diseases and pest infestation. In the coming five years it is planned to increase area under field crop cultivation from 442,600 ha to 565,000 ha and the productivity increases from 0.6 ton/ha to at least 1 ton/ha; corresponding total cereal production will increase from 297,440 tons to 597,780 tons (MoA, 2018). Growing cereal

crop after cereal could deteriorates the farming land and the Ministry of Agriculture set a strategic policy to include pulses and oil crops that can enrich soil fertility and serve as a source of nutritious crops to the farming community and the population of Eritrea at large. By the end of 2023 the ratio of areas covered by cereals, pulses and oil crops will shift to 55: 22.5:22.5 respectively. This is clear indication of diversifying crop production as set by the agricultural policy system of the country.

In the upcoming five years, to secure sustainable agricultural development in general and field crop production and productivity in particular, rigorous action is planned to support crop production through on farm soil and water conservation practices, crop rotation, provision of agricultural inputs such as improved seeds, fertilizers, pesticide, herbicide and assorted machinery services. Moreover, short, medium and long term trainings will be conducted to extension to researchers, extension agents and farmers. Training on crop productivity process, development of improved variety, seed production managements and soil and water conservation practices (in situ water conservation and water diversion to cropping areas) and crop husbandry programs are some of the focuses.

2.0 Crop Production Systems

2.1 Current crop production levels of major staple food crops, average crop yields, and trends, by crop

2.1.1 Crop Production Systems

The agricultural production systems characteristic for the country range from nomadic pastoral to intensive irrigated horticultural system. The vast majority of producers use traditional crop varieties, local animal breeds, and management practices. They are dependent on animal traction and household labour, and use almost no modern inputs. A small number of farmers use more modern technologies for commercial production. Due to the predominance of traditional production practices rapid return in the form of higher productivity can be obtained through the generation and dissemination of improved technology for the existing production systems.

All highland farming systems were unique in that by and large no modern inputs and no modern varieties were used. Population pressure and thus farm size are very important factors as the latter determine the farmers' ability to practice soil improvements such as fallowing and growing low yield leguminous crops (FAO, 1994). Many farmers in many areas of the highlands are practicing mixed farming. Sorghum, barley, wheat, maize are the priority crops from cereals, where as chickpea, lentil, field pea, faba bean are the priority legume crops. In the lowlands of the country, sorghum, millet and oil crops like sesame and groundnuts are well grown. Like the highland farmers, traditional farming system was common and they use local varieties for many years. In other words, farmers were not getting enough agricultural inputs through strong agricultural extension systems like improved seeds, fertilizers, pesticides, herbicides in all agro-ecological zones land preparation is carried out with traditional steel-tipped plough drawn by a pair of oxen. Method of planting is broadcasting and no chemical treatment is used. Crop protection using chemical is rare. Harvesting is done by sickle and threshing is done by oxen treading the grain. Grains are stored in large clay pots. Seed was selected by physical characteristics and threshed and stored separately till the next season. Seed source in many cases is from farmers whereby they keep seed for the next season and sometimes they share with their families and neighbours. Small scale irrigation from hand-dug wells tapping the shallow groundwater is practiced. Perennial irrigation is also practiced from shallow underground water along the Rivers of Barka and Gash. Invariably, irrigated plots are planted with vegetable and fruit crops to take advantage of the urban markets. When livestock production is considered, it accounts for a large portion of rural household income. Individual households have different kind of animal. Oxen, camels and equines are used for transport and traction. The livestock composition within the country is estimated to include cattle 1.9 millions, sheep 2.1 millions, goats 4.7 millions, camel 0.3 millions, equines 0.5millions and poultry 2.5 millions (MoA, 2019).

In Eritrea agriculture plays a central role in economic development because increases in farm productivity will provide food, income and employment for the population, marketable surpluses for urban populations, and export/cash crop production for industry and external trade. The Eritrean government inherited a badly disrupted economy, with a diminished

agricultural production capacity, damaged infrastructure, non-operational enterprises, and destroyed health and educational facilities. In spite of these, considerable progress has been made from 1991 until1998. The areas under cultivation and production levels for major crops, based on government estimates, have shown steady increases since independence, until the border conflict years. In1998 the country produced 85-90% of its food supply as the result of successful economic recovery program. There was substantial increase in crop production due to the establishment of large scale cereal crop farming by government, improved research and services, and good rainfall. In 1999, self sufficiency in food production dropped to 60-65% due to the devastating conflict with Ethiopia. Between 1995 and 1999 estimated real growth for the agricultural sector was 10.6%, and for crop and livestock in the same period real growth was 15.6%.

2.1.2 Cereal Production

Sorghum

Sorghum is the main food crop in Eritrea among cereals. The average area of sorghum cultivation in the last 10 years reaches up to 243,000 hectares with average national production of 121,500 tons. Nationally, sorghum accounts for more than 50% of total food crop production. Sorghum is particularly important in the lowlands of Eritrea where rainfall is erratic and crop failures are frequent, but it is also grown in nearly all regions of the country. Over 90% of the sorghum produced comes from subsistence farmers, who have small holdings and have not adopted improved production technologies. The productivity per hectare is about 0.6 ton. The most common reasons for this low yield in sorghum is drought, pests, diseases, weeds (Striga), and lack of improved technology such as fertilizers and manure (Tesfamichael et al.,2013). The National Research Systems in Eritrea (National Agricultural Research Institute (NARI) and Hamelmalo Agricultural College (HAC) have released different improved varieties of sorghum between 2000 and 2014. The released varieties of sorghum have been targeted to the different agro-ecological zones of the country (Table 2). The trend of production for this crop is on the increase side with two options. First the use of improved varieties though in limited regions it has been tremendously increased the productivity levels. In the year 2019 survey report on the improved variety of one sorghum variety in Gash Barka region yield level was estimated up to 3-4 tons per hectare. The second opportunity is the use the wealthy genetic resources of this crop.). In a sorghum genetic analysis of Eritrean and ECA countries collection it was found that the Eritrea sorghum collection have unique traits as compared to East and Central Africa sorghum collections (Tesfamicael,et al.,2014). This is therefore another opportunity for the potential improvement using landrace based diversification and breeding programs. As per the recent cultivation and production data information of the ministry of Agriculture, The trend of sorghum production is increasing from year to year.

Table 2. Improved variety of sorghum released between 2000 and 2014 in Eritrea

No	Variety Name	Year of release	Yield (ton/ha)	Agro ecological zone	Special features and use
1.	Bushka (ICSV 210)	2000	3-3.6	Central mid highlands and western lowlands	Good grain quality for injera making and palatable stover for animal feed
2.	Shambuko (PP 290)	2000	2 – 3	Central mid highlands and western lowlands	Good grain quality for injera making and palatable stover for animal feed
3.	Laba (89 MW 5003)	2000	3-3.6	Easter lowlands (under spate irrigation)	High ratoon capacity, good injera and local drink making
4.	Shieb (89 MW 5056)	2000	3.6-3.8	Easter lowlands (under spate irrigation)	High ratoon capacity, good injera and local drink making
5.	Macia	2000	2.5– 3.5	Western lowlands	Excellent injera and bread making and stover is good for animal feed
6.	Seare (ICSV 111)	2006	2 -2.5	Central mid highlands and western lowlands	Resistant to striga and drought (staygreen). Good for injera making and stover for animal feed
7.	Tebeldia (P 9401)	2010	2 – 2.5	Central mid highlands and western lowlands	Resistant to leaf rust and striga. Good grain quality for injera making and stover for animal feed
8.	Maoloba (P 9407)	2010	2 – 2.5	Central mid highlands and western lowlands	Resistant to leaf rust and striga. Good grain quality for injera making and stover for animal feed
9.	Hamelmalo	2010	2.5 -3.0	Central mid highlands and western lowlands	Striga tolerant and drought resistant (staygreen). Good for injera and porridge making

Pearl Millet

Pearl millet is the second most important cereal crop in Eritrea. The average area of cultivation is about 61,388 hectares with average national production of 28,000 tons. The national yield levels ranges from 0.2 to 0.7 ton per hectare. It is predominantly grown in less favourable environments where rainfall is variable and low (250-300 mm); and the grain is good for human food whilst the straw is used as feed for livestock. The Pearl Millet Improvement Program at the National Agricultural Research Institute (NARI), through conventional plant breeding, has identified two higher yielding pearl millet varieties, Kona and Hagaz, in collaboration with ICRISAT, which are adapted to Eritrea's marginal environments. In some regions of Eritrea, farmers are shifting from sorghum to pear millet production due to striga infestation. Pear millet is immune to striga infestation in Eritrea. Improved varieties of pearl millet have been released to farmers in different agro ecological

zones named as Hagaz, Kona, White Kona, White Bristle Kona and Gergef (Table 3) Similar to sorghum, the production of this crop is on the increasing side with available improved released varieties. The area under pear millet production is increasing from year to year. This is especially true in certain regions of Eritrea where sorghum cultivation is affected by striga. Because pearl millet is immune to striga infestation, the sorghum areas is replaced by pearl millet cultivation.

Table 3. Improved variety of pearl millet released between 2000 and 2013 in Eritrea

No	Variety Name	Year of release	Yield (ton/ha)	Agro ecological zone	Special features and use
1.	Kona (ICMV 221)	2000	1.7 – 2	Eastern and Western lowlands	Resistant to Downy mildew disease and pests. Good for injera bread and porridge preparation.
2.	Hagaz	2004	1.8-2.1	Eastern and Western lowlands	Resistant to Downy mildew disease and pests. Good for injera bread and porridge preparation.
3.	White Kona	2011	1.5-1.8	Eastern and Western lowlands	Drought and Downy mildew resistant. Good for injera bread and porridge preparation.
4.	Bristle Kona	2012	1.5-1.8	Eastern and Western lowlands	Drought and Downy mildew resistant. Good for injera bread and porridge preparation.
5.	Bristle White Kona	2013	1.5– 1.7	Eastern and Western lowlands	Drought and Downy mildew resistant. Good for injera bread and porridge preparation.

Wheat

Wheat is grown in the central and mid highlands in Eritrea. This crop is cultivated annually in an area about 22,000 hectares. The national yield reached up to 19,000 tons with productivity of 0.9 tons per hectare. The breeding program of wheat is one of the earliest researched crop commodities in Eritrea. Its improvement goes back during the Italian colonization time. However, the research during that time was conducted in limited sites of the country. Since the Eritrea's independent wheat was considered as one of the major commodity crop along with other cereals. Several wheat varieties have been developed and adopted in the country through the collaboration between NARI and International Centre for Agricultural Research in the Dry Areas (ICARDA) since 2000. The National Agricultural Research Institute (NARI) has released 16 different improved varieties of wheat between 1998 and 2014. However, the major ones that are currently under cultivation will be reviewed and discussed (Table 4). The released varieties of sorghum have been targeted to the different agro-ecological zones of the country. There is a clear indication of increasing in the trend of wheat cultivation and production in Eritrea especially with the recent practice of IFS implemented by the ministry of agriculture. The yield levels of wheat for those who are undertaken the IFS got three fold increases over the local wheat varieties.

Table 4. Improved variety of wheat released between 1998and 2013 in Eritrea

No	Variety Name	Year of release	Yield (ton/ha)	Agro ecological zone	Special features and use
1.	Pavon-76	1998	1.5-2.2	Central and mid highlands with wider adaptation	Excellent for bread preparation
2.	Quafza	2006	1.5-2.1 under rainfed 7-8 under irrigated	Central and mid highlands	Excellent for bread preparation
3.	Atila	2006	2.1-2.5	Central and mid highlands	Good for bread preparation
4.	Goumria 15	2006	1.7- 2.1	Central highland	Good for bread preparation.
5.	Croc-1	2013	3.5-4.0	Central and mid highlands	Good for bread preparation
6	Sidrra-1	2013	3.5-4.0	Central and mid highlands	Good for bread preparation

Barley

Barley is another major staple cereal crops in central highlands of Eritrea which cultivated under rainfed condition with annual rainfall ranging 400 to 600 mm. There is high genetic wealth and diversity available in Eritrea with unique traits that can enhance biotic and abiotic agricultural problems. The landraces are still the back bone of barley production in Eritrea; on the other hand, the yield is below 1 ton per hectare in farmer's field. However, there were several research programs on barley since 1997 in collaboration NARI with ICARDA through farmer's participatory breeding. This results into the release of improved version of landraces in the country. Barley has been also grown as mixture with wheat locally known as Hanfetz. Barley is known for its multipurpose preparations in food such as good local bread, roasted grain and key ingredient of beer as malting barley. The improved varieties and adopted since 2002 are categorized into food barley and malting barley (Table 5).

Table 5. Improved variety of barley released/ adopted between 2002and 2013 in Eritrea

No	Variety Name	Year of release	Yield (ton/ha)	Agro ecological zone	Special features and use
1.	Tokondae (Food barley)	2002	1.5 – 1.9	Central highlands	Good bread preparation and stover for animal feed
2.	Shishay (Food barley)	2002	2.1-2.3	Central and mid highlands	Excellent for bread preparation and animal feed
3.	Rahwa (Food barley)	2002	1.1-2.1	Central highlands	Good bread preparation and stover for animal feed

4.	Kulih (Food barley)	2006	1.7- 2.2	Central and mid highlands	Good for bread preparation
5.	Proctor (Malting barley)	2002	2.2	Central and mid highlands	Developed by Ethiopian Research Institute. Good for preparation beer
6.	Holker (Malting barley)	2002	2.2	Central and mid highlands	Developed by Ethiopian Institute Agricultural Research. Good for preparation beer
7.	Beka (Malting barley)	2002	2.2	Central and mid highlands	Developed by Ethiopian Institute Agricultural Research. Good for preparation beer

Maize and Taff

Maize and Taff are the two least researched crops in Eritrea. It is only the farmers traditional varieties and landraces widely grown for the two crops. Taff yield is below 0.7 ton per hectare. These two crops are also widely grown in Ethiopia. With the current normalization of Eritrea with Ethiopia, those taf and maize varieties developed by the Ethiopian Agricultural Research Organization can be adopted in Eritrea climatic condition. The commonly grown taf landraces are red and white grains and mixes of the two. There are three improved and adapted maize varieties released by NARI. These are:

Maize 04 SDIVE

- The source of the variety is from CIMMYT
- It gives yield ranges of 2.5 – 3.0 ton per hectares
- Good for injera, bread, porridge and snack preparations
- Well adapted to eastern and western lowlands
- Released by NARI in 2013

Early Local

- This variety is developed from local landraces and released by NARI in 2013
- Has yield levels of 1.0 to 1.5 tons per hectare
- It is extra early and with drought escaping mechanism
- Well adapted to central midlands, eastern and western lowlands
- Good for injera, bread, porridge and snack preparations

Maize Alla

- Developed for its earliness from local maize population
- Released by NARI in 2013 with yield levels ranged 2.5 – 3.0 ton per hectares
- Well adapted to central midlands, eastern and western lowlands
- Good for *injera*, bread, porridge and snack preparations

2.1.3 Other Field Crops

In addition to cereals there are different pulses, oil crops and industrial crops grown in different part of Eritrea. The commonly grown Pulse crops include faba bean, lentil, chick pea, common pea, cow pea and grass pea. Faba bean, lentil cowpea and common pea are cool season crops grown in the central and mid highlands under rain fed condition. However, chick pea and grass pea grown under residual moisture when the main rainy season recedes. The major oil crops in Eritrea include sesame, ground nut, linseed, Niger seed and cotton. Except linseed that is grown in central and mid highlands the remained are grown in eastern and western lowlands. Besides, there are two industrial crops cotton and sisal. For these crops cultivar grown are landraces and farmers varieties where there was no research conducted.

In areas where improved seed is distributed, a significant amount of yield increment estimating 50-100% was recorded. In line with the supply of improved seed, soil and water conservation activity is going on as top priority of the Government of Eritrea. Taking this in to consideration, several big and small dams as well as small and large diversion schemes were constructed by the ministry of agriculture.

2.2 Description of the country's main agro-ecologies and their cropping systems

Agro-ecological zones

In Eritrea, in spite of its limited and smaller area, it has a wide range of agro-climatic conditions related with altitude, which goes from below sea level up to 3,000masl. Based on the agro-climatic and soils parameters, Eritrea is divided into six Agro-ecological zones as summarized below (figure 3). The summary of this category of agro-ecological zones is mainly related to the climatic information and cropping system such as rain fall, temperature, altitude and crop production (Amanuel et al., 2002).

1. Central Highland Zone (CHZ)

This zone is above 1500 meter, which comprises moist highland and midland with heavily eroded plateau and most part with warm to cool semiarid climate. The annual rainfall, occurring in main rainy season (June-September), ranges from less than 400 mm to more than 700 mm and the potential evapo-transpiration is 1300-1800 mm. There are three important production systems are in this agro-ecological zone (Central highlands, Central North midlands and Central Southern midlands). The rain fed cereal/pulses system are the major production system. It also depends on animal power ploughing and threshing (oxen). Major crops grown are wheat, barley, sorghum, finger-millet, maize, taf, peas, beans, chick pea and linseed and horticultural crops like potato, tomato, cabbage, lettuce and oranges. Small ruminants are reared by most of the families for meat and milk and as a source of cash. Communal grazing areas and seasonal migration of herds to the lowlands are prevailing.

2. Western Escarpment Zone (WEZ)

This zone ranges between 600-1500 meters above sea level and has a warm to hot semiarid climate. Its soil is determined by the geology of the central highlands. However, in terms of climate, cropping and population density, it has much in common with the south-western lowlands with which it joins. The average annual precipitation, occurring in summer like in the CHZ, is between 400-500 mm. The production system is agro-pastoralist and the main rainfed crops grown are sorghum, pearl millet, taf, maize, sesame, cowpea and chickpea. Larger herds compared to the CHZ include cattle, sheep and goats. The area crossed by the river Anseba is particularly suitable for production of citrus, grapes, a wide range of tropical fruits and all kind of vegetables under irrigation (Amanuel et al., 2002).

South-western Lowland Zone (SWLZ)

Hot, semi-arid, 500-950 m in altitude with average annual rainfall ranging between 500 to 700 mm. This zone has hot semiarid climate and summer rainfall in excess towards the south-west. Topographically is flat with soil quite different from those of the highland and transition zone. The population density is very low. The principal production systems are semi-sedentary agro-pastoralist system; crop/livestock sedentary mixed system. There are also nomadic pastoralist tribes whose main activity is livestock rearing (primarily camels, cattle and small ruminants). This zone practices small scale irrigated horticultural system and commercial farming. Grain sorghum, pearl millet, and sesame are the major crops. This zone is identified as having the greatest potential for agricultural development.

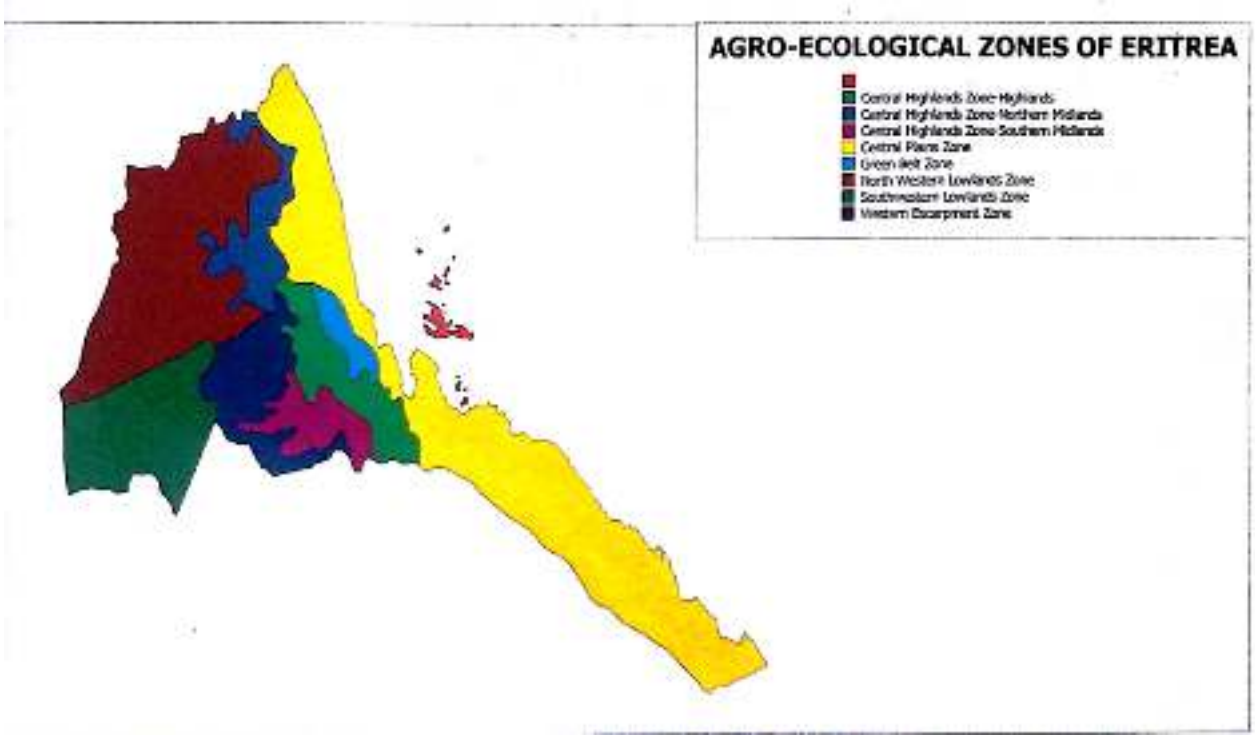

Figure 3. Agro-ecological zones of Eritrea

3. North-western Lowland Zone (NWLZ)

This zone has an altitude of 400-1600 meters above sea level with hot arid climate and rainfall ranging between 200-500 mm with summer precipitation in the extreme North West is below 200 mm. The principal production systems are the nomadic pastoralist and irrigated commercial fruit/vegetable production. Grain sorghum and pearl millet are major crops grown in this zone.

4. Green-belt Zone (GBZ)

The zone, located on the eastern escarpment of the CHZ, has elevation more or less 750 to 2,200 meters above sea level with microclimate range from sub humid temperate to humid tropical (figure 3). It is characterized by the highest rainfall area in the country with average annual precipitation from 700 to 1100 mm, occurring between November and March. The slopes are often steep and the permanent population density is low but is used also by neighbouring central highland people for seasonal transhumance. The production system is mixed cereal/pulse based including cultivation of permanent trees (coffee in the higher areas), annual crops (maize, wheat, barley, sorghum) as well as different pulses and vegetables, potato in particular. In the lower areas, citrus, bananas, vegetables, maize and sorghum are cultivated (Amanuel et al., 2002).

5. Coastal Plain Zone (CPZ)

The CPZ ranges from below sea level to 600 m with desert climate where rainfall, occurring during winter (short rains) like in the GBZ, is less than 200 mm. It has an average rainfall of less than 200 mm. The production system is nomadic pastoralist. Rain-fed arable cropping is non-existent; however, grain sorghum and vegetables are produced under spate irrigation that flooded from the central highlands.

2.3 Current status of agricultural extension activities

The extension strategic plan of MoA emphasis for the resources and outputs and offer the greatest possibilities for supporting future agricultural growth. The strategic plan includes effective water management and reforestation, increase field and horticultural crop productivity through agronomic practices and input supplies, improve livestock productivity and human capital development including management skills.

The intended outcomes of Eritrean research and extension services are improved food production and enhanced food security through a partnership between farmers and extension providers. However, the adoption of technology and agronomic practices and sustainable use of natural resources are generally limited by availability of operating funds.

Responsibility for the delivery of extension services is situated at the zoba (region) local government or sub-zoba (district) level, where extension officers work closely with influential village elders and other farmers who are considered to command respect in local communities(Jay and Coventry, 2010). Where project funds are available, local influential

farmers may assist in the dissemination of key extension messages. The extension program in Eritrea stretched its horizon throughout the country. Enough extension experts are available at head quarter level, Zoba (regional), sub-zoba (district) and village administration levels. The extension program at head quarter level has the following major functions.

- implement strategic policies of MoA in all regions of Eritrea,
- Conduct training at all levels on different agricultural practices,
- Create linkages at national with relevant stakeholders, regional and international linkages.
- The extension experts have MSc., BSc, Diploma and certificate qualifications.

The function of agricultural extension at zoba (regional), sub-zoba (district) and village administration levels conduct various activities including farmers advisory service, conduct on farm and demonstration trials (improved seed and fertilizer trials), Input distributions (Seeds, herbicides and tractor services) through credit and marketing unit, and rain farmers on seed production, crop management and soil and water conservation practices. The number of experts varies from region to region according to the potential productivity, size of the zoba (region) and sub zoba (district) and number of household. However, the Experts qualifications are graduates at BSc and Diploma level assigned up to village administration. Currently there are no non governmental and private sector organizations entitled to facilitate the agricultural extension program in Eritrea.

2.4 Level of adoption of improved crop varieties, by crop

Farmers obtain seed for cultivation from both farmers' seed systems and formal seed systems. However, more commonly, farmers get access their seed from sources farmer-based seed systems by individual farmers saving seed from harvests, exchanging seed with their neighbors or purchasing grain from the local market and using the same as seed. The level of adoption of improved crop varieties varied from crop to crop as well as farmer to farmer. The major factors for low adaptation of improved crop varieties in Eritrea include:

- **Insufficient and fragment land for seed production:**

In Eritrea farmers' landholding is small and fragmented. Without enough land available for seed production existing fragmented land have to be subdivided, limiting the producer's ability to ensure the appropriate level of isolation. This lack of isolation, in turn leads to contamination of seed. Additionally, the continuous use of the same land on an annual basis can result in accumulation of diseases. Due to the rigid isolation distance farmers can't multiply improved seeds that results into low adoption.

- **Lack of supply of appropriate varieties:**

Variability in supply of appropriate varieties can lead to lower demand due to farmer frustration in having access to the variety one season and not having access to it in the next season. Interviews indicate this can lead to farmers leaving the formal sector or using older varieties with more stable supply.

- **Limited awareness and reluctance of farmer to use improved variety:**

Limited availability of information about best agronomic practices and a lack of current market data for farmers can lead to a low level of awareness about the appropriate varieties to use and potential level and source of supply of these varieties. Small scale farmers in Eritrea have a long history of using their own traditional variety and they are reluctant on the use of improved variety. It is for this reason they used to adopt the improved variety slowly. However, since 2016 the trend of farmer's interest to use improved varieties is increasing through the continuous popularization and promotion by the Ministry of Agriculture.

2.5 Level of utilization of fertilizer and manures to increase crop yields, by crop

Eritrea has been endeavoring to address the issues related to traditional farming practices and resource conservation in order to improve agricultural productivity. It launched a major development program known as the "Integrated Farming System (IFS)" whose main thrust was to increase crop production through the use of modern farming practices, namely the provision of fertilizers, seeds of improved variety, machinery ploughing and harvesting services. However, for majority of the Eritrean farmers the level of inorganic fertilizer utilization is very low. The main reasons are farmers have limited access due to non availability, high cost and if available priority of application is given to high value horticultural crops. Besides, priority of fertilizer supply in field crop improvement is given to those farmers who joined the cluster IFS for seed multiplication of improved varieties by MoA. Aside from government there are several other sources of inputs fertilizers for farmers, which include: commercial purchases from private traders. However, this supply is unaffordable for small scale resource poor farmers. The alternative source of fertilizer is to use farm yard manure (FYM). Even this FYM is available for those who own livestock resources. Therefore the general trend of fertilizer utilization in Eritrea is low in both inorganic and FYM.

2.6 General description and trends of the current system for marketing surplus production of staple crops

Majority of the population of Eritrea relies on agriculture for their livelihood, practicing a subsistence form of farming. Due to biotic and abiotic factors the yield of the major field crops are below 1 ton per hectare. Almost 90% of the crop production for Eritrean population comes from subsistence farmers who produce for their family consumption. In the previous ten years no or limited surplus production has been recorded. However, in a good season, surplus grain is traded in order to provide some form of cash flow for families, and much needed grain for the domestic market place only. After the peace agreement between Eritrea and Ethiopia the value of food crops becomes cheap and the population get access good price in the grain market places. As the Eritrean population is dependable on the staple field crops, the market trend development and opportunities for these staple crops are optimistic and available.

3.0 National Agricultural Research System

3.1 Background

After independence of Eritrea 1993, the government has initiated the task of establishing public sector organizations to stimulate economic growth and to provide basic services for its population. Strengthening the national agricultural research system and extension services were among of the high priority given sector. Through the assistance of ISNAR and FAO medium term and long term strategic plan for the national research system was developed in 1994.

The agricultural research policy of Eritrea emphasizes increased production of traditional and high value crops and livestock, and the development of irrigation and water resources adequate to support an export oriented agricultural sector. The broad strategy for improved agricultural research system is a major increase in the flow of relevant technologies to farmers to underpin productivity growth in the agricultural sector, with particular attention to traditional production systems and the promotion of high value commodities for export. Research systems have been engaged in developing, testing and disseminating agricultural technology to producers that enhances national and farm level food security that is the highest priority of the government. There was two way approaches for the implementation for the research in Eritrea:

1. The identification and promotion of high value crops/commodities to increase income levels from agricultural products
2. Improvements in the production levels of traditional food crops and livestock.

Farmer participatory research which involves farmers in planning and executing the testing and adaptation of agricultural innovations to suit their needs and circumstance was another recently used research approach. Priority setting was based on identification of farmers' constraints at two levels: between production systems, and among commodities and themes.

3.2 Description of the public institutes and universities actively engaged in crop breeding

a. Description of the National Agricultural Research Institute (NARI)

The Agricultural Research and Extension Division was established in 1994 with its goals, objectives and strategies. In 1997, it was restructured as Department of Agricultural Research and Human Resource Development (DARHRD) and then in 2003 into the National Agricultural Research Institute (NARI). NARI is one of the three departments of the Ministry of Agriculture; its mandate is to conduct research on crops, livestock, horticulture, natural resource management and agricultural engineering and to provide relevant short and long-term training.

There are four divisions in NARI namely, Animal Resources Research, Crop Development Research, Natural Resources Management Research, Agricultural Engineering Research and

Human Resources Development and Training with three service giving units; Socio Economics Unit, Planning and Statistics Unit and Communication and Public Relations Unit.

The crop development research is the division that implements breeding programs in field crops. The field crop breeding program conducted at NARI includes in sorghum, pearl millet, barley, wheat and legume improvement Programs. Currently there is several senior and junior staff in NARI who is engaged in crop breeding program. Eritrea good network of research stations throughout the country. The main stations and satellite along with the major crop commodity implementing is indicated in table 6.

b. Description of the Hamelmalo Agricultural College (HAC)

HAC is the only Institution of Higher Education (IHE) in agricultural sciences established in 2005 under the National Higher Education and Research Institutes. The commencement of the college comes with several purposes including the nation's experts in agricultural sciences and natural resources managements are insufficient to shoulder the agricultural development plans of the country. The demand for appropriately trained skilled manpower by both private and public sector is very high at undergraduate and post graduate levels. The demand for research and consultancy services in the areas of agriculture is increasing. Short but intensive courses to upgrade capabilities of personnel needed for national reconstruction is very highly demanded. Thus the objective of establishing of this college is to train human resources at undergraduate and post graduate levels; execute basic/fundamental, applied and adaptive research and services to society with outreach and consultancy services. The college has both nationals and expatriate teaching staff with diverse experience and area of specialisation. Currently the college has six departments namely Agronomy, Horticulture, Plant Protection, Animal Science, Veterinary Sciences and Land resources and Environment with one service giving department called Allied Science. All the six departments offered undergraduate programs in degree and diploma level. Besides, the departments of Agronomy, Horticulture, Animal Science and Land resources and Environment has been offering postgraduate programs at MSc. Level.

The staffs of the Plant Science (Agronomy, Plant Protection and Horticulture departments) besides to the academic teaching activities they are engaged in research programs. One of the researches program is the improvement of crop variety through breeding. There is several senior and junior staff engaged in field crop breeding programs. The major crop commodities along with breeding centers and agro-ecological zones are indicated in table 6. The NARI and HAC staff who are involved in field crop breeding program is also indicated in table 7. Besides, the senior staffs of NARI and HAC are also participated in national, regional and international collaborative breeding activities.

Table 6. Plant Breeding Centers in Eritrea

Organization	Station	Agro-ecology	Region	Mandate Crops
National Agricultural Research Institute (NARI)	Halhale	Highland and midland	South	sorghum, wheat, barley, legumes, maize, fruits and vegetables, forage crops
	Goluj	Western lowland	Gash Barka	Sorghum, pearl millet, sesame, cotton
	Shieb	Eastern lowland	Northern Red Sea	Sorghum, millet, date palm
	Shambuko (sub station)	Western lowland	Gash Barka	sorghum, millet, legumes, vegetables, Forage crops
	Hagaz (sub station)	Western lowland	Anseba	Sorghum, millet, peanut vegetables and citrus
	Gahtelay (sub station)	Eastern lowland	Northern Red Sea	Citrus and date palm
	Tekreret (Substation)	Western lowland	Gash Barka	Banana and Mango
Hamelmalo Agricultural College (HAC)	Hamelmalo	Western lowland	Anseba	sorghum, millet, peanut vegetables, citrus, Mango and guava
	Agronomy (Department)			sorghum, millet, peanut, sesame and pulse crops
	Horticulture (department)			Hot pepper, Tomatoes, Egg plants, Guava, Mango and Citrus
	Plant Protection (Department)			Breeding on different field crop diseases and pests

3.3 Nature of Recent or ongoing crop improvement activities by crop

Currently the national agricultural systems both NARI and HAC are continuing the previous crop improvement activities in two ways. The introduction of improved germplasm and adaptation trials is still in place to find superior cultivars suitable to the Eritrean climatic condition. The second approach is focusing on the Eritrean germplasm to make diversified through introgression with introduced exotic cultivars or local landraces with local. Varieties that developed with the second option can give more durable and sustainable production. As Eritrea is the center of origin for majority of the field crops, there are special features in the Eritrean landraces that can overcome many agricultural production constraints. The details of the recent and ongoing crop improvement activities and the outcomes are indicated in detail in section 2.1.1, 2.1.2, 4.2 and 4.3.

3.4 Level of capacity of public crop breeding institutions

There are several experts involved in plant breeding program in Eritrea. The plant breeding personnel indicated are Eritrean national staff available at the National Agricultural Research Institute and National Higher Education and Research Institute mainly in Hamelmalo Agricultural College (Table 7). Similarly the biotechnology program that includes Molecular Breeding and tissue culture experts available at the National Agricultural Research Institute and National Higher Education and Research Institute that includes Hamelmalo Agricultural College.

Table 7. Number of national staff involved in plant breeding and their educational level in NARI and HAC, Eritrea

Educational Level	Plant Breeding by year						Biotechnology by Year (Molecular Breeding and Tissue Culture		
	1995	2000	2005	2010	2015	2019	2005	2015	2019
PhD	1	2	3	3	2	2	2	3	4
MSc	2	4	3	2	2	3	-	-	1
BSc	4	6	7	10	12	17	1	2	4
Diploma	3	6	4	2	3	1	1	1	1
Total	**10**	**18**	**17**	**17**	**19**	**23**	**4**	**6**	**10**

As per the data available for 2019, currently there are about 23 experts engaged in field crop breeding in the head quarter of NARI, Halhale and HAC and other research centeres and sub stations that are found in different regions of Eritrea (Table 7). The Biotechnology program and experts are found in the main centres at Halhale of NARI and Hamelmalo Agricultural College only. The experts in breeding and biotechnology indicated are mainly engaged in cereal crops (Sorghum, Wheat, Barley and Pearl millet), Oil crops (ground nut and Sesame) and Pulses (Chick pea, Pea, Faba bean and Grass pea). Even though the trend of experts seems at the increasing level, there are still gaps of qualified breeders on the major field crops. The young generation requires further long term training in plant breeding and biotechnology fields to sustainably continue the breeding efforts so far in place and also fill the gap.

Infrastructures used in plant breeding in NARI and HAC, Eritrea

The infrastructures and laboratories used directly or indirectly in plant breeding is indicated as follow:

Halahale research station: In the NARI, at Halhale research center the infrastructure and laboratory includes laboratories for general seed testing, soil science, tissue culture, biotechnology and national seed bank. These laboratories have basic equipment to conduct research that can contribute to crop enhancement. However, they lack some chemicals and consumables.

Hamelmalo agricultural College: the facilities and laboratories at HAC include laboratories for general agronomy, general seed testing, tissue culture, food science and biotechnology.

3.5 Recent or ongoing collaborations with public institutions, farmer-based organizations, and private sector in seed supply

Nationally, the staffs of NARI and HAC have good collaboration in conducting breeding programs on priority crops such as sorghum, millet, maize, barley, and wheat and grain legumes. Besides, between 2007 and 2017 the MSc training program at Hamelmalo Agricultural College helps to create good linkage between the MSc candidates and the national research system to conduct breeding program and research on field crops.

Under crop breeding program there was strong collaboration program with the CGIAR centres such as ICRISAT and ICARDA. The ICARDA collaborative program since 2004 was focused on wheat and barley breeding and diversification with full participation of farmers. The variety selection program on the two crops is still under progress. Legume crops are also important crops under the mandate of ICARDA such as chickpea and lentils. Some participatory trials in farmers' fields has been conducted on materials that are collected from farmers' fields and introduced from ICARDA. Similarly, the collaboration program between NARI and ICRISAT has been initiated since 1995 targeting on sorghum and millet programs. Continuous introduction of genetic materials of sorghum and millet have been implemented and tested for initial adaptation, advanced and on farm trials with backstopping of ICRISAT experts. Since 2004 the breeding programs of Eritrea on field crops become very strong with the national breeders. As a result of these two collaborative programs a number of field crop varieties have been released for farmers use in different agro-ecological regions. The on farm and farmers participatory breeding has given strong footage to the Eritrean breeding program where farmers got chance to select appropriate and promising germplasm adapted to their farming situation.

In addition to the CGIAR collaboration program effective linkage were established with regional networks such as the ASARECA and INTSORMIL. With these networks, the Eastern and central African countries conduct breeding programs jointly. Most of these linkages were with neighbouring countries such as Sudan and Ethiopia where they share similar climatic conditions and field crops. However, currently neither private seed supplying and nor crop variety licensing arrangements for production of seed by third party entities is available in Eritrea.

4.0 Status of Seed Supply

4.1 History of crop breeding and seed supply in Eritrea

The Eritrean plant breeding program started in 1995 with the assistance of the international research institutions such as ICARDA, ICRISAT, CIMMYT, CIP, and DANIDA. The program focused on the development of improved varieties of wheat, barley, maize, sorghum, and pearl millet and locally adapted farmer varieties for specific agro-climatic zone of the country. The approach was to build upon the adaptation and the preferred characteristics of the farmers own varieties as well as improve these for disease resistance, drought tolerance, yield potential and uniformity. The program was intended to produce superior experimental varieties to produce breeder and foundation seed and supervise certified seed production to assure that quality seed is available to farmers. Sorghum breeding program was initiated in the three research sites namely Halhale, Goluj, and Shieb and one sub-station Shambuko by crossing improved exotic with popular landraces varieties and improved exotic with improved exotic. The program was focused on improving sorghum yield, earliness, high ratoon capacity, striga resistance, pest and disease resistance etc. Crossing activities and nurseries follows evaluation and selection of pedigree segregating bulks advanced into different generations and yield trial to obtain the desired sorghum character.

In the previous 25 years a number of research programs under field crop improvement have been conducted. All the breeding program conducted in the different stations in Eritrea are based on commodity in relation to the agro-ecology systems prevailed in that particular site. In majority of breeding commencement is based on farmers' problem and commodity priority of the MoA strategic plan set. Since 1995, the following major breeding and research programs have been conducted by crop commodity. The logical and systematic selection and testing process for the different field crops is generally similar. The breeding program during 1995-2000 has been following by two methods of crop development.

b. Farmers variety (Landraces) based breeding

This was initiated from already collected accessions in gene bank and newly collected landraces. The landraces were evaluated with farmers and conduct preliminary testing on research station. The landraces that were found useful and usable was promoted for release and multiplication. Similarly, landraces that was found good source of parent materials for crossing also selected for further breeding program of landrace based diversification.

c. Introduction of Exotic Germplasm and lines

Between 1995 and 2000 many exotic field crop exotic genetic materials (germplasm and line) have been introduced from ICRISAT, ICARDA, CIMMYT and INTSORMIL. The exotic germplasm and lines introduced were for crops such sorghum, millet, barley, wheat, chick pea and other pulses. The procedure for the development of these genetic materials include initial screening and selection followed by on station (advanced testing) and on farm testing for farmers verification and selection. The promising selected germplasm were released and promoted to large scale seed multiplication. During these years the breeding program in

Eritrea was not very strong and all the breeding activities conducted were done in collaboration and back stopping from these CGIAR centers.
The varieties found promising have been released by the national research program in accordance with the guideline of the national seed system of Eritrea. Small quantity of foundation seed have then multiplied and supplied to the Agricultural Extension Department (AED) for further certified seed production. The certified seed production has been multiplied in cluster form of contract farmers where they enter into agreement with the AED and Regulatory Service department (RSD) to perform all the necessary crop management that required for quality seed production under the packages of integrated farming system.

4.2 Current status of the Eritrean plant breeding program and its future trends.

Modern plant breeding in Eritrea started from 2000 and onwards where hybridization and introgression of landraces with landraces, landraces with Exotic lines and exotic with exotic germplasm programs have been initiated. Since 2004/05 breeding using modern techniques such as biotechnology (Marker Assisted Selection, Marker Assisted Backcrossing, Gene pyramiding, tissue culture and mutation breeding) have been conducted in collaboration with regional, bilateral and national programs. Few selected and major breeding programs are indicated below.

In 2004 a project on fighting striga funded by Association for Agricultural Research in East and Central Africa (ASARECA), sorghum and millet network called ECARSAM, was initiated to use molecular markers tightly linked to striga resistance Qualitative Trait Loci (QTL) in the marker-assisted selection (MAS). By using MAS and farmer participatory selection the project aimed at transferring striga resistance gene from resistant donor (N13) to susceptible farmer preferred sorghum varieties. The NARI selected two susceptible farmer preferred sorghum varieties (FPSV) called Hugurtay and Harriray and crossed (hand emasculated) with the striga resistant donor (N13) to produce F1 (N138Hugurtay) progenies. This F1 generation was planted to be back crossed and produce BC1F, BC2F1, and BC3F1. These lines were planted/advanced and on-farm trials to be evaluated for their striga resistance in striga hot spot area. The lines with resistant to striga have been released. Similarly, diversity analysis of sorghum landraces along with collection of regional accession in eastern and central Africa conducted in 2013 using SSR markers that resulted in the identification unique traits in the Eritrean sorghum collection. Subsequently, the unique characters identified have been incorporated with other sorghum varieties using conventional breeding and used as parent material.
It is also worth to mention that in the last 10 years, NARI and HAC have been able to develop and release three sorghum varieties that are fit to the highland and midland area and six improved sorghum varieties that are well adapted to the lowland area of the country.
In millet, the program was intended to produce high yielding, pest and disease resistant varieties by crossing local landraces with exotic ones. One of the major problems in cultivation of pearl millet in Eritrea is downy mildew disease that affects the yield. As a result, in the last 10 years four varieties were developed and released in the pearl millet

growing areas of Eritrea. The breeding activity is still continuing to develop high yielding varieties.

Eritrea is known as a country of diversity especially for barley and therefore selection of best barley varieties and their comparison with exotic variety was initiated in 1995 and the local cultivars outshined the exotic ones. In the previous 10 years four food barley and three malting barley varieties have been developed and adopted by the farming community in barley growing areas of Eritrea.

Introduction of wheat germplasm from ICARDA and CIMMYT was started in 1996 and since then variety selection between the local land races and exotic ones was going on and four varieties were selected and grown by farmers. In 2004 a new project on farmers' participatory approach in conducting plant breeding program was launched by ICARDA under the Challenge Program project. At the initial stage germplasm existing in the local gene bank was used. Crossing between the best selected lines was done by the participation of farmers and selected bulks were used as entries in the new farmers' initial, advanced and elite trials which finally end up in release and increasing seeds at large scale. In the recent years six improved wheat have been developed and widely adopted by the farming community in wheat growing areas of Eritrea.

There are several new opportunities for the breeding program in the future. ICRISAT is initiating the backcrossing of a higher endosperm beta carotene (the precursor of human vitamin A synthesis) trait into one Eritrean millet landrace with yellow seed coat. Breeding of top cross hybrids which is comparatively easy and a wide range of male-sterile seed parents available from ICRISAT will be the second opportunity for the Eritrean breeding program. An introduction of striga resistant (SRN, 39, IS9830), striga tolerant (ICSV 400, KSV4, CS35, CS95), drought resistant, stay-green (B35, KS19) sorghum materials will be very important for NARI and HAC to improve the susceptible farmer preferred sorghum varieties in Eritrea. As Eritrea is rich in crop diversity especially on barley, faba bean and chickpea, improvement through reliance on indigenous materials are in progress. Improvement through crosses and recurrent selection of the attributes of the local landraces especially for disease resistances is a potential breeding program to be exploited. Introduction of suitable genetic materials especially for wheat and lentils are still in progress.

4.3 Recent and ongoing activities aimed at increasing supply of improved seed and opportunities of seed access

In the last four years the number of released varieties since 2000 was well documented and the list of released varieties were prepared by RSD. In addition seed multiplication of released varieties have been performed under the follow up crop production division of AED head quarter in collaboration with regional MoA offices in four regions, namely Central, Southern, Anseba and Gash Barka. The seed supply increase of improved varieties are mainly for field crops mainly sorghum, pearl millet, wheat and barley. However limited seed increase also under progress for maize, finger millet, pulses and oil crops. The method of seed increase is through selection of appropriate farmers in specific regions who grow the

intended improved varieties. The MoA (AED and RSD) select farmers and enter in to agreement for contract with farmers in cluster form. Under this integrated farming system, clustered farmers have the obligation to carry out all the necessary crop husbandry and MoA to supply in puts such as fertilizers and pesticides. As per the agreement, contracted farmers in turn will get a 25% premium for their seed produced. The credit and marketing section of MoA handles all these activities of buying and storing of the improved seed produced. However, for the acceptance of the seed to be used in the next growing season, the national variety release committee (NVRC) of Eritrea conducts survey annually in farmers' field either to reject or to accept the contracted farmers' field under the chairmanship of RSD (figure 4). Once the seed produced is certified by the NVRC, it is sold to farmers at subsidized prices via the extension system's offices both at regional and sub region levels.

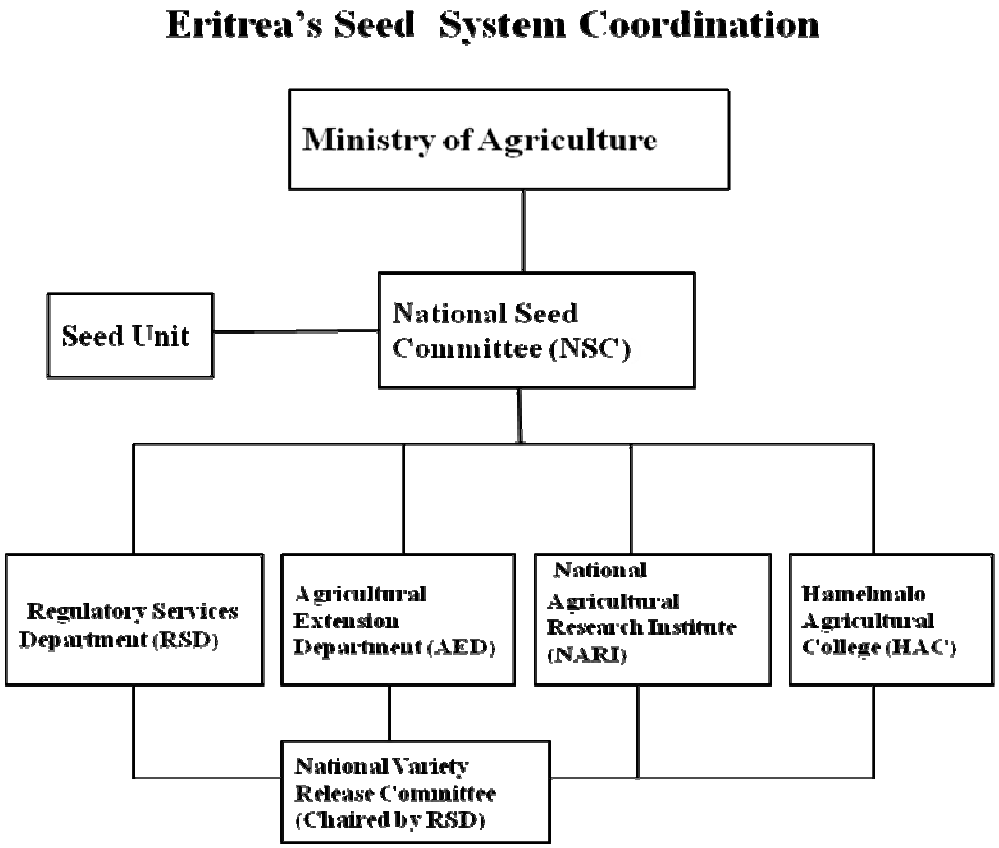

Figure 4. Seed system coordination in Eritrea

The demand for improved seed in the country by the smallholders is increasing from year to year. The smallholder farmers have two options to access the improved seed. The first option is though regular channel of the MoA in regional office and the second option is farmer to farmer seed exchange. However, the second option can't assure the quality of the seed as the farmers can contaminate with other landraces of the same variety and also can mix the improved seed with other crop varieties while storing in their homes.

4.4 Number of private seed companies, non-governmental and farmer-based organizations operating in the country and their estimated annual seed supply

Recent efforts and plan to develop Eritrea's seed sector use three strategies.

- Support for variety development, registration, release and multiplication
- Improvement in the quality of seed sold to farmers
- Re-orientation of public sector agencies along commercial line with cost recovery pricing policy

However, currently there is no private seed enterprise dealing with quality seed production and non government organizations operating in the seed system of Eritrea. This could be one of the problems that reduce production and productivity because users could not get quality and pure seed in a sustainable way. While considerable progress has been made in crop enhancement program by the public crop breeding program, seed availability continues to be inadequate for a number of reasons. Farmers differ widely in wealth and resource availability, seed pricing because many farmers are still unaware of the benefits of improved varieties and farmers tend to save their own seed or obtain seed (of traditional varieties) through farmer to farmer exchange. The national seed strategy has been modified to further improve seed availability and meet the need of different categories of farmers. The poorest and resource poor farmers (informal seed sector) are targeted by the extension staff. The national seed that coordinate seed multiplication at national level target community/ village based system where cluster farming community to be included that can ensure moderate production and timely supply through distributer at affordable price. Experience from other countries showed that seed distribution by only governmental agencies couldn't be sustainable. It is therefore private seed sectors/ companies are needed that work more closely with governmental institutes and agricultural departments and what crops to focus on to ensure affordable and profitable seed. The development of private seed companies is thus vital for many reasons; reliability, sustainability, cost effectiveness, responsiveness to farmers' needs, greater commitment to quality seed and generation of employment are some of the important aspects.

The farmers based organization is partially implemented in some regions of Eritrea funded by an Irish development agency called Vita. This agency assists the farmers based seed multiplication in supporting and facilitating the seed multiplication with financial support and backstopping in collaboration with NARI breeding experts. The seed produced under such multiplication is supplied to credit and marketing of MoA in AED. The procedure of seed multiplication regulation is followed as set by the national seed system under RSD.

4.5 Facilities and equipment available for seed processing and packaging in the country

There are limited facilities and equipment available for seed processing and packaging in Eritrea. The facilities and equipment are located in the three departments of MoA and HAC. The Agricultural Extension Department has the facilities of stand threshers in different

regions, seed cleaners in two regions (South and Gash Barka) and seed store houses of different sizes in almost all regions. The National Agricultural Research Institute and HAC have the seed testing laboratories. The Regulatory Service Department has the seed laboratory for pathology and entomology. However, these facilities are suffered with spare parts, chemicals, consumables, skilled manpower and training opportunities. The trained manpower on seed inspection, seed technologists and laboratory technicians are some of the major gap which needs attention for quality seed production in Eritrea.

4.6 Tonnages of seed certified and marketed in the past five years by crop

The quantities of seed production in the past five years were fluctuated from year to year as well variety to variety. The reasons for the production of the improved varieties were due to rainfall situation and other biotic factors. The amount of rainfall in the year 2015 and 2017 was lower than the rest of the years. During the cropping season 2019, the amount and distribution of rainfall was excellent throughout the country. According the NVRC survey evaluation and draft report, the amount of improved seed production was higher in 2019 as compare to other years (Table 8).

Table 8.Quantity of seed production and distribution (tones) of sorghum, pearl millet, wheat and Barley (2015-2019) in Eritrea

	Major field crops of Eritrea				
Year	**Wheat**	**Barley**	**Sorghum**	**Pearl millet**	**Total**
2015	7.0	NA	98.1	13.0	**118.1**
2016	104.7	NA	121.7	17.2	**243.6**
2017	25.4	NA	98.8	12.4	**136.6**
2018	110.6	NA	68.6	33.8	**213.0**
2019	818.9	NA	73.5 *	36.8*	**929.2***
Total	**1,066.6**	**NA**	**460.7**	**113.2**	**1640.5**

***** The figures are expected yield estimated by NVRC, 2019
Source: Agricultural Extension and Regulatory Service Departments and CAADP, 2019

4.7 Number of agro-dealers currently in operation, by region

There are limited private agro-dealers found in Eritrea. Those that are available in the country are concentrated in the central highlands the capital city, Asmara and Tesseney town in Gash Barka. These agro-dealers mainly sell chemicals such as pesticides and herbicides and sprayers. They also sell some vegetable seeds and seed grasses. Currently there are no agro-dealers focused for field crops.

4.8 Level of importation of certified seed from neighboring countries, by crop

The importation of improved seeds is governed by the provision of the export-import policy that is set by the Regulatory Services Department of the Ministry of Agriculture. The policy of the ministry focused on providing the frame work for import of seeds and plant materials into the country and laid parameters that would govern the import of seeds. In the department of RSD, the division of Plant health and Quarantine regulates the seed importations. The directorate of plant health follows the legal procedure for commercial consignments of seed imported. The regulations include the import permit and phytosanitary certificate supplied by the export country and the seed consignment inspected and sampled at the port of entry. Once these procedures finalized the directorate of Plant Health and Quarantine approves the entry and grant certificate. Currently there are no certified seeds imported from neighboring countries, however, with current peace agreement between Eritrea and Ethiopia there will be high potential opportunity to exchange improved seeds to Eritrea by adhering the regulation of both countries. The climatic condition of Eritrea is similar to that of Ethiopia and Sudan. The crops grown in these countries are generally similar. Therefore improved crops developed in these countries can exchange and grown without much difficulty. Farmers in Eritrea are becoming well aware on the importance of improved seed. Thus there is considerable potential and high prospect for improved seed supply in Eritrea.

5.0 National Seed Policy Framework

5.1 Documents which control the production and supply of seed

The Regulatory Services Department (RSD) is designated as the Seed Regulatory Body, for the proper implementation. This includes the production and supply of improved seed. However, The RSD regulates and control of seed production and supply in coordination with other public stakeholders (AED, NARI and HAC).

The Regulatory Sevice Department implement the control of the production and supply of seedthrough several activities that include,monitor all activities of the seed sector and develop seed database system, investigate and advice on certificate of qualification for Seed establishments, control directly fields of pre-basic and basic seeds and approve parent stock seed used for the production of seed of all classes. Besides, the RSD regulates the license seed sellers and maintain a register for puroses of effective implementation, organize and manage an efficient seed control and certification system, approve or reject a land unit and certify or refuse to certify the seed lots tested. The NSC and NVRCthrough RSD keep linkage between all stakeholders of the seed sector including regional, sub regional and international organisation and undertake evaluation of varieties, inspection of seed multiplication fields, seed sampling and supervise labeling of seed containers.

5.2 Process for the official release of improved crop varieties

The process for the official release of improved varieties follows the legal frame work set by the RSD. The breeders of the crop do all the pre release evaluation on station and on farm trials. Once the variety satisfied the breeder for its performance then breeder applies for release of the earmarked variety. The seed regulatory body receives the application. The variety is evaluated under a two stage procedure and to make suitable for commercialization in Eritrea. In the first stage, which is referred to as pre-release, the applicant applies to NVRC for official evaluation of a variety. In the second stage, the applicant applies for the full release of the variety after the official evaluation. A candidate variety is then evaluated for Distinction, Uniformity and Stability (DUS) in accordance with UPOV as well as in Value for Cultivation and Use (VCU) as guided by the NVRC, over a minimum period of two cycles. During the pre-release period of testing for registration, the variety is registered temporarily. A limited quantity of seed is also supplied to be multiplied or imported and cultivated in order to test and develop its market. An applicant can present results of the performance of the variety to the NVRC for its consideration. The variety to be release should fulfil the criteria of DUS test and performance above average trial performance that helps for the decision to release a variety by the NVRC. Upon satisfying the required criteria, the variety will be then entered into the National Variety List which will be maintained by Seed Regulatory Body. Finally the seeds of the listed variety will be allowed for commercial provision in Eritrea. All these process of for the official release of improved varieties supervised by the seed regulatory body which composed of different experts.

5.3 Procedures for seed certification

In Eritrea, no seed shall be certified unless it has been inspected, sampled, tested and complies with the standards set out in the Seed Proclamation. Seed certification is based on the technical guideline which is distributed to all zoba (administration regions) and other stakeholders in the country. For seed of a listed variety to be certified, it should meet minimum field standards for cropping history of land unit, isolation, off-types, disease and number of inspections conducted. It should also meet seed laboratory standards for moisture content, physical purity and germination capacity. Seed will be certified in seed classes and can also be offered for sale as Quality Declared Seed (QDS) or emergency seed classes. Only cultivars which have been approved by the National Variety Release Committee (NVRC) is eligible for certification. However, before the NVRC conduct the inspection process, the RSD along with AED in zobas follow up all the process of seed multiplication including field selection, isolation distances, status of the crop and all required agronomic practices. Three stages of seed inspection conducted during the process. These include inspection during planting, during crop vegetative growth and at harvesting time. Any seed which contains noxious weeds or noxious ergots is not be eligible for certification. Seeds that failed of meeting the minimum number of field inspections to be certified will be tested for physical purity and germination capacity and that will be marketed as Quality Declared Seed. Seed need to be cleaned before being presented to certification. Equipment such as threshers and containers which are used for the processing of seed is cleaned beforehand to prevent the admixing of any other seed with the seed which is to be presented to certification. Once the seed satisfied the listed procedure and standards it will be ready for use by the farmers' community.

5.4 Current status of the regulatory agencies in charge of seed certification

The regulatory service department operates at head quarter level in Asmara and regional level in the six zoba administration regions (Table 9). In all zobas the work of seed certification followed up by the regional inspectorate office. All the procedure of seed certification process is also followed in all regions based on the guideline circulated from head quarter. The head quarter in Asmara follows all the process of seed certification, give guidance and instruction to all regional inspectorate offices. Besides, the laboratory work for seed certification is located in Asmara. The seed certification and quality control is done in accordance with standard procedures and techniques developed by RSD. The template used in checking the seed certification and testing for quality includes germination test, moisture content test and purity test.

Table 9. Number of Regulatory Services staff in seed certification

Number of staff	**Zoba/ region**					
	Head Quarter (Coordinators and laboratory technicians)	Anseba	Debub (South)	Maekel (Central)	Gash Barka	**Total**
MSc	1	-	-	-	-	**1**
BSc	4	1	2	2	2	**11**

Source: Regulatory Services Department, 2019

Infrastructure

The Regulatory Services Department has one seed laboratory that helps for seed certification. The seed laboratory conducts germination test, moisture content and purity tests. All the regional inspectorates' send their seed samples to the seed laboratory for checking the indicated parameter tests before the improved variety granted certification.

The major constraint in regulatory service is lack of capacity building on young staff. Long term training at MSc level is required in all fields the regulatory service operating. The field of specialization required include in plant health and quarantine, seed science technology, agronomy and plant protection skills.

5.5 Current status and procedures of basic (foundation) seed supply

The variety found superior and promising by the breeder released after NVRC verify its superiority. Breeder and foundation seed was then multiplied by NARI under the supervision of the Breeder. . Foundation seed of the released varieties are then produced every year and deliver to the AED staffs of the MOA who follow the seed multiplication program. The foundation seed then multiplied as certified seed production under the supervision of AED and RSD to assure that quality seed is available to farmers.

The procedure of foundation seed supply is through the National Agricultural research Institute to the Agricultural Extension Department. The AED enters an agreement with contract farmers for the multiplication of this seed as certified seed in larger areas. The AED through the credit and marketing unit buy the harvested certified seed for next cycle growth. It is through this continuous process the seed supply reaches to the farmers. However, since there are no private seed companies in Eritrea, seed supply are therefore only through government organizations and channels. So far no policies for supply of basic seed by private sector are available.

6.0 Summary and Conclusion

6.1 Summary

Considering the policy of the GoSE to increase food security, development of improved high yielding variety got more focus/importance as the result the breeding program was given more emphasis by working on priority crops such as wheat, barley, sorghum, pearl millet, and maize and grain legumes. Taking into account the limited number and quality of researchers involved in plant breeding activities which is still a big problem in making big changes, the progress so far achieved could be rated high. Indeed, within the last 15 years, NARI and HAC made a significant progress in developing improved varieties. These varieties are adaptable, high yielding, tolerant to disease and pests. The released varieties are currently in the hands of many farmers. Yield records for the last three years revealed that the improved varieties were 50-100% superior as compared to the local varieties. Therefore, plant breeding program in Eritrea is bringing more benefit to the farmers and thus Government is aware of the advantage and importance of this program.

Seed systems, consisting of the breeding, management, replacement, and distribution of seeds, are at the core of sustainable food and agriculture systems. In Eritrea, Farmers access to seed for agriculture from both farmers' seed systems and formal seed systems. However, more commonly, farmers access their seed from sources within farmers' seed systems, such as local grain and social networks. Seed obtained from farmers' seed systems are produced, re-used, and stored on-farm or at community level and in-situ by farmers from their own harvest; through exchange and barter among friends, neighbors, and relatives and cash purchase. However, with the current trend of development of improved seeds, the RSD of the MoA supports the formal seed system which is increasing from time to time.

Majority of the certified seed in Eritrea is produced under contract small scale farmers whom their land is small and fragmented. Involving small scale farmers with smaller land size greatly increases the cost of production and administration. To overcome this situation contracts are arranged through extension workers and local administration by consolidating individual field into blocks of cluster fields. However, this type of approach can temporarily solve the seed management and distribution system. In the long run the need for establishment of private seed companies with trained seed multipliers will be vital. The demand for improved seed by small and commercial farmers is at the increase rate in Eritrea; however, the seed system is not well developed. There are no as such barriers to the success with seed systems development in Eritrea. With increase trend and the full endorsement of the government that is led by the Minister of Agriculture, it is believed that rapid progress can be made in the development of seed systems, within the context of a full collaboration with the government and private seed companies. The establishment of private seed companies can maintain trained seed experts, prepare technical packages, monitor actual seed production frequently and supervise seed processing with own facilities. Besides, they can control easily the seed promotion and marketing in collaboration with governmental seed regulatory body. Private seed companies can also open market of import or export seed from/to neighboring countries when needed.

The government of Eritrea promoted wider visions in the increase of crop productivity that lead to food security. To attain this, the government through the ministry of agriculture has endorsed full support for improving seed systems. With the increasing demand of improved seed of field crops, there is wider opportunity for seed system improvements in the country.

6.2 Conclusion

- Access to improved seed by farmers can have an impact in crop production if all the actors in seed production technology work together for the same objectives.
- The Agricultural Extension Department is the key partner in disseminating improved seed and is working in full-fledged throughout the country. However, since majority of the farmers are not much aware on improved varieties, a lot of work is still ahead to popularize the new released varieties.
- The linkage between the NARS, AED and RSD should strengthen so that farmers will get exactly the type of seed they need.
- With the current involvement of small scale farmers in seed production system, there is likely to have an impact in increasing access of improved seed to more farmers in Eritrea.
- Seed management and distribution through public institutes only will not be effective for sustainable seed system in Eritrea. It is thus highly recommended that the private seed companies can fully or in parastatal engagement in seed system in coordination with governmental organizations without affecting the policy of seed system of the country.
- With the increasing of seed demand of improved field crops, the seed business will be feasible and highly profitable in Eritrea.

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