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Agricultural based Livelihood Systems in Drylands in the Context of Climate Change

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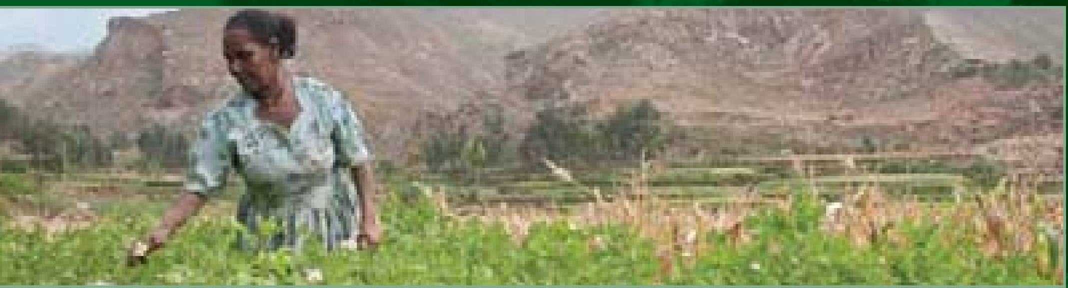

ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

ENVIRONMENT [CLIMATE CHANGE] BIOENERGY MONITORING AND ASSESSMENT

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ENVIRONMENT [CLIMATE CHANGE] BIOENERGY MONITORING AND ASSESSMENT

Agricultural based Livelihood Systems in Drylands in the Context of Climate Change

Inventory of Adaptation Practices and Technologies of Ethiopia

Kidane Georgis, Author and Principal Research on Dryland Agriculture
Ethiopian Institute of Agricultural Research (EIAR)

in collaboration with
Alemneh Dejene, Team Leader, Environmental Sustainability and Climate Change Adaptation, FAO, Rome
Meshack Malo, Natural Resources Officer, FAO Subregional Office for East Africa, Addis Ababa, Ethiopia

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Alemneh Dejene, Team Leader,
Environmental Sustainability and Climate Change Adaptation
Climate, Energy and Tenure Division
Natural Resource Management and Environment Division
Food and Agriculture Organization of the UN
Rome
Italy

CHAPTER 1

INTRODUCTION AND BACKGROUND

Dryland agro-ecologies: The drylands of Ethiopia consist of a wide range of agro-ecologies including the arid, semi arid and dry sub-humid and cover about 75 percent of the total land mass. They are prevalent mainly in the north, east and central areas of the rift valley, also south and southeastern parts of the country, including a very wide and diversified range of agricultural environments (Map 1 of Ethiopia).

The lowland dryland areas in Ethiopia, which are the focus of this study, cover about 55 percent of the land mass of the country (Ministry of Agriculture and Rural Development). The altitude ranges from -124 to 1500 masl. and the rainfall ranges from 200 to 700 mm annually, with a growing period of 90 to 180 days.

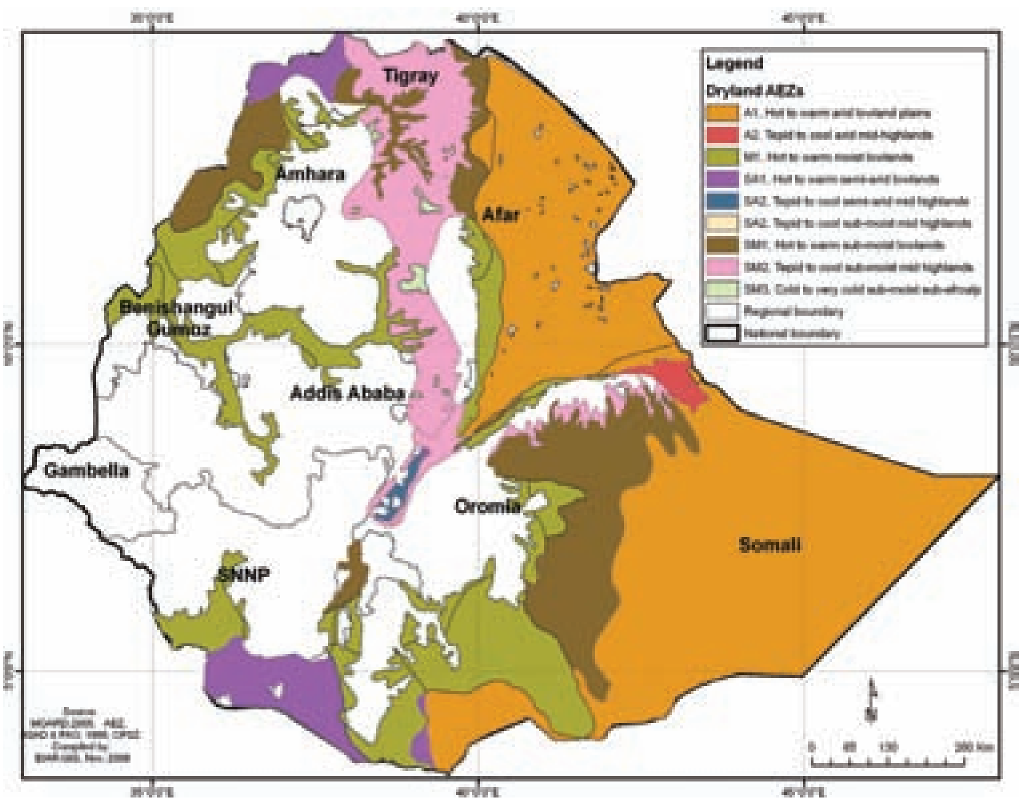
Population: It is estimated that about 1/3 of the populations in Ethiopia (estimated at 80 million) currently live in these dryland areas. Furthermore, it is also important to note that the population of these areas is continually increasing, because people are moving from the highly degraded highlands, where populations are rising, to the fertile lowland drylands. As a consequence, populations in the drylands are exceeding the current carrying capacity and this land is becoming degraded.

Farming systems: The production system is smallholder based and mainly under rainfed conditions. Rainfed agricultural production is thus the basis of all subsistence farming in most parts of the dryland zone and accounts for most of the land area cultivated annually. In general, the farming systems are mixed, with highly integrated animal and crop production. A typical farming household in these semi-arid areas owns a small area of land (generally less than 1 ha) on which crops are produced and partially supports variable number of cattle, goats, donkeys, sheep. The holdings are not only small and marginal, but also are unconsolidated and scattered, making it difficult for farmers to work on all their fields at the same time.

Resource Base: Drylands agro-ecosystem is the home to various types of plants, crops and domestic and wild animals. For example, the rangelands provide important forage for livestock and wildlife. The area is one of the main centers of biodiversity of sorghum, finger millet, field peas, chickpea, cowpea, perennial cotton, safflower, castor bean, sesame and other crops.

Livestock are a living bank for farmers in the dryland agro-ecology, as livestock serve as insurance against crop failure and as a source of food, usually for dairy rather than meat production. Furthermore, these drylands are a center of livestock genetic diversity, for example the distinct breeds Borana, Jijiga cattle, the black headed Ogaden sheep, the Afar goat, the Somali goat and the camel resources. The conservation and utilisation of this livestock biodiversity requires full understanding of the ecosystem.

Map of Ethiopia with Dryland agro-ecologies



Characteristics of drylands: The rainfall is low in amount, erratic, and uneven in distribution, making droughts a common experience. Furthermore, the rainfall is generally concentrated in a few heavy storms with high intensity. Vegetation is consequently very sparse and generally degraded, leaving large areas of soil unprotected. Apart from in valley bottoms, soils in many drylands have low organic matter content, are highly eroded and have low fertility. The high temperatures and strong winds which characterize these environments result in high evapotranspiration rates, which further exacerbate the limited availability of moisture. In general the ecology is fragile and the environment is unstable.

MAJOR CHALLENGES OF THE DRYLAND PRODUCTION SYSTEMS

The major challenges threatening the dryland communities relate to the degradation of the natural resource base, which is leading to soil and vegetation loss, fertility decline, water stress, drying of water resources, lakes and rivers. This degradation is being exacerbated by increasing climate variability and change, with profound impacts on the livelihoods of dryland communities.

Social factors: The social problems of drylands such as in Ethiopia include low economic capacity, with limited capital available for investment, which when combined with the environmental degradation results in highly vulnerable production and livelihood systems and thus poverty is pervasive. The other challenges faced by local people include poor health caused by inadequate diets and contaminated water, exacerbated by limited infrastructure. Most importantly, farmers and herders value keeping large numbers of livestock, irrespective of the land and grazing capacity, resulting in overgrazing which is one of major causes of land and natural resources degradation in the drylands.

Additional problems for people living in the drylands include high levels of crop and livestock diseases and pests also weed infestation of crops, low productivity of grazing lands, lack of improved fodder crops and inadequate livestock water supplies. Consequently, agricultural production and productivity is generally low and thus local communities are confronted with serious food security and poverty problems.

The over-riding factor limiting agriculture production and productivity in the dryland areas today is climate change and variability. To address this, steps are being taken by the national research systems to develop potential adaptation technologies and practices which are presented in this document.

However, pressure and attention on the drylands is expected to increase in the next decade in light of specifically climate change compounded by growing populations in the regions migrating from the densely populated highlands into the drylands areas.

OBJECTIVES OF THE STUDY

In the effort to address the challenges which smallholders crop producers and herders face in dryland areas, the paper aims to review and document the available practices and technologies by focusing in the following issues:

- **Assess the current climate change challenges, predicted future impacts and their observed effects in the drylands;**
- **Document and inventory technologies and practices in agricultural-based livelihood systems, including crops, livestock and their integration, also agroforestry production systems;**
- **Review the strategy used by the national research system to address the major challenges of the dryland production systems in the context of increasing climate variability and change;**
- **Assess the action taken in relation to Ethiopia's National Action Plan for Adaptation (NAPA);**
- **Discuss and assess the relevance of the technologies developed, identify best-bet practices to improve the livelihood of the dryland farming communities; and**
- **Plan the way forward.**

CHAPTER 2

CLIMATE CHANGE:

OBSERVED CHANGES AND THEIR EFFECTS ON THE DRYLANDS OF ETHIOPIA AND OTHER PARTS OF AFRICA

Observed changes and their effects on the drylands of Ethiopia and other parts of Africa: It is now profoundly clear that climate change is a global problem which is having profound impacts on poor countries of eastern Africa including Ethiopia, whose contribution to greenhouse gas (GHG) emission is insignificant. The IPPC Report (2007) highlighted that Africa will be one of the regions hardest hit by the impacts of climate change although it contributes the smallest amount of the total carbon dioxide (CO2) emissions (3.6 percent). The same report also predicted a significant decrease in crop yields, with smallholders most vulnerable.

Climate-related hazards in Ethiopia include drought, floods, heavy rains, strong winds, frost, heat waves (high temperatures) and lightning. Although the historical social and economic impacts of all of these hazards is not systematically well documented, the impacts of the most important ones, namely droughts and floods, are widely discussed.

Ethiopia is highly vulnerable to drought and this is the single most important climate-related natural hazard which periodically affects the country. Drought can occur anywhere in the world, but its damage elsewhere tends to be less severe than in Africa in general and Ethiopia in particular. Recurrent drought events in the past in Africa have resulted in huge loss of life and property, as well as migration of people.

In Ethiopia, climate variability and the frequencies of extreme events have increased over recent times. This is greatly menacing the various agricultural sectors and natural resource base upon which the poorest Ethiopian citizens depend for their livelihoods. Improvements in crop production are dwindling, lagging very much behind the rapid rate of population growth, thus there is increasing food insecurity at both household and national level and endemic grinding poverty.

Water availability has dramatically declined in Ethiopia's rivers, streams, lakes and reservoirs. Climate change, in conjunction with human activities and triggered by climate-related disasters have already killed Lake Haramaya, and Adele. The predicted likely death of Lake Tana, Lake Ziway and River Awash, with the resultant loss of water resources and valuable biodiversity are too costly and painful to tolerate. There is great fear over the challenge of meeting the demands of escalating population water needs for food production including for irrigation, also domestic, municipal, and industrial and energy uses. Feed and water availability for livestock has greatly reduced and consequently livestock numbers have declined. This has already claimed lives and lost millions in financial and capital assets - threatening the livelihoods of the great majority of already marginalized pastoralists.

Assessment of the reports of disasters attributable to droughts over Ethiopia over the past two millennia indicate that the recurrence interval has decreased in the majority cases, from once in forty to a hundred years in the first millennia to once in fifteen to forty years during the Middle Ages, to once in ten years in the nineteenth century and once in six years in the twentieth century. This declining trend has continued in the last seven years of the twenty-first century to once in three years, which shows recurrence intervals of less than three years over some hot spots.

Rainfall variability and climate-related risks have been major causes of the country's food shortages and famines in the past and they continue to pose serious threat to Ethiopia's development.

It should also be noted that climate variability has also a direct bearing on the country's economy. According to Temesgen (2006) and Saddoff (2005), the contribution of agriculture to total GDP of the country is directly related to climatic variability, verifying its direct impact on the country's economic performance. The authors show that the percentage contribution of agriculture to GDP is very low in years of severe drought, crop failure and famine (1984/1985, 1994/1995, 2000/2001), as compared to better seasons (1982/83, 1990/91).

The other climate-related hazard which periodically affects Ethiopia is flooding. Major floods occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996 and 2006 which caused loss of life and property.

The trends observed in drylands of Ethiopia are more or less similar to those in East Africa, notably Kenya. Fluctuations in African lakes and the retreat of glaciers on Mt. Kilimanjaro provide a guide to long term changes in drylands. There has been increased risk of drought in drylands areas of Africa coherent with observed climate change trends as stated in IPCC Working Group 1. A recent study on local level assessments shows overall decline for rainfall in most major dryland areas such as Fogera catchments in northern Ethiopia, the Awash basin (Central), Omo-Gibe basin (South-West, upland catchments of Dire Dawa and Ogden in the East. Interviews with farmers across the nations also confirmed the same experience (Temesgen *et al*. 2009).

Available evidence suggests that Africa is warming faster than the global average and is likely to continue to do so, although with notably variations. Some African drylands are seeing even greater warming than elsewhere, while in East Africa temperatures have fallen close to the coasts and major inland lakes (Boko *et al.* 2007).

Despite this scenario, unfortunately, changes in drylands may be non-linear. Higher rainfall (quantity and length of season) in the short to medium term could be cancelled out by increasing temperatures, which will increase evapotranspiration. Non-linear effects will make climate adaptation an even more difficult task, liable to pitch stakeholders into competition for resources. For example, conflicts have already arisen (e.g. in Nyanyuki, Kenya) from the movement of crop farmers into previously pastoral areas under perceived increasing rainfall. The distribution of costs and benefits of such encroachments between farmers and pastoralists requires careful negotiation.

CAUSES OF VULNERABILITY TO CLIMATE CONDITIONS IN ETHIOPIA

The causes of the vulnerability of Ethiopia to climate variability and change include very high dependence on rain-fed agriculture, which is very sensitive to climate variability and change, also the under-development of water resources, low health service coverage, high population growth rate, low economic development level, low adaptive capacity, inadequate road infrastructure in drought prone areas, weak institutions, lack of awareness, etc.

Vulnerability assessment based on existing information and rapid assessments carried–out for this study indicated that the sectors most vulnerable to climate variability and change are agriculture, water and human health. In terms of the livelihoods approach, smallholder rain-fed farmers and pastoralists are found to be the most vulnerable. The arid, semi-arid and the dry sub-humid parts of the country are affected by severe drought.

CHAPTER 3

THE ETHIOPIAN NATIONAL ACTION PLAN FOR ADAPTATION TO CLIMATE CHANGE AND DRYLANDS

It is now well recognized that climate change poses serious threats to agricultural production, the natural resource base and the livelihoods of communities. The threat is particularly severe in the drylands. In line with this, attempts are being made to mainstream potential response measures to reduce the resulting impacts. At the higher level, the Government of Ethiopia has signed and ratified all the Rio Conventions, namely the United Nations Framework Convention on Climate Change and its Kyoto Protocol, the Biodiversity Convention and the Convention to Combat Desertification.

In efforts to address the impact of climate change, the Government has prepared the National Adaptation Program of Action (NAPA) with the primary objective of identifying and promoting activities that address the urgent needs for adapting to the adverse impacts of climate change.

In Ethiopia, through the NAPA process, twenty priority project ideas were identified that address immediate climate change adaptation needs of the country. These projects broadly focus in the areas of human and institutional capacity building, improving natural resource management, enhancing irrigation agriculture and water harvesting, strengthening early warning systems and awareness raising – all relevant in improving livelihood systems in drylands.

Within this listing, priority projects/ activities were identified for development using criteria for prioritizing adaptation options (based on the generic criteria as proposed by the Least Developed Countries Expert Group (LEG) (see Table 1, which shows the eleven projects identified which directly focus on drylands).

TABLE 1

List of NAPA priority options for implementation, Ethiopia, 2007 (based on Multi-criteria Assessment (MCA))

Rank	Title of project	Average standard score
1	Promoting drought/crop insurance program in Ethiopia	1.0
2	Strengthening/enhancing drought and flood early warning systems in Ethiopia	1.0
3	Development of small scale irrigation and water harvesting schemes in arid, semi-arid, and dry sub-humid areas of Ethiopia	0.99
4	Improving/enhancing rangeland resource management practices in the pastoral areas of Ethiopia	0.95
5	Community based sustainable utilization and management of wet lands in selected parts of Ethiopia	0.95
6	Capacity building program for climate change adaptation in Ethiopia	0.85
7	Realizing food security through multi-purpose large-scale water development project in Genale– Dawa Basin	0.80
8	Community-based carbon sequestration project in the Rift Valley System of Ethiopia	0.78
9	Establishment of national research and development (R&D) center for climate change	0.78
10	Strengthening malaria containment program(MCP) in selected areas of Ethiopia	0.78
11	Promotion of on farm and homestead forestry and agro-forestry practices in arid, semi-arid and dry-sub humid parts of Ethiopia	0.78

The actions taken in implementing these priority areas will be assessed to indicate the relevance of research and development by the NARS and also to indicate the gaps and suggest the way forward.

To address the problems of the drylands and implement the NAPA agreement the strategy employed by the NARS is indicated below.

CHAPTER 4

INVENTORY OF CURRENT ADAPTIVE TECHNOLOGIES AND PRACTICES IN AGRICULTURE BASED LIVELIHOOD SYSTEMS

The economy and the livelihoods of dryland people are based on agriculture and most of their agricultural practices are performed under rainfed conditions. As a result, agricultural production and productivity is highly influenced by rainfall availability and distribution, which ultimately controls the length of the growing period and thus crop yields.

To address these issues, the National Agricultural Research Systems (NARS) have been working to develop agricultural technologies and practices at both experimental and farm level conditions to raise crop yields. Some of main technologies and practices are presented below.

CROP PRODUCTION IN THE DRYLAND AREAS OF ETHIOPIA

In the dryland areas of Ethiopia, crop yields are principally limited by the low and highly variable rainfall, both between and within seasons. This is now being aggravated by the ongoing climate change. The length of rainfall period is being reduced, as it is generally starting later and finishing earlier.

Production is also limited to the progressive decline in soil fertility, as the farming practices do not adequately restore nutrients. This loss of soil fertility is also linked to a decline in soil organic matter content, resulting in limited soil water holding capacity, poor water infiltration rates, thus limiting the availability of both water and nutrients to the crop plants.

There is also evidence which indicate the temperatures are increasing, leading to higher rates of evapotranspiration and heat stress to crops, further limiting their yield potential.

Thus the production in these areas is declining consequently food in security, poverty and overall poor livelihood conditions prevail in these areas.

In order to address these problems drought resistant, early maturing and heat tolerant crop species and varieties have been developed by the research systems in Ethiopia. These crop technologies include cereals which are the major food crops, also grain legumes, oil crops and fiber crops.

Cereals: The major cereal crops in the dryland areas are sorghum, maize, tef and millet. These are the major food crops for humans diet and also provide feed for animals, The improved varieties developed by the NARS in Ethiopia in collaboration with CGIAR centers such as CIMMYT, ICRISAT, ICARDA and others are describes below. The crop varieties, the adaptation areas and the growing conditions are detailed below.

Sorghum

Sorghum is a very important crop in the country, with high genetic potential grain yield of 7.0 to 9.0 t/ha, while the national productivity is low (about 1.7 t/ha CSA, (2008). Productivity could be doubled using improved varieties (see Table 3).

Table 2

Sorghum varieties recommended for dryland low rainfall areas of Ethiopia

Sorghum variety	Main Description	Best adaptation areas
Gambela-1107	Yield potential ranges from 2.5–3 t/ha. Utilization - good for injera making. It is relatively resistant to most pest and diseases of sorghum.	Well adapted to low elevations (<1600ml) with more than 600 mm of rainfall annually in semi-arid areas including Gambella, Yabello, Jijga Kobo, Shewa robit.
76-T1-23	IA very early maturing variety (60–70 days to anthesis) which fits well to the dry semi-arid areas. Utilization - good quality for making injera with high preference of customers.	North Wello in Kobbo Alamata area, Cheffa area, north Shewa and Meiso area.
Melko-1	An early maturing, drought and heat resistant variety. Utilization - white seed with good for injera making quality. Also high biomass production therefore is good for animal feed.	Dry semi-arid areas with short growing season. It is released for north Shewa, Kobbo and other similar areas.
Gubiye and Abshir	Similar in characteristics to Melko-1 in terms maturity, drought and heat resistance and utilization. Additional attribute is its resistance to the parasitic weed called striga.	north Shewa, Kobbo and Meiso areas and well adopted by farmers and other dry-semi-arid areas.
Macia	High yield potential of about 3 t/ha. This variety stays green, has broad leaves with juicy thick stem and good quality crop residue used for livestock fodder.	It is widely adapted in semi-arid areas and short growing areas with elevation of less than 1600 m.
Seredo	Bird resistant, drought tolerant, with high tannin content and very good for arekie making (local drink).	All dry semiarid of the lowlands particularly in the rift valley areas where problem is a major constraint for sorghum production.
Teshale	Early, days to maturity 100–120, yield 3.0–4.5 t/ha, high biomass production used for feed.	Dry lowland with altitude less than 1600 m, lowlands of north wello and north Shewa.
WSU-387-Melkam	Early, days to maturity 118, yield 3.7–5.8 t/ha, high biomass production used for feed.	Dry lowland with altitude less than 1600 m, lowlands of north wello and north Shewa.
Area Yeju	Early, days to maturity 120, yield 5.0 t/ha, high.	Lowlands of welo and similar <1600 m, dry semi-arid areas.
Raya	Early, days to maturity 130, yield 3.0–3.8 t/ha.	Lowlands of wello, SIrinka area <1600 m, dry semi-arid areas.

Misiskir	Early, days to maturity 126, yield 4.1 t/ha.	Lowlands of wello, SIrinka area <1600 m, dry semi-arid areas.
Girana-1	Early, days to maturity 122, yield 4.1 t/ha.	Lowlands of wello, SIrinka area <1600 m, dry semi-arid areas.
Gedo	Early, days to maturity 134, yield 4.1 t/ha.	Lowlands of wello, SIrinka area <1600 m, dry semi-arid areas.
Abshir	Days to maturity 100–120, yield 1.5 –2.5 t/ha.	Lowlands of wello, SIrinka area <1600 m, dry semi-arid areas.
Gobie	Days to maturity 100–120, yield 1.9 –2.7 t/ha, striga resistant.	Lowlands of wello, SIrinka area <1600 m, dry semi-arid areas.
Birhan	Days to maturity 100–120, yield 4 t/ha.0striga resistant.	Lowlands of wello, SIrinka area <1600 m, dry semi-arid areas.
Harmat	Days to maturity 100–120, yield 1.5–2.5 t/ha, striga resistant.	Lowlands of wello, SIrinka area <1600 m, dry semi-arid areas.
MACIA	Days to maturity 110–130, yield 3.0–4.5 high yielding, malt type.	Lowlands of wello, SIrinka area <1600 m, dry semi-arid areas.
Redsazi	Days to maturity 106–112, yield 2.0–4.0 t/ha, malt type.	Lowlands of wello, SIrinka area <1600 m, dry semi-arid areas.

Source: Ethiopian Institute of Agricultural Research, unpublished data, workshop 2010

The improved varieties identified by NARS are early maturing and well adapted to the dryland areas of Ethiopia. Most of the varieties also combine high yielding capacity with earliness, also disease and pest resistance. Some of the varieties are also resistant to striga, the parasitic weed which is a threat to sorghum production in many African and Asian countries. The sorghum varieties for the lowland dryland areas altitude up to 1600 above sea level are given in the following table.

In the last decade production is increased by 162 percent, due to increased area coverage (69 percent) and increased productivity by about 58 percent. However improved seed and fertilizer have not been changed. In 2007 from the total areas covered by sorghum 0.14 percent used improved seed and 19 percent used fertilizer (CSA 2007 percent).

This indicates that although there are improved varieties with high genetic potential developed, due lack of improved seed and limited availability of other inputs such as fertilizer the farming communities could not benefit from the technology. Lack of improved and other inputs is therefore limiting production and productivity leading to food insecurity. This needs policy attention. This problem is not only for sorghum but also for other crops and will be address later in the discussion part of this document.

Maize production

Maize production in the drylands is becoming increasingly important, with about 40 percent of the national total maize produced in these drought-stressed areas. As a consequence, the major objective of the maize improvement program of the research system is to increase maize production and productivity in the drought prone areas by generating improved maize production technologies suitable for dryland agriculture.

In order to adapt maize cropping to dryland conditions where climate change is major threat, NARS have developed varieties which are early maturing, drought and heat resistant, disease and pest tolerant, also able to yield under other stresses (see Table 3).

TABLE 3

Release improved maize varieties for dryland rainfed areas

Maize variety	Main Description	Best adaptation areas
Melkassa-1	Maturity 85 days; flowering 48 days; plant height 150–170cm; yield 2.5–3.5 t/ha in research center; farmers' field 2.5–3.5 t/ha; 1000 seed weight 300–320 g; seed color, yellowish; tolerant to rust and blight; extra-early maturing.	Well adapted to low rainfall semi arid areas of Ethiopia with rainfall ranging 450–570 mm.
Melkassa- 2	Maturity 130 days; days to anthesis 65 days; plant height 170–190 cm; seed color white; yield 4.5–5.5 t/ha in research center; farmers field 4–4.5 t/ha; 1000 seed weight 360–410 g; resistant to rust and blight.	Central Rift Valley (CRV), kobo and Meiso and similar agro-ecological areas.
Melkassa-3	Maturity 125 days; days to silking 64; plant height 165–180 cm; seed color white; yield in research center 4.5–5.5 t/ha; farmers field 4.0–5.0 t/ha; 1000 seed weight 380–420 g; resistant to rusts and blight.	CRV areas, Kobo, Yabelo, Sirinka and Mieiso.
Melkassa-4	Maturity within 105 days; plant height 40–165 cm; flowering 53 days; resistance to rust-less tolerant; cooks faster; seed color white; seed shape -semi dent; yield 3.5–4.5 t/ha in research center; 3–3.5 in farmers' fields; 1000 seed weight 350–400g.	Released for drought stressed mid altitude areas of Ethiopia, Melkassa, Mieiso, Ziway, Wolenchiti.
Melkassa-5	Maturity within 125 days; plant height 185 cm; anthesis 60 days; resistance to rust-less tolerant; cooks faster; seed color -white; seed shape -semi dent; yield is 3.5–4.5 t/ha; 1000 seed weight 380–400g.	Released for drought stressed mid altitude areas of Ethiopia, Melkassa, Mieiso, Ziway, Wolenchiti and Shewa Robit, rainfall ranging from 600–800 mm.
Melkassa-6Q	Early maturing about 120 days; yield 3–4 t/ha in research center; in farmers' fields is 3–4 t/ha; 1000 seed weight 300–320 g.	Recommended for low rainfall areas (500–800 mm) which include Melkassa, Mieiso, Ziway, Wolenchiti and Shewa Robit and other similar areas.
Melkassa-7	Early maturing about 120 days, yield 4.5–5 t/ha in research center; in farmers field is 3–4 t/ha; 1000 seed weight 300–320 g; tall with good forage yield.	Recommended for low rainfall areas (500–800 mm) which include Melkassa, Mieiso, Ziway, Wolenchiti and Shewa Robit and other similar areas.

Source: Ethiopian Institute of Agricultural Research, unpublished data, workshop 2010

Tef Production

Tef is the major cereal crop grown in Ethiopia and its production exceeds that of most other cereals. Each year, the area of production allocated to tef is estimated to be 2.5 million hectares and the production could reach about 0.9 million tons of grain or about one quarter of the Ethiopia's total cereal production (CSA 2008).

Tef is grown either as a staple or as standby. As a staple, it is planted as other cereals, normally sown late and harvested during the dry season. During dry seasons or late onset of rains, the production area of tef increases. As a standby, the farmers wait until the main crops (maize and sorghum) show signs of failing. Then they sow a fast maturing tef variety as a backup for sustenance in the case of disaster. It is thus an important crop for drought prone areas where climate variability and change is major threat. The crop varieties developed for adaptation for these problems are indicated in Table 4 below.

Table 4

Improved tef varieties for drylands

Tef variety	Main description	Best adaptation areas
Sidama DZ-Cr-385	Grain yield potential is 1.2–1.8 t/ha with a straw yield of 6.5–8.0, seed color is white. Provide high biomass for animal feed and other purposes.	Altitude 1350–1700m with rainfall of 300–600 suitable dryland semiarid areas.
DZ-Cr387 Ril 127 (Gemechis)	The yield potential in research center is 1.5–2.2 t/ha as compared to 1.2–1.4 t/ha in farmers yield. It is very white colored seed with good quality seed and high market value.	Altitude ranging from 1450–1700 m a s l and rainfall 600–1950 mm. It is adapted in almost all semi-arid areas falling within this range.
DZ-Cr-37 (Tsedey)	Grain yield potential is 1.4–2.2 t/ha with a straw yield of 8.2–9.0. It is white colored seed with good quality seed and high market value.	This include areas with altitude ranging from <1600 to 2000 m a s l and rainfall 300 to 700 mm. It is adapted in almost all semi-arid areas falling within this range.
DZ-01-96 (magna)	Grain yield potential is 1.4–2.8 t/ha with a straw yield of 8.2–9.0, seed color is very white	Altitude 1800–2400 m with rainfall of 300–700 mm, high quality tef
HO-Cr-136 (Amarech)	The yield potential in research is 1.3–1.8 as compared 1.2–1.4 t/ha in farmers yield. It is brown colored seed with good quality seed and high market value.	Altitude ranging from 1600–1700 m a s l and rainfall 300–800 mm. It is adapted in almost all semi-arid areas falling within this range
DZ-01-1681 (key tena)	Grain yield potential is 1.6–2.5 t/ha with a straw yield of 8.4–9.3, seed color is brown	Altitude 1600–2000 m with rainfall of 300–500 mm.
DZ-01-354 (Enatit)	Grain yield potential is 1.7–2.8 t/ha with a straw yield of 8.5–13.0, seed color is pale white	Altitude 1600–2400 m with rainfall of 300–700 mm.
DZ-01-99	Grain yield potential is 1.7–2.2 t/ha with a straw yield of 8.5–13.0, seed color is brown	Altitude 1400–2400 m with rainfall of 300–700 mm.
DZ-Cr-44	Grain yield potential is 1.7–2.8 t/ha with a straw yield of 12.5–14.0, seed color is white	Altitude 1800–2400 m with rainfall of 300–700 mm.

Source: Ethiopian Institute of Agricultural Research, unpublished data, workshop 2010

Grain legumes

Grain legumes are important food and feed crops in the dryland areas of Ethiopia. Several legumes exhibit good drought and heat resistance, which makes them potentially very valuable for crop diversifications in low rainfall conditions. There are also crop species and several cultivars which combine earliness with drought resistance - this special attribute makes them important for increasing crop production on sustainable basis Through selection of crop species and varieties for drought, heat resistance and early maturing several species and varieties has been developed.

Common bean (*Phaseolus vulgaris L.*)

Common bean is one of the most important grain legumes grown in many areas of the lowlands of Ethiopia, particularly in the Rift Valley. In these areas, farmers grow white beans mainly for export purposes. Thus beans are important cash crops commodity. Haricot bean, particularly the brown seeded variety, is also a principal food crop in southern and eastern part of Ethiopia. It is a cheapest source of plant protein for farmers in the dry areas. Many varieties have been developed by NARS (see Tables 5 and 6).

TABLE 5

Available improved bean varieties: export types

Bean variety	Main Description	Best adaptation areas
Awash-1	Grown mainly as an export crop and is highly preferred by the farming community. Yield potential in research center ranges 2.0–2.4 t/ha and 1.2–1.5 t/ha in farmers' fields.	Adaptation areas: The variety is adapted semi-arid areas with low elevation and rainfall and short growing period (very maturating 75–90 days) particularly CRV including Nazret, Awassa and other similar areas.
Awash Melka	Days to maturity 95–100, it is an early maturing grain yield ranges from 2.2–3.2 t/ha.	Almost all semi-arid areas of the country including the adaptation areas mentioned above.
Argene	Days to maturity 85–90, grain yield ranges from 2.0–2.2 t/ha, the seed is small size.	It is well adapted to the central rift valley and similar areas.
TA01JI	Days to maturity 85–90. Early maturing, grain yield ranges from 2.2–2.5 t/ha, the seed is small size.	Central rift valley and similar areas, fit areas with short growing period.
Chore	Days to maturity 87–109, grain yield ranges from 2.0–2.3 t/ha, the seed is small size.	All bean growing regions In the country including the dry and wet semi-arid areas.
Chereche	Days to maturity is 89–95, early maturing grain yield ranges from 2.2–2.8 t/ha, the seed is small size.	In the lost semi-arid areas of the Hararghie highlands and similar areas.

Source: Ministry of Agriculture and Rural Development (MOAR 2008, Plant and animal health Regulatory Directorate, crop variety register issue No 11, Addis Ababa, Ethiopia

TABLE 6

Available bean varieties for domestic use

Bean variety	Main Description	Best adaptation areas
Nasir	Days to maturity are 88; early maturing grain yield ranges from 2.3–2.5 t/ha; the seed is small size.	All bean growing regions.
Dimtu	Days to maturity are 86; early maturing; grain yield ranges from 2.0–2.3 t/ha; the seed is small size.	All bean growing regions.
Goberasha	Days to maturity are 90–95; early maturing; grain yield ranges from 2.2–2.5 t/ha; the seed is small size.	Jimma and similar areas in SW Ethiopia.
Ayenew	Days to maturity are 90 – 95; early maturing; grain yield ranges from 2.2–2.4 t/ha; the seed is medium.	East and West Hararghe.
Gofta	Days to maturity are 90–95; early maturing; grain yield ranges from 2.2–2.4 t/ha; the seed is large size.	East and West Hararghe.
Tabor	Days to maturity are 80–90; early maturing; grain yield ranges from 2.0–2.4 t/ha; the seed is small size.	Southern Ethiopia.
Wedo	Days to maturity are 74–84; early maturing; grain yield ranges from 12–22 t/ha; the seed is large size.	North eastern Ethiopia.
Melka-Dima	Days to maturity are 91; grain yield ranges from 1.8–2.3 t/ha; the seed is large size.	Central Rift Valley and similar environments.
Ibado	Days to maturity are 90–120; grain yield ranges from 2.0–2.9 t/ha; the seed is large size.	Southern Ethiopia.
Omo-95	Days to maturity are 90–120; grain yield ranges from 1.7–3.2 t/ha; the seed is large size.	Southern Ethiopia.
Haramaya	Days to maturity are 100; grain yield ranges from 2.0–3.2 t/ha; the seed is large size.	Eastern Haraghe and similar areas.
Dinknesh	Days to maturity are 92; grain yield ranges from 2.5–3.2t/ ha thus is very high yielding; the seed is large size.	Central Rift Valley and similar areas.
Batu	Days to maturity are 75–85; grain yield ranges from 1.8–2.5t/ha, high yielding, the seed is large size.	All bean growing regions.
Dame	Days to maturity are 90–115, grain yield ranges from 1.8–3.0 t/ha, very high yielding, the seed is large size.	All bean growing regions.

Source: Ethiopian Institute of Agricultural Research, unpublished data, workshop 2010
Note: all the grain yields are from research center

Cow peas (*Vigna unguiculata)*

Black eye bean: Adaptation areas: The variety is well adapted to semi-arid areas specifically to Kobo-Alamata plain, CRV, Shewa Robit, semi-arid areas of Tigray, Jijiga areas in the Somali region and Borena areas. The altitude ranges from 100–1600 m a.s.l and rainfall from 300–600 mm. The maturity period ranges from 80 to 85 days and so it is very early and suits areas with short growing season. The yield potential ranges from 1.6–2.0 t/ha.

Other cow pea varieties: including TVU1977OD-1, WWT, Bole and Assebot are also released as early maturing and drought and heat resistant varieties for the semi-arid and arid areas of the country. These varieties are highly preferred as food crops with high protein supplement. The biomass is also utilized as feed for animals. They are in large production by the farming community (see Table 7).

Note: This crop cowpea is highly preferred as food and feed crop in most dryland areas but particularly in Jijiga area of the Somali region.

TABLE 7
Improved cow pea varieties for drylands

Cow pea variety	Main Description	Best adaptation areas
Black eye bean	Drought resistant, early maturing 80–85 days, determinate, erect type, yield ranges 1.6–2.0 t/ha.	Well adapted to the drylands with short growing period, altitude1000–1600 m, and rainfall 300–600 mm.
TVU	Drought resistant, early maturing 80–85 days, Intermediate, semi-erect, yield ranges 1.6–2.0 t/ha additional advantage high fodder production.	Same as above.
White wonder trailing	High quality grain and fodder, very early maturing 65–90 days, grain yield t/ha ranges 18–20 suitable for drylands.	All dryland area lowland areas less that 1800 m.
Assebot	Early with days to maturity 75–80 with grain yield of 1,8–2.0 t/ha in research and about 1.7 on farmers field.	Altitude ranges 1300–1650 m with rainfall 350–750 mm the best adaptation areas is the Assebot Meiso and other similar areas.

Source: Ethiopian Institute of Agricultural Research, unpublished data, workshop 2010

Mung bean (*Vigna radiata*)

Mung bean is very early maturing crop, which is also drought resistant. It has great potential for the semi-arid areas due to its short growing cycle. Special features include high yield; good nutritive value, the earliness and drought resilient features, the reasonable cost of production and the ability to stimulate striga without being parasitized. Some improved varieties for the drylands have been and are describe below.

TABLE 8
Improved Mung bean varieties for drylands

Mung bean variety	Main Description	Best adaptation areas
N-26	Early maturing to maturity days 70–80; yield 1.4–2.0 t/ha with high protein content.	1000–1650 m, with rainfall 350–750. It is adapted to many low growing period areas such as the Rift Valley, Kobo, Showa, Robit and other similar areas.
Borda	Early maturing to maturity days 70–80, yield 1.4–2.0 t/ha with high protein content , additional good forage yield.	Same as above.

Source: Ethiopian Institute of Agricultural Research, unpublished data, workshop 2010

Pigeon pea (*Cajanus cajan*)

Pigeon pea is a high-value multi-purpose legume crop, with similar uses to chickpea and other legumes. It is a drought resistant crop which improves soil fertility by fixing nitrogen, conserves soils and produces highly valuable grain for export and local consumption. It has high demand in export markets. Pigeon pea produce wood for energy supply and above all produces biomass for animal feed, thus it is multipurpose crop which integrates crop and livestock production. It is well adapted to the semi-arid and arid regions, for example Konso, Sirika, Kobo and other areas in Ethiopia.

EIAR introduced three improved varieties of pigeon pea, which are early maturing and drought resistant. These varieties include ICEAP 87091, ICP 7732, ICEAP 87091, ICEAP 7732 (see Table 9).

TABLE 9

Improved pigeon pea varieties for drylands

Pigeon pea variety	Main Description	Best adaptation areas
ICEAP 87091	Early days to maturity 110–120 days, grain yield 1.0–1.5 t/ha, source of fodder, fuel wood, improve soil fertility, reduce erosion, high vale crop.	Altitude ranges 1000–1650, with rainfall of 350–750 mm fits to dry and wet semi-arid in south central and northern part of the country.
ICP 7732	Intermediate growing period 120–130 days yield 1.0–1.5 t/ha, provides quality fodder, and good for apiculture production.	The same as above.

Source: Ethiopian Institute of Agricultural Research, unpublished data, workshop 2010

Oil Crops

There is a shortage of oil crops supply in the dryland areas of Ethiopia. Research has been undertaken under both rainfed and irrigated conditions and the recommended varieties are indicated in Tables 11 and 12 below. The major oil crops in the dryland areas of Ethiopia are sesame and groundnuts. The varieties developed by NARS for dryland areas and climate change adaptation are detailed in the following sections.

Sesame (*Sesamum indicum*)

Sesame is one of the oldest crop cultivated for its oil. It is mostly grown as a rainfed crop in the Semi-arid regions. Sesame has a heat and light requirements and is sensitive to low temperature. This oil crop has some commercial value in the Kobbo-Alamata plain and Zobul areas in northern Ethiopia. It is predominantly drought resistant and very intolerant to water logged soils, it can be grown in pure stand, but it usually intercropped with sorghum or maize or millets. Because of its good price, it is likely to be used as a cash crop, especially if white seeded varieties are made available through research.

There are 9 varieties developed both rainfed and irrigated of the dryland. These varieties include Kelafo-74 T-85 Kelafo-74, E, S, Adi,. The yield ranges 0.5 to 2.0 t/ha. They are early ranging from 95 to 122 days to maturity and fit to the short growing period of the drylands. All these varieties are recommended for the drylands.

Table 10
Improved sesame varieties for drylands

Sesame variety	Main Description	Best adaptation areas
T-85	It is drought resistant and also resistant to the major pests and disease in the drylands, early maturing and white seeded with high market potential. Grain yield ranges research center 1.0 to 2.0 t/ha; farmer's field about 0.5.	Adapted to lowland areas up 1250 m, with rainfall of 500–700 mm. Well adapted to the arid and dry semi-arid areas.
Kelafo-74	Early maturing and drought resistant, yield ranges research center 0.6–1.2 t/ha; farmer's field about 0.3 t/ha.	Adapted to lowland areas up 1250 m, with rainfall of 500–700 mm. Well adapted to the arid and dry semi-arid areas particularly the Kelafo area in the Somali region.
E	Very early drought and pest tolerant yield ranges research center 0.6–1.2 t/ha: farmer's field about 0.3 t/ha.	Adapted to lowland areas up 1250 m, with rainfall of 500–700 mm and most sesame growing areas.
Adi	Early, short cycle drought and pest resistant yield ranges research center 0.6–1.2 t/ha; farmer's field about 0.3 t/ha.	Same as above.
S	Yield under rainfed is 0.4–1.0 t/ha and irrigation 1.2–1.6 t/ha; oil content 44–47%.	To area with short growing areas with days to maturity 90–115 fit all dryland areas.
Mehado-80	Yield under rainfed is 0.4–1.0 t/ha and irrigation 1.5–2.2 t/ha; oil content 44–47%.	Well adapted to areas with altitude, with days to maturity 90–110, fit all dryland areas.
Abasena	Yield under rainfed is 0.6–1.2 t/ha and under irrigation 1.2–1.9 t/ha; oil content 43–47%.	Well adapted to dry lands with days to maturity 90–115.
Argene	Yield under irrigation is 1.5–1.8 t/ha; under rainfed not given;oil content 43–46%.	with days to maturity 95–105 fit all dryland areas.
Serkamo	Yield under irrigation is 1.5–1.8 t/ha; under rainfed yields not given; oil content 43–46%.	Days to maturity 95–105, fit to all dryland areas

Source: Ethiopian Institute of Agricultural Research, unpublished data, workshop 2010

Ground Nut (*Arachis hypoaea L.*)

Groundnut is also a very important cash crop for the smallholder dryland farmer in Ethiopia. The crop provides cash revenue to the small farmer and their family on local market; for instance, a kilo of sesame is sold at ETB 4.

Table 11

Improved ground nut varieties for drylands

Groundnut Variety	Main description	Best adaptation areas
Nc-4X	Days to maturity 130 to 165; drought, heat and disease resistant; yield 5.0–6.5 t/ha under irrigation and 2.0–3.5 t/ha under rainfed; oil content 44–49%.	Well to the Haraghie area including Bable, Besidimo dry semi-arid areas.
NC-343	Days to maturity 130 to 165; drought, heat and disease resistant, yield 5.0–7.0 t/ha under irrigation and 2.0–4.0 t/ha under rainfed; oil content 44–49%.	Well to the Haraghie area including Bable, Besidimo dry semi-arid areas.
Roba	Days to maturity 130 to 165; drought, heat and disease resistant; yield 5.0–6.5 t/ha under irrigation and 2.0–3.5 t/ha under rainfed; oil content 42–49%.	Well to the Haraghie area including Bable, Besidimo dry semi-arid areas.
Sedi	Days to maturity 130 to 165; drought, heat and disease resistant; yield 5.0–6.5 t/ha under irrigation and 2.0–3.5 t/ha under rainfed; oil content 44–49%.	Well to the Haraghie area including Bable, Besidimo dry semi-arid areas and rift valley areas.
Manipeter	Days to maturity 130 to 165; drought, heat and disease resistant; yield 5.0–6.5 t/ha under irrigation and 2.0–3.5 t/ha under rainfed; oil content 44–49%.	Well to the Haraghie area including Bable, Besidimo dry semi-arid areas. And the rift valley areas.
E	Days to maturity 130 to 165; drought, heat and disease resistant; yield 5.0–6.5 t/ha under irrigation and 2.0–3.5 t/ha under rainfed; oil content 44–49%.	Well to the Haraghie area including Bable, Besidimo dry semi-arid areas. And the rift valley areas.

Source: Ethiopian Institute of Agricultural Research, unpublished data, workshop 2010

Other Crops

There are also root crops, for example cassava, sweet potatoes, also other oil crops and cereals which could be introduced to Ethiopia.

AGRONOMY

Management Practices for Efficient Utilization of Available Resources to adapt to climate change

In the dryland areas, the growing period is short and all the important activities such as land preparation, planting, weeding and other field operation should be performed at the right time. The importance of timeliness and precision is highlighted in several research publications and outlined in the following section.

Cultural Practices

In the drylands, the resource needed for successful crop growth and development (water nutrients and other growth factors) are usually limited. Therefore, timelines and precision in field operation in the drylands is very important to achieve timely and efficient resource utilization. This includes early land preparation, timely planting, weeding, appropriate seeding depth and plant population (seed rate). If these are optimized, the result will be substantial increase in both grain yield and biomass production. Optimization of these field operations is thus vital to increase crop production.

Land preparation methods: Land preparation is the first and important agronomic practice to ensure the field is free from weeds and crop stubble, also soil pulverization helps in better root development. In rainfed areas, cultivation does not need much plowing. The conservative tillage practices should be followed before the onset of rains for better conservation of rainfall in the soil and destruction of weeds. Heavy deep tillage practices and a large time lag between land preparation and sowing should be avoided to reduce soil and moisture losses. In arid areas, the saying "touch-me-as-little-as-possible" holds good for plough-plant system and a combination of plough and blade is sufficient for better tilth and good seed bed preparation.

Experiments have been conducted in the drylands to evaluate the effect of time, frequency and type of tillage - these indicated that early plowing and planting increased grain yield of wheat by about 84 percent compared to the traditional practice of late plowing and planting (Kidane 2003).

Planting time: In dryland areas, limited soil water is the overriding factor constraining crop production. As a result, selecting appropriate crop species and cultivars which can fit to the growing period of a given area and adjusting planting dates in such a way that critical growth stages coincide with the optimum environmental conditions generally leads to efficient utilization of the limited resources. Under dryland conditions, dry or early sowing gives substantially higher yields compared to the traditional late planting after two or three effective rainfall. For example, at Kobo, dry sown sorghum produced 3.1 t/ha, whereas, sowing after one, two and three effective rains gave 2.4, 2.0, 1.4 t/ha, thus the former is recommended practice.

Planting depth: Early planting generally gives high yield under dryland farming as indicated above, but if the first rains are small showers which initiate germination but not sufficient for successful germination, then pests and diseases will attack the seedlings and consequently stand establishment will be poor, leading to reduced yield. This can be avoided by adjusting the planting depth. Results of trials in the drylands of Ethiopia have indicated that 4 cm depth of planting is optimum for sorghum production in the semi-arid areas (Reddy and Kidane 1993).

Planting density: Plan population density should also be adjusted to the available resources, particularly the soil water and nutrient level, to improve water-use efficiency. The first step is to determine the optimum plant population for a particular locality. Thereafter, maximum exploitation of the available resources (available water, nutrients and radiant energy) could be made by using appropriate special arrangement of plants. Research results in Ethiopia had indicated that up to a 20 percent increase in yield could be obtained in the drylands through improved spatial arrangement and population (Reddy and Kidane).

Weed control: Weeds are some of the most serious crop production constraints. Weeds are potent competitors with crops, particularly in dry areas. They are capable of utilizing soil water and nutrients much faster than crop plants. Furthermore, they play host to several pests and diseases. It is therefore essential that weeds are controlled at the right time.

Studies conducted at Melkassa areas of Ethiopia indicate that weed control during early stage (20-30 DAE) and mid season (4045 DAE) result in higher yields and this is recommended for maize production in the Rift Valley areas. Through better weed control, up to 50 percent yield increase can be obtained (Kidane 2003).

Research finding from different counties in the semi-arid areas of Africa have clearly demonstrated this finding. The impact of improved crop husbandry and agronomic practices on output and productivity in semi-arid areas as indicated below.

Table 12

Improved agronomic in crop yield increase in drylands

Agronomic Practice	Impact on output in drylands of Africa	Remarks
A. Optimum time of planting	Up to 50% increase output in dry areas is possible.	Considerable research has already been done for dry areas of Africa.
B. Improved spatial arrangements and plant populations	Up to 20% increase in yields.	Only a well-coordinated extension effort is required.
C. Improved field preparation and tillage practices	Up to 30% in drier areas and areas with "difficult" soils in the humid zone.	A lot of as yet unfinished research is being undertaken.
D. Use of the best variety available	Up to 30% in large areas.	Development is very fast.
E. Better fertilizer	Up to 50% in large areas.	In Asia, there is a good database on fertilizer response. In Africa less satisfactory.
F. Better weed control	Up to 40% in many areas.	Can very easily be improved.
G. Better pests and disease control	Up to 30% almost everywhere.	Much more research is required everywhere.

Source: Kidane *et al.* Ethiopian Institute of Agricultural Research, 2005

In summary, in dryland areas where resources such as soil water and fertility status are low and where the length of growing period is usually short and variable, the timeliness and precision of field operations is important for increased production and productivity. Hence, as indicate earlier, the genetic potential of crops can only be realized if both improved varieties and management practices are integrated and implemented. This is an extremely important issue in the context of adaptation to climate change and variability.

Agronomic management practices for efficient water conservation and utilization

It is important to conserve every drop of rain that falls to the ground and efficiently utilize it to increase production on sustainable basis. A number of technologies have been developed and major ones are indicated below:

Tied ridges, *in situ* water harvesting: Use of tied ridges is very effective in soil water conservation and results in 50-100 percent grain and 80 percent straw yield increase being obtained compared to the traditional method of planting in the flat seedbed in many semi-arid areas of Ethiopia. It is widely adopted in many semi-arid areas.

Adaptation areas in the drylands of Ethiopia

North dryland areas: Tigray in the valley bottom areas of south Alamata, western areas in Humera, Sheraro, central Mekele areas; Amhara region Kobo, Shewa Robit areas.

Eastern areas: Jijiga and Meiso, Haramaya areas, Hirna other similar areas.

Central Ethiopia: central rift valley, Ziway, Melkassa areas and other dryland areas in the Oromiya region. Better management of rain water with tied ridges, as well as being important to increase productivity, is also effective means of reducing climate induced risks.

Mulching: Most of the soils in the semi-arid areas are highly degraded with poor physical, chemical and biological properties. The soils have the problems of compaction or surface sealing / crusting which lead to low water infiltration and high runoff. Mulching is traditionally used to alleviate these problems and research results in central Rift Valley indicated that use of mulches at the rate of 3 tons increased yield by 30 percent compared without mulching The mulching materials are obtained from pigeon pea and *sesbania sesban* drought resistant and as such results could be implemented with no problem.

The use of *Sebania sesban* mulches were also found to increase grain and stover yield substantially compared to the control (without mulching).

Use of tied ridges with stover mulch: Mulch conserves more water and leads to higher dry matter and grain yields of maize compared to minimum tillage. The use of mulch effectively controlled runoff through increased surface water storage, which in turn increased the time available for infiltration and also minimized evaporation, surface sealing and crusting. It was also reported that, when a combination of tied ridges and maize stover mulch were used, a crop of maize was realized for a season of extremely low rainfall (171 mm) whereas no yield was obtained from the conventional tillage plots with or without farmyard manure. Fertilizer use also increases water use efficiency (Kidane 2004). This practice is found to be very important with the current problems of variable rainfall condition in the drylands.

Shishallo: Farmers in the semi-arid regions of Ethiopia plant sorghum and maize at high seed rate to ensure enough plant stands. Then they cultivate the land through a practice called shilshallo to reduce the plant stands, breaking the soil crust and thereby both improving water infiltration and controlling weeds. The main problem with this practice is that it was not being performed at the correct plant stage, which was leading to substantial plant loss due to the breakage of the plants and consequently was associated to grain yield loss. This problem was improved though research. It is now found out that growth and yields were enhanced when the shilshallo was performed at earlier stages (6-8 leaf stage for sorghum and 4-6 leaf stages for maize as compared to the farmers practice performing shilshallo at 10 leaf stages for both crops).

Integrated agronomic management practices: Improving rainwater management alone cannot deliver increased productivity. Water management must form part of a farming system that includes a whole range of inputs such as fertilizer, pesticide, improved seed and adequate farm power.improving water productivity: Weeds should be controlled as early as possible to avoid completion. Fertilizer need to be applied at recommended rate weeds should be controlled early. This integration of management practices resulted in increased maize yields of between 37 and 117 percent, as compared to the farmers' traditional practices (see Table 13).

Table 13.
Integrated agronomic management practices for improving water productivity

Management practices	Yield (t/ha)
Broadcasting, no fertilizer, late weeding 6 weeks after emergence, flat planting (check, farmers practice)	1.3
Row planting, no fertilizer, late weeding 6 weeks after emergence, flat planting	1.7 (37)
No fertilizer, Late weeding 6 weeks after emergence, tied ridges	1.9 (46)
No fertilizer, early weeding 3 weeks after planting, tied ridges	2.3 (73)
40 N 46 P_2O_5, early weeding 3 weeks after planting, tied ridges	2.9 (117)

Kidane *et al.* EIAR 2003

Gap in crop yield between research stations and farmers field

Farmers have not benefited as expected from these technologies. This can be shown by the assessment of the growth of the food grain yields over a sixteen year period from the 1979/80 to 1995/96, during which the gain in production has come largely from area expansion and not improved technologies (i.e. yields per ha) (see Table 14). The crop yields obtained from research stations is substantially higher that in field trial and farmers yield.

Table 14
Food grain yield (t/ha), research station and farmers' field

Crop	Research Station 1979[a]	Field Trials 1979[b]	Farmer 1979[a]	Farmers 1995/1996[b]
Teff	2.4	1.8	0.8	0.8
Maize	9.0	5.0	1.2	1.7
Wheat	5.3	3.2	0.9	1.2
Sorghum	5.0	3.0	1.2	1.4
Barley	5.5	4.9	0.8	1.1
Haricot Beans	2.5	1.8	0.7	0.7
Horse beans	2.9	1.5	0.6	1.1
Field beans	1.3	1.0	0.6	0.7
Ground nut	4.5	3.5	0.3	na
Sesame	2.0	1.1	0.3	na

[a] Source: World Bank 1983, source: (CSA 1996)

One major reason for the above gap in yields between the research station conditions and farmers fields is lack of inputs and improved management practices. The poor research-extension linkage is also a problem, limiting the promotion of recommended management practices. Thus, there is a need to improve input availability and affordability to farmers in all areas, through strategic public investments that support the involvement of the private sector. Policies that pledge and support the private sector to make these inputs available to farmers in remote areas through incentive mechanisms are vital.

LIVESTOCK AND LIVESTOCK PRODUCTION IN ETHIOPIA

Technologies and best-bet practices to improve livestock production

Ethiopia has the highest number of livestock in Africa and its livestock population is the tenth largest in the world. Livestock in Ethiopia in general and the dryland areas in particular are the principal capital of the farmer (4.0 TLU per household). If properly managed and utilized the sector has the potential for economic development. Livestock are the mainstay for dryland peoples, particularly the pastoralists and agro-pastorals who are the main victims of drought and climate change. Livestock production gives opportunities for economic and social development which go beyond the objectives of food security. Livestock production is therefore economically, socially and politically a very important sector in Ethiopia's agricultural system.

In the dryland areas, climate change is already impacting livestock production, for example, changes in temperature and precipitation are affecting farming conditions and the capacity of the land resources to produce enough feed for livestock. Droughts and floods are striking with increasing frequency. Livestock disease epidemics, many of which can be linked to the effects of climate change, are increasing in frequency and severity. Overall, these events are leading to a reduction in livestock production.

Thus, without effective adaptation measures, livestock producers, especially small-scale producers, who form the majority, will continue to suffer substantial losses. The questions now is how we can develop technologies and utilize them adapt to the ongoing climate change and variability and improve their production?

The NARS, in collaboration with other organizations, have developed technologies to address these problems - evaluation and synthesis of this effort is discussed below.

INVENTORY OF BEST-BET INDIGENOUS PRACTICES AND KNOWLEDGE

Management practices

Traditional livestock management practices, developed by herders and pastoralists over the generations, could be extended into different areas and applicable to other communities without the need for further research. This would contribute to improving livestock production in the drylands and adapting to climate change. These traditional practices are indicated as follows and are in line with the NAPA's priority action.

- **Livestock are bred for their resilience to drought, high temperatures and**

diseases rather than their productivity. Because of this, growth and fertility rates are generally poor.

- **Herd species diversification:** is common, with many herd owners rearing a variety of different stock to reduce overall herd vulnerability to drought and disease. This practice is useful because the change in vegetation composition due to climate change and variability has forced pastoralists to spread the risk by raising different but easily adaptable livestock types. The Afar pastoralists, who used to raise cattle, currently prefer to raise camels and small ruminants and tend to reduce the number of cattle. The Somali pastoralists too prefer camels followed by small ruminants and cattle. Among Borena pastoralists, camel is becoming popular after cattle.
- **Keeping large herd size:** retaining a large herd size at the beginning of a drought will increase the likelihood that more will survive at the end of drought period.
- **Communal ownership of grazing areas:** communities have access to a vast variety of potential grazing and watering areas, which is controlled and regulated by defined social groups.
- **Human and livestock movement:** a response to seasonal variations in forage availability. Pastoralists exercise conservation of grazing resources for dry seasons, thereby mitigating feed shortages.
- **In the dry seasons,** when milk yields decline or are insufficient for subsistence, pastoralists depend on livestock and agricultural produce markets. They sell their sheep, goats and cattle, especially males and unproductive females, to purchase grain for home consumption. As the degree of severity of a drought increases, the pressure to sell their breeding stock increases.
- **Conservation of dry season grazing reserves:** use of crop by-products is an additional drought coping mechanism.
- **Watering frequency:** Livestock watering frequency primarily depends on the season, type of livestock and distance from watering points. Reduced frequency of watering is a common coping mechanism in areas where watering points are far from base villages.
- **The sale of livestock:** The primary interest of pastoral family is to maximize herd size, for insurance and security purposes, rather than keeping cash. In good years, pastoralists residing close to towns do sell livestock products such as milk and butter. In addition, male sheep and goats are sold to enable the pastoralists to purchase cereals and other household food supplies, also to cover expenses for medical care, payment of debts, taxes and social obligations. In addition, during post drought, male stock are sold to enable the purchasing of female breeding stock from the adjacent highlands.

These are traditional practices can be used to assist livestock herders to adapt to climate change.

A second issue is to address the problem of using the technologies developed by the research systems to increase production under the current climate change scenarios.

Available technologies

Some technologies have been developed to improve livestock production under the impacts of predicted climate change. The challenge now is how to get these technologies and practices adapted to local conditions and adopted on a wide-scale. Some communities may require new technologies and others need the revival of traditional technologies and practices. The important thing is to select what works the best / best-bet technologies and then seeks ways of making them widely available to the livestock-keeping communities.

Breed improvement: Small ruminant sheep and goat

The total number of sheep and goats in Ethiopia is estimated to be nearly 48 million, which is the third largest number among African nations and ranks eighth in the world. Traditionally, sheep and goat have served as ready cash and a reserve against economic and agricultural production hardship especially during drought periods (Alemu Yami and R.C. Merkel 2008).

Sheep and goats are widely adapted to different climates and are found in all production systems. They also have lower feed requirements than cattle, due to their smaller body size. This allows easy integration of small ruminants into different farming systems, particularly in the drylands.

Sheep and goats also have higher survival rates than cattle under drought conditions e. Moreover, because of their reproductive rates, flock numbers can be restored more rapidly. With regard to goats, water economy is also an important biological feature. It is common for goats only to require to be watered every four days and still provide a reasonable amount of production, whereas sheep and especially cattle need more frequent watering. Being small-sized animals and thus lower costs / value, sheep and goats require a smaller initial investment, however, their small size, together with early maturity, makes them suitable for meeting subsistence needs for meat and milk. Because of all these attributes, small ruminants are important components of sustainable farming systems for the dryland areas, which are already under pressure from and climate change, hence their focus in this discussion paper.

Recently, the Ethiopian MoARD, in collaboration with USAID, introduced drought resistant and highly productive small ruminants (sheep and goat) through the project entitled Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP) for the dryland area. The introduced sheep and goat breeds include Dorper sheep and Boer goat.

Dorper sheep *highly productive*

The Dorper is a South African mutton breed, from the initial crosses between Dorset Horn and Blackhead Ogaden also called Blackhead Somali and Blackhead Persian – thus these breeds have Ethiopian blood.

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Dorpers are highly adaptable and do well in harsh extensive conditions as well as in more intensive operations. As a strong and non-selective grazer, the Dorper can advantageously be incorporated into a well-planned range management system. The characteristics of the breed include the ability to walk long distances and to forage well in permanently dry areas and in times of drought.

Dorper sheep have a natural tolerance to high temperatures and heavy insect populations, most probably due to their Blackhead Persian origin. They are productive in areas where other breeds barely survive. The other good characteristics include high fertility rate with an unrestricted breeding season.

The Dorper have a fast rate of growth, with mature rams weighing between 100 and 125 kg. Mature ewes average 73–100 kg and have excellent meat qualities. A live weight of about 36 kg can be reached by the Dorper lamb at the age of 3–4 months ensuring a high quality.

The dorper has a thick skin which is highly prized and also protects the sheep under harsh climatic conditions. The Dorper skin is the most sought after sheep skin in the world and is marketed under the name of Cape Glovers. The skin comprises a high percentage of the income (20 percent) of the total carcass value.

Boer Goats, *highly productive*

The present day Boer goat appeared in the early 1900s, when ranchers in the Eastern Cape Province of South Africa started selecting for a meat-type goat. The general characteristics are that the Boer goat is a large, double muscled animal, developed specifically for meat and hardiness. Boer boats have a high resistance to disease and adapt well to hot, dry semi-deserts.

The fertility rate of the Boer is high, with a kidding rate of 200 percent common Puberty is reached early, usually at about 6 months for males and 10-12 months for females. The Boer goat also has an extended breeding season, making possible three kiddings every two years. Producing weaning rates in excess of 160 percent, the Boer goat doe is a low maintenance animal, which has sufficient milk to rear an early maturing kid. Boer does are reported to have superior mothering skills compared to other goat breeds.

Performance records for this breed indicate exceptional individuals are capable of average daily gains of over 200 g/day in a feedlot. More standard performance would be 150–170 g/day. The mature Boer buck weighs between 110–135 kg and does between 90 and 100 kg. The Boer goat also has excellent carcass qualities, making it one of the most popular breeds of meat goat in the world.

The introduction of small ruminant breeds such as the Dorper and the Boer is contributing to adaptation to climate change and food security and improving the livelihood of the communities of the drylands.

Feed Resource Improvement

Feed shortage is a further major constraint in livestock production in Ethiopia and several activities were carried out by the NARS and other institutions to address this problem in order to improve food security in relation to climate change. These include natural pasture improvement, backyard forage introduction and development, integration of forage legumes into cereal production systems and various forms of utilization of feed resources for livestock production.

The natural forage was improved through area closure, allowing the natural pasture to regenerate, with additional enrichment planting carried-out to fill gaps between natural vegetation. Highly degraded areas were particularly selected and enclosed in many dryland areas, to allow the natural pasture to rehabilitate and vegetate. Drought resistant herbaceous legumes (with N-fixing benefits) and grass species have been promoted to improve the fodder quality. Together with on-the-ground activities, community members have been organized into groups and formulated bylaws / regulations within the context of the regional state land use guidelines. Thus communities have gained considerable benefit from improved harvests of grass to feed their animals, sell out to earn cash and long grass (senbelet, local name), which is used for roofing in house construction (Water Action, CRS 2005). In this approach, community participation was the key for the success.

Several leguminous shrubs which are drought resistant leguminous forage crops, such as pigeon pea, saltbush, Senna artemisioides and Opunti (Beles), were also grown in watershed areas in many woredas in the semi-arid areas of Tigray (GTZ 2009). These forage crops can grow in areas receiving as little as 200 mm of rainfall. The crops are nutritious perennial forage shrub, valuable for small ruminants and cattle. They also provide protein and minerals (especially salt, salt bush) needed by ruminants.

Backyard forage production has also shown encouraging results, especially at Yeku in Sekota area. Most farmers have now started growing livestock forage in their backyards or even on part of their farm plot. These farmers, aside from fulfilling their livestock feed requirement, are often also making better cash income, from the sale of forage seeds to agricultural offices and NGOs. In the last reporting period, 86 farmers each has sown cow pea on a plot size of 0.125–0.25 ha.

These forage crops are very effective in soil and water conservation, soil fertility improvement and rehabilitation of degraded areas, as demonstrated in most watershed areas in Ethiopia.

In addition, there are several feed resources including forages identified by the NARS and CGIAR (mainly ILIRI) which are playing an important role in drylands by having multipurpose value to the farmer, other than as a feed resource for his livestock. A large number of indigenous forages, which can be screened and selected for use as feed, grow in the dry rangelands of Ethiopia. The germplasm available and suitable species for use as livestock feed in arid and semi arid environments in Ethiopia and Africa are available. Thus large quantities of these germplasm can be evaluated and promising species identified for incorporation into livestock production systems.

Some examples of the available forage resources and their utilization in the dryland areas of Ethiopia include, *Acacia, Alysicarpus, Cassia, Crotalaria, Indigofera, Rhynchosia, Stylosanthes, Tephrosia, Vigna* and *Zornia* are among the most important leguminous genera, which are well distributed in arid and semi-arid areas. Among these, *S. fruticosa* is indigenous to Ethiopia and other dry areas in East and West Africa and is an important feed source in rangeland areas.

Grasses are very drought-tolerant and tend to have a wide distribution in the very arid areas in the Sahel. Important indigenous genera include *Aristida, Cenchrus, Chloris, Echinochloa, Eragrostis, Panicum, Pennisetum* and *Sporobolus*. Birdwood grass (*Cenchrus setigerus* Vahl) shows very good adaptation to drought and can grow with as little as 200 to 250 mm annual rainfall, whilst buffel grass (*C. ciliaris* L.) and veldt grass (*Ehrharta calycina* Sm.) require about 350 mm to grow (Humphreys 1980). Other tropical genera which perform well in drought conditions are *Panicum, Pennisetum* and *Sporobolus* (Harlan 1983). All these grasses species are tested in the drylands of Ethiopia and could be used to solve the feed problem and increase livestock production.

Many tree and shrub species are also important feed resources in dry areas, especially for goats. The major species browsed for forage in these areas in Ethiopia are *Acacia senegal* Willd., A. tortilis (Forsk.) Hayne, *Balanites aegyptiaca* Delile, *Bauhinia rufescens* Lam., *Combretum aculeatum* Vent., *Colophospermum mopane* (Kidane 2005).

Probably the most important leguminous fodder/forage tree indigenous to Ethiopia is Acacia (including *Faidherbia*). This genus has about 130 species widely distributed in Africa. Many are very drought-tolerant and can survive over a wide altitude range. One of the most widespread and useful *Acacia* species is the umbrella thorn (*A. tortilis*), whose pods and seeds are an important feed resource for livestock and wildlife in Africa (Menwyelet *et al*. 1994; NAS 1979). From the nutritional analysis of seeds of different *Acacia* species, Aganga *et al.* (1997) concluded that they could partly help solve the shortage of energy and protein feedstuffs during the dry season and supplement low quality forage grazed by ruminant livestock.

This analysis indicates that there are many feed source in the dryland areas which could contribute to adaptation to climate change and increase livestock production on sustainable basis.

DRYLAND FORESTRY

This section firstly highlight the problems of natural resource degradation, which are leading to food insecurity and imbalances in the environment in the dryland areas, which are the hot spots of climate variability and change. Subsequently, the role of agroforestry in relation to these problems is assessed and evaluated.

The drylands areas of Ethiopia have been deforested on a large scale, resulting in massive land degradation. This is well documented. For instance, EPA (2003) estimated that rate of forest loss in the country was 100 000 – 200 000 ha annually. Currently, forest covers less than 2.7 percent of the land mass. This has opened vast areas of vulnerable steep land to soil erosion. Some three decades ago, the Ethiopian Highlands Reclamation Study (EHRS) estimated that the annual average net soil loss was 130 t/ha; a mean loss of 1 900 million tons of soil; an annual soil depth loss of 8 mm (FAO, 1986). Since then, the population of the country has almost doubled further exacerbating these figures. The annual loss in grain production due to soil degradation was estimated at 40 000 tons in 1997, reaching 170 000 tons in 2 000 (Shibru Tedla and Kifle Lemma, 1998). This translates into an annual income loss of US$150 million (Barbier, 1998), which is a loss of approximately 17 percent of the total agricultural GDP (EPA, 1997).

At this point in time, it is important to describe the contribution of agroforestry in natural resource conservation and the potential improvement in agricultural production through the integration of crop and livestock production. Trees in agroforestry systems reduce the impact of land degradation; improve soil fertility by increasing soil organic matter, minimize soil erosion by reducing runoff, increasing soil water infiltration and soil water holding capacity. Thus, the major production limiting factors of soil water and fertility are improved through practice of agroforestry systems.

In addition, trees and grasses, legumes and fodder trees found in the farming system of the drylands lead to soil stabilization, providing ground cover and wind breaks to prevent soil erosion, also contributing to soil fertility through decomposition of organic matter and microbial nitrogen fixation. There are numerous research results which verify that this results in soil carbon sequestration, which is also important for climate change mitigation.

In this section, the contribution of agroforestry in improving crop livestock production on sustainable basis through improving soil water and fertility conditions areas of Ethiopia is described. It covers the technologies developed and the use best practices of the traditional practice by the farming communities in the drylands.

INTEGRATION OF CROP-LIVESTOCK PRODUCTION TECHNOLOGIES

A practice of integrating crop and livestock production, also alley cropping of woody species with crops of various forms, which is also called agroforestry, is widely practiced by traditional farmers in Ethiopia. Despite its potentials, this old practice is still a much-neglected area in terms of research and development, which requires more quantification to improve productivity. There is a substantial body of evidence to show that alley cropping can result in higher productivity, better control of environment, while safeguarding against unfavorable conditions including adaptation to climate change and variability (e.g. shade for humans, animals and soils). Technologies developed in the semi-arid areas of Ethiopia and elsewhere confirmed the contribution which alley cropping can make.

Experiments conducted in the dryland areas in the central Rift Valley areas and northern Ethiopia on alley cropping leguminous shrubs (pigeon peas, *L. leucocephala* and *Sesbania sesban*) with annual crops sorghum, maize and beans resulted in increased grain yields for human consumption and fodder for livestock feed (Kidane 1987). It was indicated that there was a possibility of producing two crops per year, without reduction in yield. Both stover and grain yields of food crops from the alley cropping system were better than yields from pure stands. At Melkasa in the central Rift Valley, grain yields of the annual crops increased by up to about 30 percent. This was obtained when haricot bean was alley cropped with *C. cajan* compared to mono-cropping. In addition, the legume trees, especially *S. sesban* and *C. cajan*, produced substantial amounts of dry matter (a biomass yield increase of 2-3 t/ha of *Sesbania* was obtained at Sirinka in North Ethiopia) which can be used for animal feed, fuel wood or as a green manure or mulch to improve soil fertility.

In the Eastern part of Ethiopia 5t/ha of *Sebania sesban* dry matter was obtained in alley cropping with wheat. Application of this as a mulch in the wheat field increased grain yield significantly from 0.5 t/ha to 1.0 t/ha (about 100 percent increase) and 2.0 t/ha to 3.8 t/ha (more than 90 percent straw yield increase) over the control (Bishra *et al.* 2004).

- Alley cropping is a better alternative to the traditional mono-cropping system, as it helps to integrate crops with livestock, soil and water conservation and forest production. Thus, in view of the continuous decline of agricultural production and environmental degradation at an alarming rate because of various activities, in the context of increasing climate variability and change, the research in these areas and elsewhere in Ethiopia should focus on identifying multi-purposes trees to both human and livestock needs and which can be adapted to the different agricultural zones of the country.

In many drylands, for example in Harerge region, farmers maintain *Acacia albida* trees in their farm for fertility maintenance. In agreement with this Poshen (Murphy, H.F. 1968) reported a statistically significant increase in crop yields by 56 percent on the average for crops under tree canopies when compared to those away from the trees. This is attributed to increase organic matter, increased water infiltration rate and holding capacity of the soil near the tree due the foliage from the tree. For this reason *A. albida* is maintained by farmers in the field with annual crops. Similar study in Alemaya area showed that farmers keep *Coria* Africana in their field for shade (to rest underneath its leaves) to minimize the effect of heat stress in the drylands, for fodder, and for fuel (the pruned branches) (Kidane 2009).

In the coffee-producing areas of Ethiopia, trees in another traditional agroforestry system are important shade for coffee. According to the results of a survey done in some part of this production area, a shade of 30 percent as a result of these trees was observed in farmers' fields (Kasahun 1983). Common shade trees responsible were *C. africana, Croton mycrostachya, Acacia spp.*, and *Albizia spp*. In addition to shade, these trees have other important alternative uses. For example, *Cordia* is used for timber production, *Albizia* and *Acacia* are good in maintaining soil fertility as well as soil moisture at the beginning of dry season, and the leaves of some of these trees are used for dry animal feed.

SOME COMMON MULTIPURPOSE TREE CROPS IN ETHIOPIAN LANDSCAPE, WITH PARTICULAR EMPHASIS ON ADAPTATION TO CLIMATE CHANGE

In recent years interest has grown in the utilization of 'multipurpose' trees particularly tree crops. The variety of products that can be obtained from them and the number of uses for which these trees can be put to have pushed these multipurpose trees to the forefront in rural development plans in Ethiopia.

In the drylands of Ethiopia the important tree species include neem (*Azadirachta indica*), also *Moringa stenopetala, Moringa oleifera, Leuceana leucocephala, Pithecellobium dulce,* and other useful shrubs, for example pigeon pea (*Cajanus cajan*) and cactus (*Opuntia ficus-indica*) which are currently used to conserve the soil and water and improve agricultural production.

Neem (Azadirachta indica): The essential uses of the neem tree are in the control of agricultural insect pests, also medicine for malaria and other aliments. The crop also has various uses in forestry, agriculture, the environment for which it has not been given sufficient attention so far in Ethiopia (Personal communication with the Ethiopian association for the promotion of Neem). Neem was introduced to Ethiopia some three to four decades ago and some trees have been grown in parts of the hot lowlands, such as: Asayeta, Humera, Dire-Dawa, Awash and Ogaden for shade, ornamental purposes and as an avenue tree around homesteads and along roadsides. This tree crop is now becoming popular in the drylands Afar, Somali, Tigray. Neem is also found to be important for soil and water conservation. Thus this tree crop conserves resources, while also mitigating some important diseases and pests which are threats to humans and animals and are manifestation of climate change. *Moringa Stenopetala* (**Bak.**) **Cuf.**: *Moringa stenopetala* is often referred to as the African *Moringa* tree because it is native only to Ethiopia and northern Kenya. It is multipurpose tree and all parts of the tree, except the wood, are edible - providing a highly nutritious food for both humans and animals. The flowers are a good **nectar source for bees** and the seeds are **a rich oil source for cooking and lubricant uses**. Many parts of the plant have been used in medicinal preparations. Whole plants have been used as living hedges, fences and windbreaks. The wood is very soft; useful for paper but making low-grade firewood and poor charcoal. The crush seeds can also be used for cleaning water for drinking. This crop is traditionally grown in the Konso area, south Ethiopia. It has now been introduced to the central and north Ethiopia.

Cactus *opuntia*, *Beles*: This is a very drought resistant multipurpose cactus with multiple uses, that can grow on degraded and marginal land. It is used as human food (both fruits and leaves), also forage for livestock, the fruits can be a cash crop either sold fresh or processed as juice or jam, also for medicinal purposes. Cochineal, lice grown on leaves of *opuntia* from which a natural red dye called carmine is produced which are used worldwide in cosmetics, food and pharmaceuticals (pilot phase in Tigray). Cactus grown in the dryland areas of northern of Ethiopia is a food and feed security crop. It is important as drought crop and good climate change adaptation.

Inventory of the role of community-based development and commercialization of NTFPs in dryland areas in relation to adaptation to climate change

The drylands of Ethiopia are well endowed with natural resources. Among these resources, woodlands consisting of *Acacia, Boswellia* and *Commiphora* species represent important biological resources with significant economic and ecological functions. Although data on the extent of these resources is largely unavailable, some estimates on woodlands well-stocked with economical important tree species put the areal extent to be about half a million ha (Mulugata and Habtemariam 2008). The woodland resources are a source of income, food and medicine for the local populations, but most importantly these woodlands represent the source of export products such as gum, gum olibanum and myrrh - generating tens of millions of birr annually (Mulugeta and Habtemariam 2008). In terms of ecological functions, the woodland resources increase the resistance of the local ecosystems against the ever expanding desertification frontiers in the peripheral areas of the country. The woodland resources also play a significant role for stabilizing local climates and also sequester carbon.

Information on non-timber forest products and their socio-economic significance in Ethiopia: implications for policy dialogue

Non-timber forest products (NTFPs) include a variety of fruits, nuts, seeds, oils, spices, resins, gums, honey and beeswax, medicinal products, firewood and many more products and/or services specific to the particular areas from which they originate, especially the drylands.

Ethiopia's has exported forest products for centuries, comprising mainly NTFPs such as gums, incense, spices, honey and wax. For instance, in the period 1996-2003, Ethiopia exported 13 299 tons of natural gum and earned Birr141 064 151 (~US$18 000 000), while there was also a large import of lumber during the same period. In addition, national level forest industry (timber related industries) based employment amounts 9 583 employees, compared to 20 000–30 000 employees in gum and resin related business alone. Similarly, over 85 percent (approximately 60 000 000) of the population of Ethiopia depend on herbal/wild medicines for their primary health care and biomass-derived fuel for their energy. The dependency on herbal medicines and biomass based fuel has saved the country a huge cost for the importation of modern drugs and petroleum.

Beekeeping is and has been widely practiced by many households and contributes significantly to the livelihoods of the rural farmers. Beekeeping is particularly important in areas where rain-fed agriculture is less favored (e.g. drought prone areas). In the highly degraded areas where production is limited and high levels of food insecurity are endemic, it is important means of survival. Examples of areas where beekeeping is particularly important includes many highly degraded and sloping areas in northern Ethiopia such as the Sekota, Astbi-Wonberta, hawzen in Amhara and Tigray regions.

Beekeeping is improving the livelihoods of rural people through increasing the income of smallholders in the drylands. It was observed that annual income of beekeepers increased from about US$5 000 in 1998 to about US$1.8–2.1 million benefiting 10 878 households in 2007. In the same decade, average honey productivity increased from 5 kg to 30–50 kg/hive/year and price of quality honey increased eight fold.

In many areas of the watershed program, similar success has been obtained. The watershed programme has particularly improved the availability of forage, increasing production and also improved the market linkages. Notably, high quality honey is being produced by the farming community under the watershed programme in the Tigray region, changing the income situation of farmers and improving their livelihoods.

The role of NTFPs is very important, particularly for dryland forestry and is line with NAPA objectives therefore should be considered in the program of climate change adaptation.

Assessment of the role of wild plants in food security and commercial level uses in the drylands

The collection of wild plants as a food source is widespread in Ethiopia, especially in food insecure areas, including most drylands, where a wide range of species is consumed (Guinand & Dechassa Lemessa, 2000; Vivero, 2002). The consumption of wild plants is a necessary part of the strategies adopted by people in order to survive in harsh environments and periods. There are 120 species of plants recorded as wild food plants in Ethiopia, of which 50 species have been listed and classified as typical "famine-food" plants (Guinand & Dechassa Lemessa, 2000). Many pastoralists do not store and carry food over long distances, but rely on the seasonal products of forested areas.

Ripe fruits of *Cordia africana, Balanites aegyptiaca, Dovyalis abysssinica, Ficus* spp., *Carissa edulis,* and *Rosa abyssinica* are commonly consumed in many rural Ethiopian regions, particularly by children. Fruits of *Opuntia ficus indica* and *Borassus aethiopum* are consumed and traded in the market for cash generation in Tigray and Afar, respectively.

In general, the food values of the Ethiopian trees and forests have not been systematically explored and documented, despite frequently recurring famine problems. There is also low level of dependence on forest food in Ethiopia compared to eastern and southern African countries. However, wild plants could play an important role in food security, particularly in the context of the current and predicted threats of climate change. There is substantial opportunity to domesticate these wild plants and to expand their market value. They are also important security in the rapidly changing global environment, as wild reserves of biodiversity for human use. However, the challenge now is that many of the plant species used as wild foods are rapidly disappearing, even before known to science. There is urgent need for their conservation to be prioritized in the NAPA, the climate change adaptation program of action of Ethiopia.

CHAPTER 5

ASSESSMENT OF AGRICULTURAL TECHNOLOGIES TO ADAPT TO CLIMATE CHANGE IN DRYLANDS

The key strategies and thematic areas used to address the major challenges in the dryland areas in relation to the threats of climate change include:

- **Natural resource conservation and management:** with a major focus on rainwater harvesting and efficient water utilization; also efficient soil fertility and nutrient management;
- **Crops and cropping systems:** selection of the most suitable crops and cropping systems as per land capability class and rainwater availability (length of growing period), selecting early maturing and drought resistant crops;
- **Livestock strategy:** feed (fodder and/or forage) development and management, development of appropriate grazing practices, development and introduction of improved breeds, also integration of livestock and crop production; and
- **Agroforestry practices:** which integrate crop-livestock production; conserve soil water, assist in supplying energy, improve and fertility etc.

EVALUATION OF PRIORITY RESEARCH AREAS AND APPROACHES IN EACH SECTOR

The main objective of this assessment is to evaluate whether the technologies developed to assist farmers to adapt to the ongoing climate change are appropriate or otherwise. Are the technologies bringing the expected outputs, if not what are the problems, what should the way forward be to bring the expected impacts?

CROP PRODUCTION

One of the major problems of the research approach in the crop improvement program was the focus only on varietal development. However it is evident that the major critical constraints in the dryland areas are related to water stress, low soil fertility and other factors related to crop management. The first priority should be to identify the principal agronomic and other constraints, then improve the environment. It is only then that improved varieties should be used to increase production, when it is relevant to exploit their genetic potential.

Although there have been many research activities which demonstrate that the integrated approach, combining improved varieties with agronomic practices, improve crop productivity (Kidane 2003. Miller and Kebede, 1984:7), this has not been used as a package for farmers. During the last two decades, plant breeding has been the predominant discipline in NARS, with other disciplines providing a supporting role. This approach has not resulted in improvements in crop production in the drylands.

In summary it should be noted that crop productivity is a function not only of the genetic potential of a crop, but also of the agroclimatic, topographic and the soil environment in which the crop is grown. Both the genetic potential and the physical environment can be modified. With the Ethiopian dryland context, however, it is the highly variable ecology and climate (including low soil water and fertility, resulting in crop water and nutrient stress) that currently limits crop yields. Ignoring these management factors avoids the heart of the problem.

Focus on screening early maturity crops

The crop improvement program of Ethiopian research system has concentrated on screening early maturing varieties for drought tolerance. This is a good approach, however even during the short growing period in the dryland areas, the distribution of rainfall is high variable within the season. Therefore, even a short cycle crop could be exposed to water stress at any time during its life cycle, indicating the need to develop drought resistant crops and varieties. This should be a strategy in improving crop production in the dryland areas.

Mixed cropping: There are also substantial research results which demonstrate that mixed cropping systems are more sustainable, whilst mono-cropping is inherently unstable. Mixed cropping systems provide greater resilience to drought, increase soil fertility, diversify the family diet, even–out seasonal labor requirements and provide additional products for sale.

The research on cropping systems has very weak. The research themes so far tackled at the research center level on mixed cropping systems for instance include species comparison, planting configuration and planting schedule. The aspects which are untouched are genotype evaluation for inter-cropping, nutrient requirements, weed control, physiological aspects, responses to different moisture regimes, disease and pest control and erosion control. This drawback should be addressed to improve crop production in the dry areas.

Cereal based strategy: The major problems in the traditional crop production systems in dryland areas of Ethiopia (particularly in the north) is the dominance of cereal-based mono-cropping production systems. These systems have led to loss of soil fertility, high pest infestation, inefficient use of the limited resources and limited diversification. The crop improvement program has not responded to these problems and has mostly only conducted research mostly on mono-cropping systems. The research approach in the previous IAR was to focus on major cereal commodity crops such as wheat, sorghum, maize, barley and tef. These crops were given national commodity status and so high research priority. The supply of other crops, such as grain legumes and oil crops, is limited to the farming community especially in the cereal-based cropping systems.

LIVESTOCK IMPROVEMENT

There is some indigenous knowledge and practices developed by traditional herders which have been tested and found useful. It is vital that this knowledge is documented and synthesized for widespread use in the country or elsewhere. Such knowledge should be used as the basis for future research and development. Some of the livestock keeping communities may require new technologies, while others need to build on traditional technologies and practices. For example, the coping mechanisms pastoral communities have been employing for generations can be used to design and develop new ways to cope with increasing climate variability. The important thing is to identify the best-bet technologies and seeks ways of making them available to the livestock communities.

In livestock research, the gap between past research programmes and development interventions to adapt to the impacts of climate variability and climate changes on livestock production and productivity, for example where disease / pest pressures change – need to be bridged.

Drought and flood have lead to livestock deaths, loss of reproductive and productive efficiency, deterioration in quality and productivity of grazing lands and increased destitution of the pastoral community have occurred several times recently, at progressively shorter intervals (recently less than five years). However, documented information on the magnitude of displacement, loss of life and productivity of the livestock is rare. The meteorological data available from various stations have not been utilized to verify the magnitude of climate variability and changes which have led to the catastrophic loss of livestock. Geo-referenced early warning systems need to be developed for drought, flood and disease early warning, to aid traditional mobility patterns of the pastoralists.

The major challenges to the livestock production are summarized below to indicate the way forward to improve the production and develop adaptation strategies for climate change.

Scarcity of feed: the feed resource base for livestock production in Ethiopia is natural grazing and crop residues. The quality and supply of these resources is seasonally variable. Grazing resources in the lowlands are diminishing due to expansion of cropping land, bush encroachment and overgrazing.

Lack of infrastructure: the infrastructure necessary to transport livestock or livestock products from remote rural communities, where production is concentrated, to urban markets is lacking. Livestock are generally trekked long distances for marketing, often without adequate water and feed. They are also trekked similarly long distances in search of feed and water. There are very limited market centers and stock routes with the necessary facilities such as feeding and watering points.

High mortality rates: About one-half of all lambs/kids born die due to various causes. This is a very important constraint limiting productivity. For example, annual mortality in all classes of stock averages 23 percent for sheep and 25 percent for goats.

Inadequate veterinary coverage: results in high mortality and morbidity. Certain diseases are also causing Ethiopian animals and products to be banned from export markets.

Long marketing channels and lack of market information: Producers do not have access to market information; consequently the system lacks market orientation, which is an important driving force for increased production.

Low product quality: Poor quality of live animals and small ruminant meat and meat products prevents penetration into many export markets.

Absence or inadequate provision of credit services: Livestock owners have difficulty obtaining credit to begin or expand production, purchase inputs, increase stock, etc.

Low average reproductive rates: Typical reproductive rates average as low as 55 lambs and 56 kids born per 100 mature females per year in the central highlands.

DRYLAND AGROFORESTRY

Agroforestry systems are low-cost options for sustainable agriculture. By promoting tree-based agricultural systems, the country could contribute to the general well-being of the people and the environment on which they depend. It is well-recognized that agroforestry systems play a significant role in carbon sequestration, as well as improving agricultural sustainability as compared to monoculture cropping systems. Therefore, well designed agroforestry systems should be promoted for restoring the productive capacity of small-holder agricultural fields and increasing the capacity of these farmers to adapt to increasing temperature regimes associated with global climate change.

It should be noted that tree crops have far greater importance to households and society than their simple values in production for trade. Trees are assets that farmers can often use as collateral for obtaining credit, provide a multitude of by-products such as fuel wood and medicines and perform many environmental functions such as curbing soil erosion, sustaining biodiversity and sequestering carbon. Tree crops also help to integrate local economies into wider markets by providing entry into local, national and world-scale economic chains, incorporating numerous enterprises of all sizes and leading to a high multiplier effect.

These are very useful farming systems for environmental protection, improving the livelihood of the small farmers and above for climate change adaptation. The efforts of the NARS and development programs is step forward in line with the NAPA agreements.

Dryland forestry Challenges and Problems

There are a number of problems facing the dryland forest and woodland resources in Ethiopia. These include climatic, ecological, soil related, biological and socio-economic and institutional problems.

- **Climatic problems:** These include insufficient and variable total rainfall, unpredictable variation in rainfall pattern within and between seasons, unfavorable environmental conditions including, occurrence of intermittent but serious drought periods that affect natural and plantation forests, also high malaria and tsetse infestations in the lowlands leading to burning of forests and woodlands, constraining tree planting practices.

- **Deforestation:** There is no accurate or reliable information about the extent and location of the past and present natural forest and woody vegetation cover in Ethiopia.

- **Soil related problems:** Erosion by wind and water, declining soil fertility, low organic matter and associated physical problems, also problems in salinity and alkalinity.

- **Biological problems** include aggressive perennial plants, lack of drought tolerant species and provenances, termite attack, inadequate seeds of trees shrubs with desired quantity and quality, etc.

- **Socio-economic and institutional problems:** The socio-economic and institutional problems include: poverty, population growth and poor economic performance, absence of forest policy and legislation, absence of land and tree tenure/ownership/rights, the lack of pricing and incentive policies, absence of land-use classification and land-use planning policy, lack of pricing and incentive policies, lack of stable institutional set-up for forestry, also insufficient information dissemination.

CHAPTER 6

RECOMMENDATION AND CONCLUSION

It is evident from the foregoing discussion that the climate of Ethiopia is already highly variable. It is also clear that climate change will further exacerbate this variability, by increasing the intensity, frequency and severity of unusual climatic events.

The Ethiopian economy, which is dominated by the agriculture sector, is closely coupled with climate. Efforts made to partly decouple the economy from climate variability are not yet adequate because of the lack of hydraulic infrastructures, weak water management practices and poor integration of activities across sectors. Disasters caused by climate variability are posing huge challenges on the attainment of the Millennium Development Goals in Ethiopia.

Poor harvests and crop failures due to unreliable rainfall are exacerbating the challenge of feeding the ever-increasing population in Ethiopia. The climatic variability and change has become the main reason for the increasing frequency of droughts and floods recorded in recent decades. The agricultural contribution to total national GDP is directly related to climatic variability, thus changes in agriculture directly impact on the country's economic performance. There is evidence that food production trend in the country is very much correlated to the rainfall pattern as the result reduced yield and crop failure is frequent due to failures of rainy seasons. The impact of the current climate variability on crop production have clearly been seen on its effects on crop planting times, growing season length, shift in crop type or cultivars and production and productivity.

In tackling these problems, farmers have developed by trial and error responsive strategies to cope with such calamities. This implies that fixed technology recommendations are becoming of low value or less effective. Although farmers' actions are in response to needs, it is clear that farmer innovations can work to some degree. Some of these practices can be useful and perhaps be more fine-tuned as valuable indigenous knowledge.

Research recommendations are often not tailored to address seasonal variability and there are no decision support tools or seasonal climatic information which farmers can make use in decision-making. Despite existence of ample climatic data and information from often independent sources, it is generally difficult for users to apply. The research recommendations fail to take account of climate forecasts to enable improved strategic and tactical decision-making. Strong network and partnerships are required between different concerned institutions, to bring impact based on climate information.

Appropriate research strategies should be developed for mitigation, adaptation and ecosystem resilience to address the threats posed by climate change in the dryland areas.

The strategies should aim to strengthen the resilience of agricultural livelihood systems to climate change and variability with a focus on crops, livestock and crop-livestock integration.

Ethiopia is the center of origin and diversity of many cultivated crops and therefore conservation, characterization and sustainable use of genetic diversity is vital. There are unique opportunities for new varieties to be developed with better tolerance to growing biotic stresses (extremes of temperature, droughts, flooding and salinity). In addition, collection and use of commercially promising and/or under-utilized plants is required to sustain crop production in the face of the threats from climate change.

There is also a need to study the dynamics of pests and diseases under a changing climate and crop improvement to assist in reducing reliance on pesticides and herbicides. Additional IPM options will also be required to reduce vulnerability to changes in pathogen distribution due to climate change.

One of the deficiencies identified in the crop development program is the focusing on crop varieties which are early maturing and which are resilient only to water stress. A broadening of the approach is required to adapt to the predicted impacts of climate change through higher water-use efficiency and better partitioning for economic yield.

Although technologies developments are positive steps towards adapting to climate change, the crop diversification issue is important that should be given major focus. In the immediate future, with increasing climatic variability, the stability in crop production and incomes are likely to come through the diversification of cropping systems guided by the value of outputs rather than biological productivity.

It is important to take steps to reduce the pressure on rangelands by ether reducing the high livestock populations or develop proper rangeland rotations, to reduce overgrazing, increase C sequestration in rangeland soils and increase aboveground biomass, for better drought preparedness and adaptation to climate change threats. There is also a need to provide an integrated crop-livestock production system to improve the livelihood of the farming community. Besides in the livestock production system feed resource development, survival of the livestock and the pastoral system as a whole in a changing dynamic environment will require far more innovation in this line.

Activities such as conservation agriculture and revival of crop rotation practices to provide increased C sequestration, lower energy requirements and more robust cropping systems, also conserving the natural resource base, should be emphasized to increase production on a sustainable basis. Practices including improvements in water-use efficiency and water allocation to lower GHG emissions from soils and develop production systems adapted to climate variability, especially water scarcity should be advanced.

Research should be focusing on very important livestock species for dryland areas, such as camels and small ruminants (sheep and goats) in the dryland areas, particularly pastoral areas such Afar, Somali and Borena areas. It is thus recommended that these practices are prioritized in the agricultural research and development program.

There is no accurate or reliable information data base about the extent and location of the past and present natural forest and woody vegetation cover in Ethiopia. This should be prepared. In addition, data on soil related problems such as erosion by wind and water, declining soil fertility and soil organic matter content, which is closely associated with other physical problems (surface encrustations, low infiltration etc), and problems in salinity and alkalinity should be well documented. Documentation of biological problems aggressive perennial plants, lack of drought tolerant tree species, termite attack, inadequate seeds of trees shrubs with desired quantity and quality, is very important and carried out.

Institutional and legislative problems including absence of forest policy and legislation, absence of clear land and tree tenure/ownership policy, the lack of pricing and incentive policies, coherent land-use classification and land-use policy are also constraints in adapting to improved adaptation practices in agricultural-based livelihood systems in Ethiopia. Improving the existing weak institutional framework and capacities (agriculture and forestry institutions) and improved cross-sectoral coordination, requires urgent attention.

As shown in this publication, the inventory range on current practices and technologies on agricultural-based livelihood (crops, livestock, forestry and agroforestry), most notably, at the agricultural research station level is considerable. The major challenge is to scaling-up these practices and technologies at the farm level and to share this experience widely in other areas with similar agro-ecological conditions. These efforts in scaling-up will also be crucial in moving forward in the implementation of the adaptation options identified by the NAPA process in Ethiopia.

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ANNEX 1

PROGRESS MADE BY NARS IN CREATING AWARENESS; CAPACITY BUILDING AND MAINSTREAMING CLIMATE CHANGE TO RESEARCH FOR DEVELOPMENT

The national agricultural research systems in Ethiopia are currently struggling to develop technologies to increase agricultural production and enhance the natural resource base to cope with the increasing climate variability and change in all agro-ecologies, particularly in the drylands.

The Government has given increased focus to climate variability and change as it is now top in the development agenda. In line with this, the Government organized a national conference forum on climate change which was held on 15 January, 2009 at the UNECA Conference Center, Addis Ababa, Ethiopia. The National Climate Change Forum (NCCF), in collaboration with the Ministry of Agriculture and Rural Development, took the initiative to organize the conference. The conference was sponsored by an NGO by OXFAM, America. The high level conference, the first of its kind, was opened by the Head of State of Ethiopia. This indicates that the Government of Ethiopia has given high priority and focus to climate change.

The National Climate Change Forum (NCCF) was established by Government to coordinate climate activity works nationally and to draft a climate change strategy.

It is important to highlight the activities under taken by the NARS to adapt and mitigate climate change issues.

WORK CONDUCTED ON AWARENESS CREATION BY NARS

Several awareness creation training and workshops were conducted by the NARS particularly EIAR and this work are reviewed and documented. These include:

- Raising awareness of the public about climate change and its impacts by EIAR, Melkassa Research Center; which include DAs, NGOs, Zonal Administrators of the Easter Shewa;
- Organized agricultural consultation workshop for stakeholders on “Managing the Impacts of Climatic Variability on Agricultural Systems of Semi-Arid Ethiopia”;

- Workshop on 'Making the Best of Climate change – Adapting Agriculture to Climate Variability';
- Training on response farming model, and climate change to help farmers upgrade their knowledge on climate adaptation with science and technology;
- Integratiopn of climate change adaptation into agricultural development strategy;
- A workshop on developing mechanisms and guidelines for mainstreaming climate change issues into NARS, development institution, GO NGOs of Ethiopia;
- The future plan institution such Haramaya and some research centres and interview on the work done in line to this topic.

Consultative workshop: for stakeholders', participants included directors of the research processes, head of departments, researchers, NGO (SG200, OXFAM-America) and staff of the Federal MoARD, The major aim was to disseminate knowledge, raise awareness about climate change issues, advance people's awareness about the impacts of climate change on agricultural systems and explore mechanisms for mainstreaming climate change adaptation NARS of Ethiopia.

ACTIVITIES PERFORMED

- Mainstream CC adaptation into poverty reduction, and food security improvement efforts;
- Mainstream CC adaptation into research systems;
- Institutionalize CC adaptation research;
- EIAR is in the process of creating focal point for CC;
- Assisting government, development agencies and policymakers to design policies that enable farmers to cope with the adverse effects of climate change;
- Invested on technologies on projects of climate change particularly in the Central Rift Valley (CRV);
- Documents and guide lines for mainstreaming CC into the NARS developed; and
- Indigenous climate change mechanisms of the farming communities in the dryland area.

EIAR ON-GOING PROJECTS ON CLIMATE CHANGE:

There are several on-going projects organized by the Ethiopian Institute of Agricultural Research, including:

1. Response Farming
2. Making the best of climate-adapting agriculture to climate variability
3. Managing risk, reducing vulnerability and enhancing agricultural productivity under a changing climate
4. Developing options for adapting potato crop to climate change in Ethiopia

These projects are: IDRC-CCAA-DFID funded in collaboration with Ethiopia: EIAR, HU, and NMA.

CAPACITY BUILDING

There are several efforts going on to build the human power and infrastructure by the EARS

- In the process signing of MOU with University of Germany;
- Haramaya University: Courses including Applied Climatology, Agrometeorology, Disaster Climate Risk Management and Global Climate Change are offered to different departments;
- DSSAT training;
- Besides the formal training, Haramaya University provides tailor-made training sessions of staff and candidates drawn from research centers and other higher learning institutions throughout the country on CC scenario analysis using simulation models (decision support tools); and
- EIAR has trained one PhD and two MSc agrometeorology experts, and one PhD and three MSc. are in training.

ENVIRONMENT – CLIMATE CHANGE – BIOENERGY – MONITORING AND ASSESSMENT

FAO - ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

Degradation of the natural resource base is one of the most serious problems in the dryland areas of Ethiopia. It is expected to be exacerbated due to climate change and variability, which will have profound impact on the livelihoods of rural communities. To address this, steps are being taken by national research systems to review its strategy and develop potential adaptation technologies and practices. These steps will focus on improving productivity and reducing risks of smallholders and subsistence farmers, which account for the vast majority of the rural population of Ethiopia.

The study presents an inventory of the current technologies and practices on agricultural-based livelihood (i.e. crops, livestock, and agroforestry and water management) that are developed and tested at the Ethiopian Institute of Agricultural Research national and regional research station. One of the major challenges is to further assess and screen these technologies and practices in the face of imminent climate change and variability-related risks, and to up-scale them at farm and community levels.

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