THE STATE OF ERITREA

MINISTRY OF AGRICULTURE

DEPARTMENT OF REGULATORY SERVICES
PLANT HEALTH DIVISION

AGRONOMY
IN
SPATE IRRIGATED AREAS OF ERITREA

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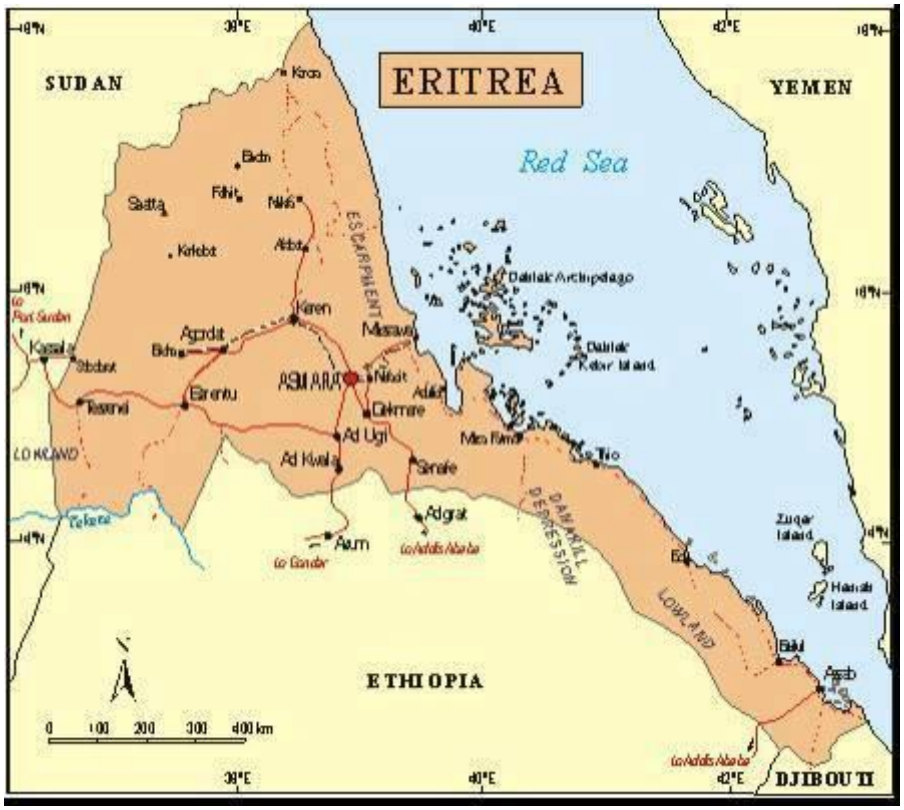
I. Introduction

Eritrea is located in the northeastern part of Africa along the Red sea to the east, Sudan to the west north, Ethiopia to the south and Djibouti at the extreme southeastern tip. The over all size of the country is about 125,000 square km and the coastline is around 1,000km.



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Eritrea is a country with a complex series of landscape and climatic features, which give to a wide variety of agro-ecological zones. Climate in Eritrea range

from hot arid, adjacent to the Red Sea, to temperate sub-humid in isolated micro-catchments within the eastern escarpment of the highlands (Figure 3). According to temperature, around 72% of the country is classified as very hot or hot (with mean annual temperature exceeding 24^{o}C) while not more than 14% is classified as mild or cool (with mean annual temperature below 21.5^{o}C) (Table, 1.2).

Land use

About 3.6 percent of the total land area in Eritrea is presently cultivated. Most of this is found in the highlands where population density per cultivated area is very high and localized scarcity of arable land occurs. Meanwhile large tracts of land, mostly in the lowland areas remain under utilized, which is a natural resource base for agricultural development.

The Main land uses in Eritrea

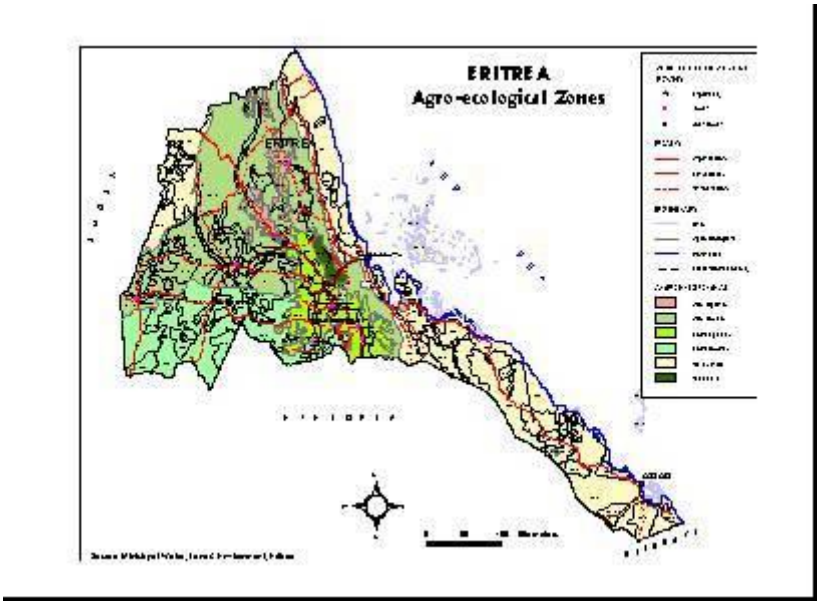
Land uses	Hectares	Percentage of total
Cultivated land rain fed	417,000	3.42
Irrigated land	22,000	0.18
Disturbed forest	53,000	0.43
Forest plantations	10,000	0.08
Woodland and scrubland	673,000	5.52
Browsing and grazing land	6,967,000	57.16
Barren land	4,047,000	33.21
Potential irrigated land	600,000	4.92
Potential rain-fed land	1,050,000	8.61
Total	**12,189,000**	**100.00**

Source: Government of Eritrea 1996

AGROECOLOGICAL ZONES OF THE COUNTRY

Agro-ecological zones and their landforms (adapted from Ministry of Land, Water and Environment, 1997)

Agr-ecological zone	Dominant crops	Land form	Area %
Moist highland	Barley, wheat, teff, sorghum, maize, finger millet, pulses	Undulating to rolling plateau, partly dissected, with hills, valleys, ridges and escarpments.	7,4
Arid highland	Sorghum, pearl millet, barley	Steep escarpments and mountains, with dissected plateau and rolling hills	2,5
Moist lowland	Sorghum, sesame, cotton, finger millet, pearl millet, maize	Undulating to rolling plains with outlying hills: lower part of western escarpment with ridges and valleys.	16,2
Arid lowland	Sorghum, pearl millet	Flat to rolling plains with outlying hills and mountains.	34,3
Sub-humid escarpment	Maize, sorghum, coffee, barley	Steep escarpment with mountains and valleys.	0,8
Semi-desert zone	Sorghum and maize under spate irrigation	Flat to rolling plains with outlying hills and mountains, islands, volcanic calderas, dunefields, and evaporite basin.	38,8



Eritrea is a land of highly varied topography, climate and rainfall. Six main agro-ecological zones are generally identified in the country, covering a broad spectrum of agricultural conditions (FAO, 1994; Bojo, 1995).

1. The “central highland zone” (CHZ): over 1,500m in altitude; over 500mm of annual rainfall and enjoying for the most part a warm to cool semi-arid climate. Potential evapo-transpiration ranges from 1,300 to 1,800 mm. This zone comprises three sub-zones that have many common features, in particular the major crops, but are distinguishable by differences in altitude, annual precipitation, relief, soils, population pressure and degree of environmental degradation. The sub-zones are: (1) Highland (h) over 2,000m, 500 to 600 mm of rain and generally a high population pressure except in the limited high elevation areas of the north; (2) Southern Midlands (SM) 1,500-200m with generally lower population pressures and more favorable rainfall (700 mm or more in the extreme south) and (3) Northern Midland (NM) 1,500-200m; but arid with less than 400 mm of rainfall and consequently very low population pressure.

2. The “western escarpment zone” (WEZ): from about 600m to 1,500m with a warm to hot semi-arid climate. Its soils and relief are determined by the physiography and geology of the central highlands, but in terms of climate, cropping, and population pressure it has much in common with the southwestern lowlands, which it borders.

3. The “south-western lowland zone” (SWLZ): 600-700 m, with a hot semi-arid climate. Rainfall is in excess of 400 mm. Soils are quite different from those of the highland and WEZ, most common are vertisols that require a different management. Topography is flat and population pressure generally very low.

4. The unique “green-belt zone” (GBZ) of the eastern escarpment of the CHZ: 750 to over 2,000m. Rainfall is very high and often in excess of 1,000 mm. Encompasses numerous micro-ecological zones that are determined by the inter-relationships of altitude, rainfall, aspect, exposure and soils at different sites. The microclimate range from sub-humid temperate to humid tropical, the relief is precipitous and comprehensive terracing is required. It differs

from all other zones in being able to support permanent crops such as coffee and tea without irrigation.

5. The “coastal plains zone” (CPZ: below sea level to 600 m; a hot desert-like climate with less than 200 mm of rainfall. Potential evapo-transpiration in excess of 2,000 mm. Crop production is impossible without irrigation, the pasture resources are poor; but extensive pastoralism occurs.

6. The “north-western lowlands zone” (NWLZ): 400 to 1,500 m, a hot arid climate with at most 300 mm of rainfall, and in the extreme NW below 2000mm. Evapo-transpiration 1,500 to 2,000 mm. Sustainable crop production is not possible without irrigation, but some niche cropping is feasible. Poor to moderate pasture resources.

As indicated in the agro-ecological zones of Eritrea western lowland and eastern lowlands are in comparable to one another for the following reasons. For the sake of the guideline, it is preferable to prepare it is a tabular way so that one can compare and contrast the two regions and select the best practice which fits to the development of crop production for the respective areas.

Characteristics of the area

SN	Description	Western lowland		Eastern lowland
		South western lowland No	North-western lowland	
1	Climate	Hot semi-arid	Hot arid	Desert-like climate
2	Elevation	600-700m	400-1500m	Below see level-600
3	Rainfall	400mm	300 extreme north- west below 200mm	<200mm
4	Evapo-transpiration		1500-200mm	Excludes 2000mm
5	Soil	Vertisols that requires a different management		
6	Topography	Flat	Flat	Flat
7	Pasture Resource	Good	Poor to moderate extensive pastoralism	Poor
8	Population	Low pressure but now it is increasing	Low pressure	Extensive pastoralism low pressure
9	Farming system	Sedimentary & agro-pastoralist	Agro-pastoralist	Agro-pastoralist
10	Production	Rain feed, shift- agriculture	Irrigation supplements but not practiced	Spate irrigation
11	Major pests & weeds	Chaffer, beetles, grass-hopper, birds, strega	Grass-hoppers	Locust, stinking-bag, Aphides
12	Fertilizer	Limited in use	Not used	Not used
13	Source of seeds	Land of diversity	Limited	Limited
14	Range land status	Extensive galley erosion, less damaged	Relatively scarce	Low productivity
15	Animal breeds Cattle	Barka	Arado	Arebo, Afar Arado
16	Goats	Barka, Shukurya, Hassani, Beledi, Lange	Maria, Barka	Rura, Shukurya
17	Sheep	Barka	Hamale, Barka	Rashaida
18	Donkey	Rifa and Highland	Rifa and Highland	Rifa and Highland
19	Camels	Bisharri, Arrir	Bisharri	Afar

II. CROP PRODUCTION SYSTEM IN TRADITIONAL SPATE IRRIGATED FARMS

1. CROPS AND CROPPING SYSTEM

1.1 Types of Crops Grown

The soils and climatic conditions in the spate-irrigated areas are very conducive to grow different types of cereal crops, oil crops and vegetable crops, mainly of semiarid in nature, which have been adapted to the climate for many years.

The major crops grown in the spate irrigated areas are sorghum and maize. Sorghum is the most preferred crop and it is widely grown in the northern part of the eastern lowland, which is north of Massawa port. Maize ranks second and is widely grown in the southern part of the eastern lowlands like in Foro, Afta and Zula.

Other types of crops grown in the spate irrigated farms include pearl millet, cotton, sesame, groundnut, tomato, pepper, okra, kerkede and watermelon. These crops are not widely and continually grown year after year like sorghum and maize, but occasionally and usually in small quantity for home consumption. Some 20-30 years ago cash crops like cotton, sesame and watermelon used to be grown on a large scale in some farms, but because of war and the recurrent drought in the country they are now grown in small quantities. The spate-irrigated farm of Marsa-Gulbub was one of the major cotton growing area in the country, but now the farmers are growing only sorghum.

The common types of land races of sorghum grown in the spate-irrigated areas vary in their characteristics. These landraces can be distinguished from each other by grain color, shape of the head, height and tillering capacity of the plant. *Hejeri* is a high yielding, short stalked, good ratoonability, has white grain and white flour, and compact head. Most likely birds less attack it.

Feterita (*Wedi Aker*) is second to *Hejeri* in preference by farmers for its short growing season and short stalks. Less preferred for human consumption and has less bird problems. Has a white grain, which forms darker flour when milled.

Hartsetsa has an intermediate stalk, compact head and high yielding and poor ratoon ability. Good for human consumption has red grain and grayish color when milled. It matures within three months.

Durra is a tall, low yielding; open headed, good ratooning ability and early maturing variety with a red seed coat. It has vigorous vegetative growth and is grown more as animal feed than for human consumption. It matures earlier than the above-mentioned types of sorghum.

Maize varieties grown in the spate-irrigated area are highly heterogeneous landraces, which are broadly classified into white and red maize based on kernel color. Various local names are given to these indigenous landraces. "*Shagal*", *Wedilebab* and "*Merora*" (Tigre, Saho) are types of white maize. They are late maturing, taking up to four months from sowing to harvest and require more irrigation water than the red types. The most common type of red maize is *Chenger, Asa Elbo* and *Berih* (Tigre, Saho), which mature in two and half to three months.

There are two types of pearl millet (*Bultug: Tigre, Tigigna*) varieties hairy (bristle) and hairless. Both types of pearl millet tiller more vigorously and have short growing season in the range of two and half to three months. Hairy type pearl millet has long panicle covered with a sort of hair like material and creamy colored grains. Even though it is less attacked by birds and highly preferred by farmers nowadays this variety is abandoning due to its low yield. Hairless type of pearl millet has the same characteristics like the hairy cultivar except it has white grains. It is grown in shallow and/or coarse soils near Wadi course, in the canal beds in the down stream.

Keren type groundnut (*Ful: Tigre, Tigigna)* used to be grown in large areas when the landholdings were bigger before the redistribution. Necessity to allot a large proportion of the smallholdings to cereal food crops and inability to market groundnut as a profitable cash crop as well as termite and high labour demand restricted the area under groundnut.

Black and red colored sesame (*Simsim: Tigre, Tigigna*) types are only used as seeds. The susceptibility of sesame to termites is the other reason for this crop being grown on small areas.

Watermelon (*Berchik: Tigre, Tigigna*) is another crop grown in spate-irrigated fields. The farmers also plant in a small area *Kerkede* (*Hibiscus sabdariffa*) that is used as a beverage like tea after drying the flower. These crops are grown mainly for home consumption only.

Table 1: Varieties of various crops under use in the spate irrigated areas

Crop	Variety	Characteristics	Remarks
Sorghum	Hejeri	High yielding, short statured, white grain and compact head. Not preferred by birds. Drought resistant.	Highly susceptible to stinkbug that is currently the most serious pest. Most preferred variety but has lost its purity due to out crossing. Used for porridge, *Tandoori* and *Ingera*.
	Durra (Alihiya)	Low yielding, very tall, open headed and grain is red colored. Stalks are very sweet so preferred as animal feed. Short duration (planted 10-15 days after Hejeri but matures at the same time). Drought resistant.	Main variety of the area before the introduction of *Hejeri*. Less prone to damage by birds, however, used for nesting because of its height. Used for porridge and *Ingera*.
	Feterita, Odaka, or Dumburi (Wedi Aker)	Most characteristics are intermediate between Hejeri and Durra. Shorter stalk and grain is white.	Flour darker. Not preferred either by farmers or birds. But it can be used for *Ingera* making.
	Hartsetsa	Intermediate statured, compact head and high yielding like Hijeri. Has poor ratoonability.	Not affected by stinkbug, needs more moisture, grain tasty but hard to process. Used for porridge*, Tandoori* and *Ingera*.
Maize	Berih	Late maturing, cobs are big and seeds are bold and white.	Only sown as first crop when sorghum cannot be grown due to late floods. Resistant to water logging, does not grow vegetative under conditions of abundant moisture.
	Wedilebab	Shorter in duration and stature than Berih. Cob size and seed quality are not favorable.	Grown as second crop after sorghum.
	Chenger	Short in duration and has very small cob.	Highland variety, planted if the floods are late.
Pearl millet	Dukun	Very high tillering capacity. Shoots produce new branches when panicles are removed. Tall statured and resistant to stink and ear head bug.	Susceptible to mildew.
Sesame	Black and Red color	Tall and branched type	Red colored type is susceptible to diseases
Groundnut	Keren Type	Bunchy type of character and small seed.	
Okra and kerkede have no specific varieties.			

Source: Field Survey, 2002

III. Current Cropping System

1. Cropping System

The cropping system is very flexible; because it is largely determined by the amount of floodwater and rainfall received, which vary from year to year.

Crops failures due to shortage of water is very common, thus the farmers have developed a copping mechanism (a cropping system) to deal with crop failures. At the beginning of a cropping season, a late maturing crop is planted. If this crop fails due to over flooding or shortage of water or insect attack, it is replaced by early maturing variety or by different type of crop (Feterita & Dumburi/Wedi Aker). If crop failure is repeated a number of times, drought tolerant sorghum variety like Durra is planted mainly for the production of animal feed for their livestock but not for crop production.

The most common cropping system followed is to plant sorghum as the first crop, followed by maize and watermelon is planted as a third crop. During that time the farm areas used to get enough rainfall to allow good germination of the newly sown maize. But, gradually it become difficult to plant maize, because of drought, enough rainfall is not received to allow good germination of the crop. These days, the main crop of sorghum is followed by its first and some times by the second ratoon. Except in areas where maize is planted as the first crop, in the other farms, the growing of maize as a second crop has been stopped. In the southern parts of the eastern lowlands where the evaporation rate is very high and the annual rainfall is very low, only one crop, maize is usually planted per year.

In the last 15-25 years, significant changes have been observed in the cropping system. Except in the farms where maize is grown as the only crop, the growing of maize as a second crop decreased significantly. Because of recurrent drought, relatively very small rainfall is received that it becomes difficult for the newly sown maize to germinate. As a result of drought a cropping system ratooning become the common practice.

In the sorghum ratooning system, the first sorghum crop is harvested and its stalks are cut and removed. Then the first ratoon is let to grow and harvested in a similar way as the first crop. Depending on the rainfall or floodwater or the amount of residual moisture on the soil, a second ratoon may grow to maturity and harvested. Usually, the second ratoon doesn’t grow and produce seed, thus it is usually harvested for animal feed.

Watermelon is sown during the hot season, when the soil is dry, thus, one to three watering is required for successful germination of the plant. The growing of watermelon is not popular in many of the spate-irrigated farms.

Farmers who have easy access to the market only grow it. Crops like tomato, pepper, okra, etc are not planted as major crops, but in small quantities at open areas or along field boarders.

Crop rotation, inter cropping and planting of leguminous crops to improve soil fertility is unknown in the spate-irrigated farm. Crop residue which can be a source of organic manure and which can help to improve the physical structure of the soil are removed from the fields to be used for animal feed or for constructing the local farmhouses.

2. CROP MANAGEMENT PRACTICES

The traditional spate irrigation is a profitable agricultural activity under the following circumstances.

a) Farming practices are improved, permanent diversion structures and canals, field bunds or embankments are constructed
b) Pests are control are controlled on time and
c) Fodder for animal feed is produced sufficiently.

There are many uncertainties in the system. Very important of all, the occurrences and magnitude of spate flood is unpredictable. The irrigation structures are temporary and are easily washed or damaged by floods. The safety of irrigation structures is dependent on the magnitude of the spate flood. Maintenance and repair of the spate irrigation system is quite frequent and laborious, because of which the farmers have little time for other agricultural activities. Weed and pest infestation are common problems.

2.1 LAND PREPARATION

In the spate-irrigated farms, land preparation is carried out for the following objectives.

a. To minimize soil moisture loses by evaporation
b. To prepare good seed bed and to sow crops
c. To control weeds

Based on the above objectives, land preparation activities can be classified into two major parts.

- Pre – Irrigation ploughing (Nekli) and
- Post – irrigation ploughing
  - For soil moisture conservation (Mekemet) and
  - For seed bed preparation and weed control

2.1.1 Pre – Irrigation ploughing, " Nekli

Pre–Irrigation ploughing, locally known, as "*Nekli*" is a primary tillage, whereby a field is ploughed when soil surface is dry, that is before they receive the first irrigation water. The soil is ploughed to break the dry and usually compacted soil surface. The purpose of the pre-irrigation ploughing or *Nekli* is to break the hard and dry soil surface, so that the floodwater will infiltrate the soil quickly before much of it is lost by evaporation or by draining through broken field bunds. After irrigation every deposits of sediments seal the soil surface. Thus, if a field receive very small mount of floodwater and some more irrigation water is expected, the ploughing may be repeated for the second time.

2.1.2 Post – Irrigation ploughing

When a field receives sufficient irrigation water or when no more floodwater is expected, a conservation tillage known locally as " *Mekemet*" is done. Mekemet is practiced after the field receives irrigation water and when the soil surface is just dry enough to allow ploughing. The land is first ploughed to break the crested and compacted soil surface. A cylindrical or flat wooden log, which is pulled by a pair of oxen, is then run over the whole field. The operator stands on the log as the oxen pull it. By this operation the soil is further broken into smaller pieces and at the same time the loose soil is compacted.

The objective of this operation is to minimize soil moisture by evaporation. First, the dry and lose soil at the surface acts as a cover against the excessive heat of the sun thus reduce evaporation from the soil. Secondly it breaks the capillary movement of the water inside the soil. The loose soil acts as a buffer between the inside part of the soil and the atmosphere. If planting must be done without much delay, this conservation tillage or "*Mekemet*" is not done.

2.1.3 Ploughing for sowing and weed control

When crops are sown, normally the land is ploughed in order to soften the soil and prepare a good seed bed. By this operation, weeds are destroyed. After this, no weeding is done manually or by cultivation.

3. SOURCE OF SEEDS, SEED RATE AND SOWING TIME

3.1 Source of Seed

Most farmers prefer to produce and keep their own seeds for next cropping season, but only few are successful in producing their own quality seed. Seeds are carefully selected before or after the crop is harvested. Few farmers collect seeds before the standing crop is harvested.

Panicles of sorghum and pearl millet and cobs of maize are collected separately during or after harvesting and stored in a place safe from insect and birds attack.
The panicles or cobs are tied in bundles and hanged, some times, over firing stoves and let them to dry. These practices creates unfavorable situation for the insect pests and thus minimize the damage caused by the insects. These are not threshed until about a week before planting. The threshed seed is then stored separately in woven baskets made of doum palm leaves (*Laka*) or sacks made of sisal.

There are also farmers who do not spent much efforts and simply use what ever seed is available at hand or buy seed from the market or obtain it from friends and families.

The criteria used for selecting a crop variety in all the major spate irrigated farms are the same. Variety with high ratooning ability, short statured, early maturing and high yielding and tolerant to birds and insect attack are selected. Tall with high vegetative growth and early maturing varieties are selected if they are grown for animal food.

Vegetable and oil crop seeds are usually obtained from markets. Farmers who plant watermelon, *kerkede* and/or okra on regular bases some times use seed from previous harvest.

3.2 Seed Rate

Seed rate used in the spate-irrigated farm varies from one area to another area. In the entire spate Irrigated farms, high seed rate is commonly used for the major crops like sorghum, maize and pearl millet.

Table 2. Varieties and seed rate

Varieties	Seed rate kg/ha	Recommended value kg/ha
Sorghum	24-30	6-10
Maize	18-45	25
Pearl millet	8	3-5

The use of high seed rates resulted in a very dense plant population. This creates a high competition among the plants for moisture, nutrient and light. As a result of these competitions, the plants, especially sorghum, grow very thin and tall and the yield will be low. Some of the reasons given by the farmers for using a high seed rate are as follows.

- Densely grown crop can be thinned and used to feed their animals that do not have any other source of feed. However, the use of plants is not done systematically at appropriate the time when thinning is required. But at the time where feed is required. Generally, it acts, as store where feed is necessary to feed their animals.

- Lack of proper drainage and flooding can kill young plans, and there can be infestation of insects like locust and heavy attack by birds. These problems reduce the plant population as well as the yield. So to cope with such problems a high density plant is preferred.

- Densely grown plants suppress weeds. The majority of the farmers do not practice weeding.

However, thinning is not done at one time, but it is systematically done in such an amount that it is distributed through out the growing period and availability of animal feed is assured through out the growing period

3.3 Planting time

Planting time varies from sub-zoba to sub-zoba. A field survey conducted in 2002 indicates that each locality has its own planting time for it is determined by the availability of soil moisture, feed requirement for animals, and probability of pest infestation. The climate is also given due consideration in selecting the types and varieties of crops to be grown

Most commonly practiced planting and harvesting calendar followed for different crops grown in the spate-irrigated area of Sub Zobas of Sheeb, Foro and Ghelalo are given in table 9-11.

4. Methods Of Sowing Crops

A local plough made of wood with a metal tipped ploughshare, pulled by a pair of oxen is used for ploughing as well as for sowing the seed. The local plough is called “Jihaz” When sowing the seed, a simple tube, called “Jeleb”, is attached to the handle of the plough. Jeleb is a tube about 70cm long and 6-10cm in diameters. It can be made of plastic, metal or wood. The seed is hand dropped through the tube to the ground in front of the plough shear.
The seeding rate within a field is not uniform either, because there is no mechanism to control the flow of the seed from the hand to the ground. It all depends on the individual farmers experience. In some areas maize is sown by broadcasting. The seed is broadcasted by hand and then covered by ploughing under.

Pearl millet and sorghum is planted by a special method of drilling, known as “ Seluka”. Seluka is a conservation tillage method, practiced when it is required to plant crops without disturbing the soil so that the soil moisture is conserved.

A Seluka (planting stick) is shown in Fig? At its bottom part it has a special attachment for applying pressure by the foot. Stepping one foot on the stick makes a hole. The stick is then given 180^0 rotation to open the hole wider.

In Seluka system of planting pearl millet, a hole is drilled using a special stick. The spacing of the holes is usually kept at 1m x 1m. 4-6 seeds are dropped in every hole and are immediately covered by knocking the soil around the hole by foot.

Watermelon, okra, tomato, pepper and kerkede are directly planted in rows by digging holes (*Angesh*) with hoes in the soil right up to the moist zone. Then the seeds are placed and covered with thin layer of soil by knocking the soil by foot. Farmers soak seeds of watermelon and okra in water for overnight before planting in order to enhance germination. Thus shortens the time of seed emergence.

Sesame is planted in two ways i.e. broadcasting and row planting. The row planting is also carried out with the help of Jeleb. Similarly Groundnut and cotton are also planted in rows with Jeleb.

5. Insect pests and Diseases

The entire spate irrigation farms are a good habitat for insects and it is the main breeding area for locust in east Africa. Their intensity and their rate of multiplication are tremendous. The hot climate and high humidity of the spate-irrigated farm areas favor the development of many insects and diseases. Most farmers are very familiar with most of the insects, even though they seem to have very limited knowledge about diseases. In both cases they are very helpless when it come to controlling them. The use of chemicals to control or eradicate insect pests is practiced in a limited scale.

According to the farmers interviewed in this study, the yield loss due to insects' attack is estimated to be not less than 25%. In the case of locust, stinkbug, aphids and stem borer outbreak, the losses can go up to 70-80% and sometimes more.

The important insects are locust, stinkbug, termites, lopidepteras and hemipterous insects, stem borers, aphids and whitefly. Out break of locust is usually associated with good rainy seasons.

The farmers are familiar to head smut. However there are also many types of diseases, which are not well known to most of the farmers.

5.1 Birds

Birds are one of the major pest problems in the spate-irrigated farms. The most important birds are weaverbirds like quelea-quelea, *Shika* and *Wed-Gebu*. Yield losses due to birds' attacks, as estimated by the farmers, can be as high as 20% of the total yield. In isolated fields, where the crops mature either early or later than the surrounding crops, the yield losses can go up to 70-80%. Some of the methods of controlling yield losses due to birds' attack are the following.

It is very important that similar crops are sown at the same time so that crop maturity is reached at the same time. By doing this, birds' attack is minimized on individual farmer's crop, but the losses are shared among the entire farmer more or less equally. If a crop matures earlier or later than the surrounding crops the birds' attack will be more serious.

Farmers also try to scare birds by throwing stones with the help of a sling or beating old tins to make frightening sound. Some time small watchtowers and raised beds are constructed in the middle of the field. Farmers presently are protecting their crops from birds with traditional techniques such as trying to frighten birds by constructing scarecrows, shouting, using noise making devises such as cans or cracking slings and by throwing mud or stones.

6. Harvesting

Most crops, like sorghum, maize and pearl millet are harvested after three months on average. It is important that similar crops are harvested in one area are harvested at the same time. Crops that mature late are likely to be attacked by birds and stray animals. The first shower of rain usually comes when the first crops are quite mature. This rain initiates the seed to germinate before it is harvested or cause it to route. Delayed harvesting influences adversely the performances of ratoon particularly under shortage of moisture stress.

6.1 Harvesting of Sorghum

Sorghum is harvested when the crop is matured, but not necessary when it is fully dry. This is done to allow enough time for the ratoon crop to develop. So

those farmers who want to grow the first ratoon, they harvest the main crop 10-15 days ahead of the normal harvesting time.

When harvesting, the plant is cut at ground level and is laid on the ground between the rows. It is left there for four to five days to dry up.
According to the farmers, by letting the cut plant for some days, it initiates the ratoon crop to grow quickly and produce a good yield. If the plant is left on the ground for longer period, the grain started to change its color and develop an unpleasant smell and test.

Four to five days after the whole plants are cut, then the ear heads are cut off and are transported to threshing ground. It is left there for one to two weeks until it is dry enough to be threshed easily. Threshing used to be done by trampling the crop with oxen. Nowadays, because of lack of oxen, threshing is done through beating the ear heads using a stick. A farmer working alone can thresh about 50kg per day. The husk and stalks is also brought home for animal feed. Camels and donkeys are used for transportation of cut heads and stalks from the field to the *Danda* or threshing ground, threshed grains and stalks for home as well as to market areas.

6.2 Crop Ratooning

Crop ratooning is highly practiced in the spate irrigation system. Crop ratooning is an intensive crop production system where more than one harvest is obtained from one sowing. It has also a relatively short growing period requirement for a two-crop system because the ratoon crop can mature in up to 20 to 25 days less than the first crop. But typically their ratoon yields are much lower and more variable than the first crop, especially when pest and disease carry over is a problem.

Farmers used to grow varieties of sorghum and pearl millet that have high ratooning capacity than others. For example, Hejeri and Durra variety of sorghum have a high ratooning capacity and Feterita has a low ratooning capacity.

In ratooning system, the stalk of the main crop is cut at ground level. The cut material is placed on the ground between the rows and is left there for three to five days. According to the farmers this is done to promote re-growth of the plant and to conserve soil moisture. Re-growth of the plant started after less than a week and more than 4 tillers are produced from one plant.

According to farmers interviewed in Shi'eb and Bada, when there is adequate soil moisture, a first good ratoon crop can produce as much as 50% of the main crop and a second ratoon crop can produce up to 30% of the main crop. However a second ratoon is normally harvested, before it matures, for animal feed. And another reason for harvesting the stalk of the second ratoon before it produce seed is that by such time animals are allowed to graze freely over the farm, thus, the farmers are forced to cut the crop and remove it from the field.

6.3 Harvesting of Maize

When the maize crop is ready for harvest, it is cut at the base and tied in bundles. The bundles are left standing in he field for drying. When it is dry, the cobs are detached and the husks are removed manually. The cobs are brought home for further drying and shelling. Cob shelling is also done manually or by beating the cobs with big stick. The farmers form small groups of 5 or 6 men when shelling by beating. The husk and stalks is also brought home for animal feed.

6.4 Harvesting of Groundnut

Groundnut is also lifted by pulling the plant with hand or sometimes using lifting fork. Then the crop is left in the field for further drying by putting the harvests on each other to protect from sun damage. The pods are collected by detaching them from the plant by hand. The seeds are taken out from the pods either by beating them on the threshing floor or individually by hand.

7. Crop Productivity and Use of Products

Yields of crops grown in the spate-irrigated areas vary depending on the availability of moisture, varieties of planting material, insect and disease control. The crop yields in the spate-irrigated areas are fairly high compared to the rain fed agriculture elsewhere in the country. The average yield of sorghum, maize and pearl millet varies from year to year depending on the availability of diverted floods and measures taken to control pests.
In the spate-irrigated areas, farmers collect all straws from their fields for feeding their livestock and temporarily for roofing of dwellings. Those farmers who do not own animals sell the straw. The removal and uses of the plant material for feeding animals is practiced during the season of crop growth as well as after harvesting of the crops are completed. The uses can be green (tillers of sorghum, maize and pearl millet crops) and dry plant material, which is obtained after the harvest of the crops. This implies that there is no replenishment of fertility into the soils except from the deposition of sediments by the floods.

Crops like beans, watermelon, groundnuts, pepper, okra and tomatoes are grown at the one side of a field where (wet spots of a field) excess water is accumulated to sustain the growth of the plants. However, it is planted only in small plots for seasonal household consumption and to some extent for local market.

Table 3. Productivity of various crops under spate-irrigated areas (qt/ha)

Crop	Seasons			Average
	Good	Medium	Bad	
Sorghum	38	18	8	21
Maize	20	10	5	12
Pear millet	9	5	2	5
Ground Nut	25	15	7	16
Sesame	8	3	1	4
Cotton	10	4	2	5
Okra	15	11	5	10
Watermelon	35	20	10	25
Tomato	20	15	5	13
Hot Pepper	40	16	9	22

Source: Field survey 2002. (The data need further Verrification)

7.1 Storage System

There are a number of storage systems in use. They are all traditional ones. Storage facilities are mostly sacks and baskets made of different materials, under ground stores (pits) and tikuls. So far, no studies have been conducted about the effectiveness of the different storage system, but all of them are believed to be ineffective to protect the stored crop against rodents, pests and livestock.

The most important storage problems are rodents like rats, and pests like birds, weevils, beetles and termites. Livestock like donkeys and goats are problems in carelessly stored crops.

Farmers believe that thoroughly drying of the grain both under field condition and in house reduces the infestation of storage pests. Then the threshed grains are stored in various on farm storage conditions. Crops to be stored are first sun dried and are then put in various storage systems. Unshelled maize cobs and sorghum heads are put in raised beds (*Tsehwet*) constructed of wood and located adjacent to the farmers' house for further drying and storage. This way the maize cobs and sorghum heads can stay for a year with out much damage.

Under ground storage (pit) and *tikul* are preferred by farmers for storing their harvest to escape the risk of weevils and rats. In *tikul*, the grain is dispersed on the floor and this system makes the temperature a bit cooler than the others. Storing grain in boreholes has the advantage of avoiding attack of weevils and rats. The mouth of the pit is sealed with a lid made of mud and the wall is plastered with a mixture of mud and cow dung. As a result the temperature within the pit is raised which causes suffocation for the developing of weevils thus protecting the grains from attack. The grains stored under this system produce unpleasant smell that discourage their use for food and the germination is also affected that discourage their use as seed. This could be due to boreholes airtight that kills embryo of the seed. However, the grains can be used for human consumption after well ventilation of the produce.

IV. LIVESTOCK PRODUCTION SYSTEM

Livestock production is practised in a number of different farming systems. No estimate can be made at present on effective numbers within each farming system. However, pastoralism and agropastoralism are the main production systems. Qualitatively, the Afar, Rashida, Hidareb and Saho are almost purely pastoralists; the Tigrygna and Bilen are sedentary mixed farmers; the Kunama, Nara and partly Tigre and Tigrygna are agropastoralists.

Most livestock producers in Eritrea are subsistence farmers. Their primary objective is to produce enough food to feed their family and to maintain sufficient reserves to see them through drought years. Cash income from sales of livestock is a secondary consideration and mainly directed to household necessities such as sugar, coffee, salt school fees and medicines. Production strategies are directed more at minimizing risk than at maximizing profit.

Pastoralism

Pastoralism is any production system that relies for substantial amount of its output on livestock. Although it is difficult to tell how much is substantial, a definite prerequisite for a system to qualify as pastoral is that it must involve some degree of mobility. Essentially, pastoralism denotes economies that derive the bulk of the food supply from livestock using a great variety of herding practice on natural pasture. Pastoralism usually consists of highly heterogeneous groups in their objectives, strategies, needs, management style and degree of mobility, hence, the basis for classification. In Eritrea we have nomadic pastoralism and transhumance with full mobility and agro-pastoralism with partial or no mobility.

Nomadic Pastoralism

Nomadic pastoralism essentially revolves around the husbandry of livestock and the utilisation of natural vegetation as fodder. Such an economy requires the availability of suitable domestic animals and of pastureland adequately large for sustaining the animals, because their livelihoods are totally dependent on the utilisation of marginal resources. Nomadic pastoralists are forced to constantly migrate by the need to maintain their source of subsistence, namely livestock. In its purest manifestation, nomadic pastoralism is characterised by the absence of cultivation even as a supplementary income (Khazanov1983). Typical nomads are found in the Sahel where large tracks of relatively unoccupied land allow free roaming. In Eritrea the Afar, Rashida and the Hedareb are typical examples of nomadic pastoralists.

Transhumance

Transhumance involves regular seasonal migrations between, say dry season and wet season pastures, upland and lowland pastures, upland and lowland cultivation, or pastures and salt. Probably a major difference between

transhumance and nomadic pastoralism is that in transhumance the patterns of migration are more or less predetermined under normal circumstances. Nevertheless, predetermined migration does not in any way imply rigidity in traditional resource use by transhumants. These patterns are subject to substantial deviations in times of resource scarcity such as during drought. In general, the pattern of transhumance in East Africa is usually between highlands/plateaux and lowlands/flood plains. In Eritrea the Saho, Tigre, and Tigrigna practise this between the Eastern coastal plains and the Eastern escarpments and the central highlands. The Tigrigna and Tigre are sometimes called opportunistic farmers, as often practised in the Sahel. They plant crops; usually sorghum and maize on their way East to wet season pastures and harvest them on their way back west in the dry season. In between there are many different degrees of transhumance depending on the number and kind of livestock raised, type of crops planted and distance travelled. Each of these groups has distinct production systems and set of strategies that have evolved through generations.

Agropastoralism

Agro-pastoralism is another important type of pastoralism accounting, in many cases, for the bulk of total livestock populations. It is perhaps the most highly diverse form of pastoralism, with agriculture as the main subsistence activity, but where animal husbandry is an integral part of the household economy. The availability in agro-pastoral systems is essentially due to the recurrent drought and markets for crop and livestock, which are characterised by huge fluctuations in price and volume. Tigrigna, Kunama and Nara in the South Western lowlands mainly practise Agropastoralism.

The pastoralists of the Western Lowland Zone are predominantly transhumants as they retain campsite inhabited by women and children, while livestock migrate for forage and water elsewhere. There is a greater degree of agro-pastoralism in the south west of Western Lowland Zone than in the northwest, reflecting the lower rainfall and consequent less reliable crop production of the later. Lack of water supply is the primary reason for the migration of pastoralists from the northern part of Western Lowland Zone with a shortage of feed also occurring in drought years.

Pastoralists of the Eastern Lowland Zone have shorter distance to migrate than those in Western Lowland Zone as the dry season camps for Eastern Lowland Zone are on the eastern escarpment.

In Central Highland Zone farmers use the areas that cannot be farmed (because of lack of soil or extreme slope) as rangeland. After harvest, the cropping lands are available to all stock in the community for communal grazing. Some opportunistic farmers, as often practised in the Sahelian countries, also practise a sort of transhumance. They plant crop, usually maize, on their way East to wet season pasture and harvest them on their way back West in the dry season.

1. Livestock Population & Types of Eritrea

1.1 Livestock Population

Reliable statistics are lacking on current livestock populations as demonstrated by cattle vaccination figures, which are often more than double registered population. No livestock census has been carried out since 1978, and the current livestock figures are based on estimates. At present there are 1.9 million cattle, 2.1 million sheep, 4.7 million goats, 318,914 camels, 518,459 equine and 1.1 million poultry.

1.2 Livestock Types

Cattle: The known zebu cattle breeds or types of Eritrea are:

Begait (Barka):
Barka is dominant in the Gash-Barka Region. They rank first in population size as compared to the other types. Milk and meat are the main products of this breed. The Barka is a long legged black and white breed originating in the Barka region. It has been spread to many areas on account of its milking qualities: daily yields of 6 to 8 litres are reported as general. They are relatively resistant to diseases and are also known for thei high feed conversion rate making them good meat producers. Mature body weight ranges from 267 to 316 Kg.

Arado:
The central highlands of the country are home for this breed and they are second to Barka in population. The main purpose of rearing is for meat and draft power; their milking potential is about 1 to 2 litres per day. Their mature body weight ranges from 205 to 300 Kg.

Arebo:
The coastal plains of Northern Red Sea are home for this breed of cattle, although numerically less important than the other breeds, it reportedly has a similar milking capacity and crossing potential as the Barka. Their mature body weight does not exceed 250 Kg.

Afar:
The coastal plains of Southern Red Sea are home for this breed of cattle. This breed has compact body size and is few in number compared to the Barka and Arado. Their milking potential is almost similar to that of Arado. Their mature body weight ranges from 220 to 250 Kg.

Goats:
Most of the Eritrean goats are unidentified and several types and strains are seen in the country.
The most notable is the Rora goat: it is similar in appearance to the Nubian with drooping ears and a milking capacity of more than one litre per day. Average live body weight ranges from 24 to 31 Kg.

The Barka is the preferred breed in the Gash-Barka region. Average milk production is estimated at1 to 1.5 litres per day.
The Shukria are mainly found in the western lowlands. This strain reportedly produces 1.5 to 2.5 litres per day and their milking potential warrants their trial introduction to other areas.
The Hassani is well known for its milk production: it was introduced from the Sudan and is characterised by long hairs. Average body weight ranges from 30 to 34 Kg.
The Maria is found in Anseba region and has short, round ears. Average milk yield is 1 to 1.5 litres per day. Average body weight ranges from 27 to 30 Kg.
The Lange is a milk producer found in Gash- Barka region. It is similar in body weight as the Hassani.
The Beledi is a cross breed of Lange and Hassani.
There are also unidentified mountain type goats in the central highlands.

Sheep:

All breeds are hairy types. Although all the breeds are primarily for meat production, they are also often milked for subsistence consumption.

The Shimezana type of southern highland breed is fat-tailed and small. The body weight ranges from 21 to 24 Kg.
The Rashaida type of Northern Red Sea is short thin-tailed and small. The body weight ranges from 30 to 32 Kg.
The Barka type of the Western lowlands zone is the most commonly known type of sheep in Eritrea. It is long thin-tailed. The body weight ranges from 42 to 47 Kg.
The Hamale is similar to the Sudan Desert sheep and prevalent in the Western Lowlands. The body weight ranges from 37 to 40 Kg.

Donkeys:

They are of two types. The highland donkeys and the lowland-riding donkeys commonly called the Rifa'i.

Camels:

The most common ones are the Bisharri, Arrir and Afar camels. There are also unidentified camels in the Gash-Barka and Anseba regions. The Arrir is the preferred type in the southwestern lowlands due to its high milk yield, good market price and high transportation value.

2. The Rangelands

Rangeland is a kind of land characterised by native vegetation (climax or natural potential), which is predominantly composed of grasses, grass like plants, forbs, or shrubs suitable for grazing and/or browsing. It includes land re-vegetated naturally or artificially to provide a forage cover that is managed like native vegetation. Rangeland includes natural grasslands, savannahs, shrub lands, most deserts, tundra, alpine communities, coastal marshes and wet meadows.

Generally, rangelands are frequently characterised as receiving less than 750 mm average rainfall, but also include areas with higher amounts where soil and topographies are unsuitable for cultivation.

Rangelands cover over half of the total land area and are mostly distributed below 1500 m in the lowlands, foothills of the highlands, in the arid, semi-arid, humid and sub-humid regions. In Eritrea the rangelands constitute about 49% of the total land area suitable for this use and that further 33% is barren, due to desert and steep slop.

Rangeland is more suited for livestock production than for any other forms of agriculture i.e., they are limited with regard to agricultural production, but they are capable of producing a great variety and quantity of herbage plants that serve as the basis for the extensive types of livestock Industry.

The status of the different rangelands can be stated as follows:

Central Highlands: The rangelands in the Central Highland Zone are generally infertile and usually extremely sloping, making them extremely fragile under any continuous grazing. Many show irreparable damage from erosion down to bed- rock due to constant grazing and removal of the woody over story. The grazing area has been shrinking over years because of cultivation and deforestation. Attempts to allow regeneration by closing rangelands and forest areas have shown promising results and are becoming models for the recovery of the rangelands. The recovery rate of some of the closed rangelands and forest areas is remarkable and this is making people think in terms of introducing the cut and carry system.

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Western Lowlands: The southwestern part of the western lowlands appears to be less damaged, except in those areas adjacent to population centres where bare soil with extensive gully erosion is common. There is still grass cover with stable browse over story. But in the northwestern lowlands the grass cover becomes relatively scarcer. The intensity of use of forage in the Western Lowland Zone increases to the northeast, leaving little grass and showing consequent erosion. Land degradation under cropping follows the same pattern in this zone with least damage on the flat vertisols of the southwest. The extensive and migratory system of animal husbandry allows the rangelands to recover, unlike in the highlands. But it is common to observe overgrazing in areas where there are watering points and under grazing in areas where there are no watering points.

Eastern Lowlands: In this area, rangelands are of low productivity and not in good condition in terms of ground cover, as rangelands are limited within a vast desert. Generally, the rangelands are not in good condition in terms of the ground cover of vegetation.

3. Other Feed Resources

After the rangelands, crop residues are the most important feed resources. Almost every farmer in the highlands and the agro-pastoralists in the lowlands,

store straw mainly of barley, wheat and taff and Stover mainly of sorghum to feed their animals during the dry season.

The aftermath grazing of harvested fields also give the animals a chance to supplement their grazing and browsing in the rangelands and enable the rangelands to rest for some weeks.

4. Range resource management among pastoral communities

4.1 Traditional Adaptive Strategies

The pastoralists derive more than 50% of their total food energy intake from livestock in the form of meat and milk. Milk is the most important animal product in pastoral societies and is needed every day. Most cows conceive usually once every two to three years and provide little milk during the dry season. Females comprising more than 75% of the livestock number always dominate the herd size. This reflects the pertinence of milk as the major end product of pastoral production systems. The herd also enables the production of revenue for the subsistence of the family.

Increased herd size and milk production, maintenance of an appropriate and viable herd structure and prevention of animal loss to disease have always been the core objectives of pastoralism. These are some of the reasons why large number of animals must be maintained.

As an insurance against drought, pastoralists strive to increase stock numbers, in order to provide security in case of losses, to leave a remainder of feasible size, to re-built their herd. Thus the expansion of herd sizes in “normal” times, not stricken by drought, disease or unrest, is a rational strategy and not a projection of prestige, social status and wealth. Although it is true, that parallel to increased numbers of animals, an increased social standing for the owner will develop, this has to be seen as a favourable by-product of an effort to safeguard future survival.

Traditionally, risk-reducing adaptive strategies are, herd diversification and herd dispersion. Herd diversification is practised as an insurance against major disease outbreaks since the different domestic species are generally not susceptible to the same pathogens. Beside this, the different dietary preferences of the various domestic species also allows for a better utilisation of pastures that may not be suited for one or the other domestic herbivore species.

Herd dispersion is a second risk-reducing strategy, which is frequently practised in traditional systems. Stockowners separate their herds and have them herded in areas sometimes up to several hundred kilometres apart; this is primarily a measure against forage shortages and raiding. If the family is large enough, its members manage the different herding units, and family reunions and rearrangements of the different stock sections take place either during the rainy season or during certain ritual occasions.

A related form of dispersion, although of a different significance is the formation of stock alliances and stock patronage that is independent of family size and social status. Individual animals or groups of animals are given out to other stockowners who are either needy or in some way entitled to compensatory claims. Often the original owner never recovers the animals, but in times of hardship the son or even grandson might reclaim some or even all of the loaned stock from the recipient's heirs. This risk reducing strategy is common among all pastoralists whose social organisation is based on clan and age set structures and should be regarded as a system of social security rather than an actual management tool.

The most conspicuous strategy of migratory pastoral production system was, and still is, the mobility of households and herds. The migrations, which are dictated by the availability of forage and water, can follow various patterns but are always characterised by the combination of individual stock ownership and communal land use. This combination does not usually promote sustained-yield resource exploitation whenever land becomes scarce, and in particular when dry-season grazing reserves are no longer accessible. If confined to rainy season pastures throughout the year, the mobility of pastoral households and herds will be reduced to only minor moves, for hygienic or ritual seasons, since energy expenditure for a majority move is not compensated for by a significant improvement of pastures.

4.2 Modern Adaptive Strategies

At this point it should be noticed, that the term "modern" does not apply solely to recent or present developments, though for most African pastoralists it coincides with the respective dates of independence.

Particularly those pastoralists that become impoverished after devastating droughts may be able to re-establish themselves in the pastoral sector through various social mechanisms (stock alliances, stock patronage), will turn to irrigation agriculture, where development projects are in operation, seek wage labour (usually in low income brackets) or attempt to live on famine relief. These alternatives, especially the latter two, are of steadily increasing importance since the recuperative potential of the traditional livestock economies is declining for the already indicated reasons. On the other hand, many wealthy pastoralists are successfully investing in non-pastoral sectors by engaging themselves in trade and business using the structure of the remnant economy to stimulate local markets for foreign goods (petty trade). Formal education and training is also seen as another form of capital investment as it increases the chance for jobs in the higher income brackets, that in turn are the only ones to allow reinvestment in the pastoral sector. Thus, the recuperative potential of the pastoral sector is augmented by non-pastoral activities, though limited to small portions of the population. Today, roughly most of the pastoralists are living below the poverty line, that is to say, are not self reliant in terms of food production. Only a very small minority of the pastoral population are able to diversify their economic activities into non-pastoral sectors.

V. Conclusion & Recommendation

Summary of the current cropping practices their gaps and recommendations

Cropping practice	Pro and cons	Recommendation
Irrigation	- Structures are temporary - Frequent maintenance and laborious - Little time for agricultural activities	- Reduce the effort by contracting waterway. - More time for agriculture.
Land preparation	- Good experience that meet the objectives of land preparation.	- Need to be adapted
Source of seed	- The selection practice is excellent but the quality is not maintained.	- Quality seed development and introduction of new.
Seed rate	- Use high seed rates	- Population must be maintained
Planting time	- It is flexible which meets the situation, and is based on the experience of the farmers	-Some adjustment in Raton and maize.
Methods of sowing	- The local flow and seeding tools *Jeleb* and *Seluka* are favorable means	- Improving the existing and introduction of new technologies
Fertilization	- Any kind of fertilization is not applied	- Introduction of fertilization
Plant protection a. Weeds b. Insects c. Birds	- Yield loss is estimated 30-50% and under severe condition total crop losses - High weed infestation, no weeding is practiced. - Yield loss not less than 25% - some times the losses can go up to 70-80% - Yield lose up to 20% in isolated fields up to 70-80%	- Plant protection system must be in place - Net-working - Training of farmers -Organization

Cropping practice	Pros and cons	Recommendation
Crop ratooning	- First good rotoon can produce as much as 50% of the main crop and second ratoon can produce up to 30% of the main crop.	- It needs an investigation on the benefit verse growing other crops.
Harvesting	- Threshing is done by beating the ear heads damage. - Their experience is time taking and the grain started to change its color and develop an unpleasant smell and test in sorghum, pearl millet is not matured at the some time.	- Adoption of new techniques. - Introduction of new varieties, which mature at the same time.
Threshing	Laborers, time consuming 50kg per day in sorghum and a group of 5-6 men when shelling	- Introduction of new intermediate technologies, which can be adapted easily.
Crop-residue	The husk and stalks are well collected and used for animal feed and for constructing temporary farmhouses	- Introduction of wisely use of the remains such as urea treatment, urea block... etc
Storage system	Crops are sun dried and are put in different storage facilities under ground storage (pit) and tickles are preferred.	- Conduct studies on the effectiveness of the different storage systems. - Introduction of

VI. A Way Forward

In traditional spat irrigation system, there exists tremendous opportunities for increasing crop production by more than 100%.
Based on the information collected and the recommendation set, there is a need for developing a guideline on each aspect so that one can have a whole picture of the spate-irrigation system to be developed in Eritrea. The focus will be on the most important issues and constraints of crop production in the spate irrigation areas.

1. Preferred water management strategy and number of irrigation for each crop.
2. Recommended varieties
3. Improving the existing cultural practice.
4. Increase soil fertility
5. Major pests and diseases and control measures.
6. Link with livestock keeping

1. Preferred water management strategy and number of irrigation for each crop

A crop failure due to shortage of water is very common. The preferred water management strategy is to maximum and efficient use of the flood until

adequate amount of moisture is stored in the soil. In the spate irrigation it is difficult to set frequency and time of irrigation, for it is not under full control. Putting into consideration the high rate of evaporation it is recommended to use all the floods.

In order to achieve permanent structures of diversion structures must be in place.

- Primary, secondary and traisery irrigation structure must be maintained.
- Field embankments must be maintained and improved every year for there is high sedimentation of soils.
- Standby heavy machinery will be necessary for maintenance and timely construction of the main diversion structures....
- During the month of June to August there is high temperature and scorching sun, thus most of the farmers migrate to the cooler highland part of Gheleb and Ghizghiza where they can pass the harsh weather. These months are also critical period for the main activities, hence there is a need of intervention to word permanent settlement of the people by constriction permanent houses that are suitable for the environment and water reservoirs shall be constructed to solve or improve the livelihood of the people.
- Promote private sector machinery service for land leveling, tillage and post harvesting operation, motor power and animal traction.
- Promote animal traction (training, credit , etc.).
- Promote blacksmith services for simple tools

2. Introduction of Improved Seeds

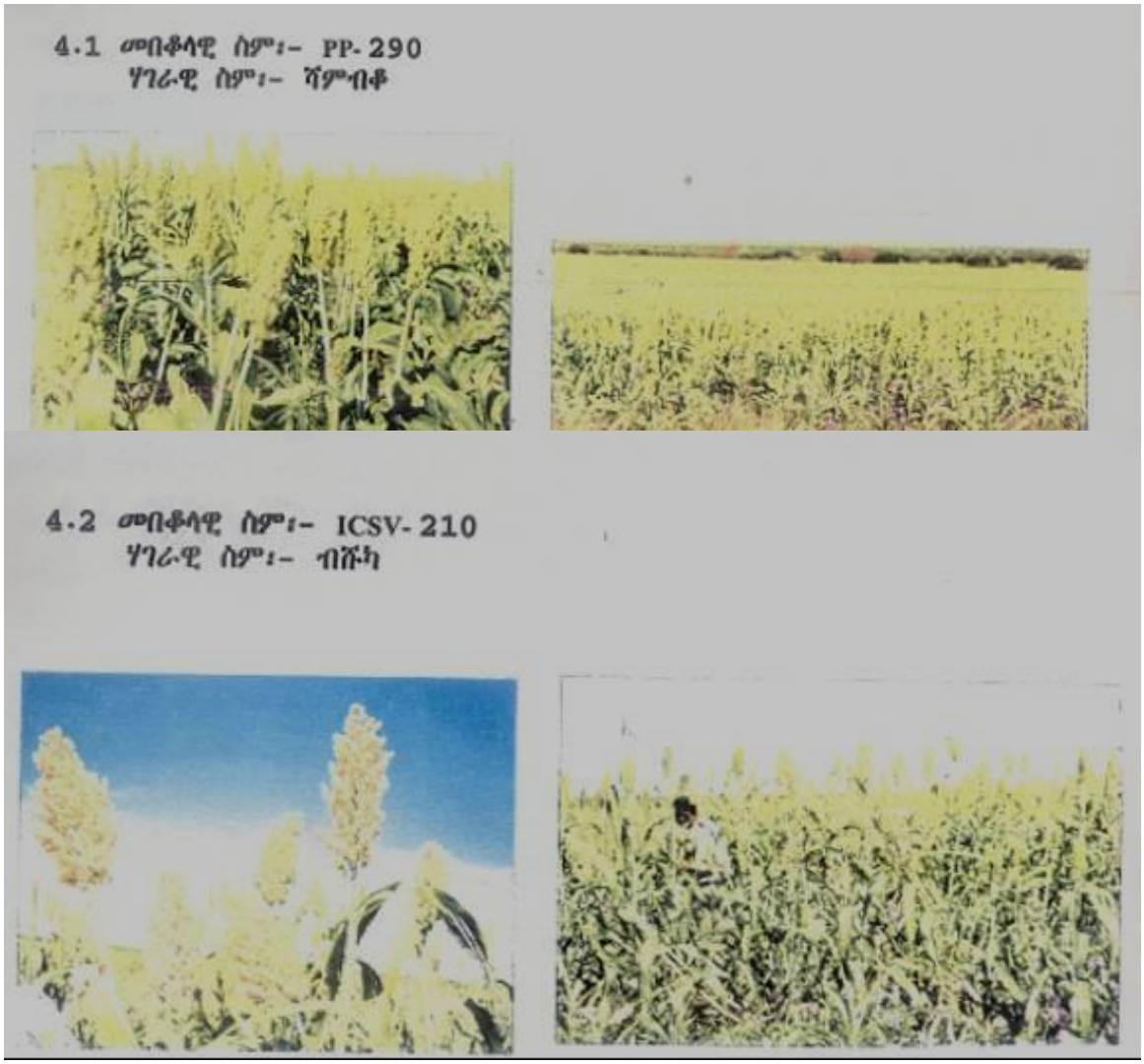
Research station for eastern lowlands is located in the spate- irrigated area and in the western lowlands. Here are the recommended varieties for both agro-ecological regions.

Recommended Research output Varieties

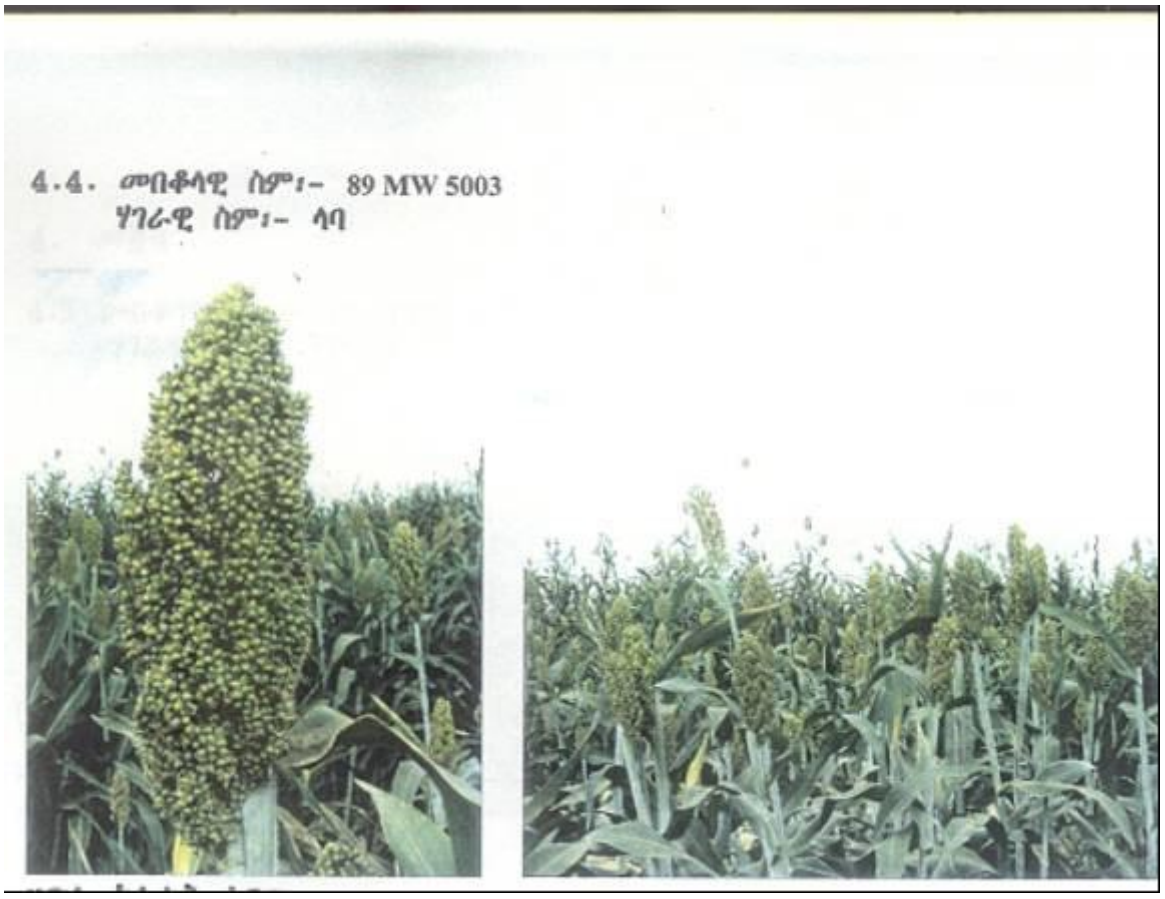
Recommended varieties as a priorities the research out put are listed below, it is advisable also to put into consideration the land races for they well adopted to the environment and had been accepted by the farmers for their performance and passed through many screenings and existed for the past years.

	Western lowland				Eastern lowland	
1.Name	PP-290	1CSV-210			89MW 5003	89MW5 056
Local name	Shambko	Bisuka	Gedam Hamam	Macia	Laba	Shiba
2. Elevation	1500M.	1500	1400	1500	1500	1500
3. Rainfall	350-650mm	450-850	400-650	450-650	Irrigation	Irrigation
4. Soil	Vertisoil	vertisoil	verti-soil	vertisoil	Loom soil	Loom soil
5. Characteristics	Easy maturity combinable	Late maturing	Easy maturity combinable	Short combinable	Easy maturity suitable to birds	Easy maturity
6. Seed rate .kg/ha	8-12	8-12	8-12	8-12	8-12	8-12
7. Fertilizer DAP kg/ha Urea kg/ha	- 100 - 50	- 100 - 50	100 50	100 50	- 100 - 50	- 100 - 50
8. Time of germination	5-7 days	5-7	6-8	5-7	5-7	5-7
9. Inter cultivation	After a month	One month	One month	One month	One month	One month
10. Weeding	- After 3 weeks - After 35-40 days	3 weeks 35-40 days	3 weeks 40 days	3 weeks 40 days	3 weeks 35-40 days	3 weeks 35-40 days
11. Height	140-160		120-140	120-140	205-300cm	250-270
12. Maturity date	110-118	180-200	116-125	116-125	110-115	112-117
13. Color	White	White	Dark white	White	White	White
14. Yield kg/ha	2000-3000	3000-3600	1700-4500	2500-3500	3000-3600	
15.Uses	Enjera, Suwa Animal feed	Enjera, Suwa Animal feed	Feed and feed	Food and feed	Food and feed	Food and feed

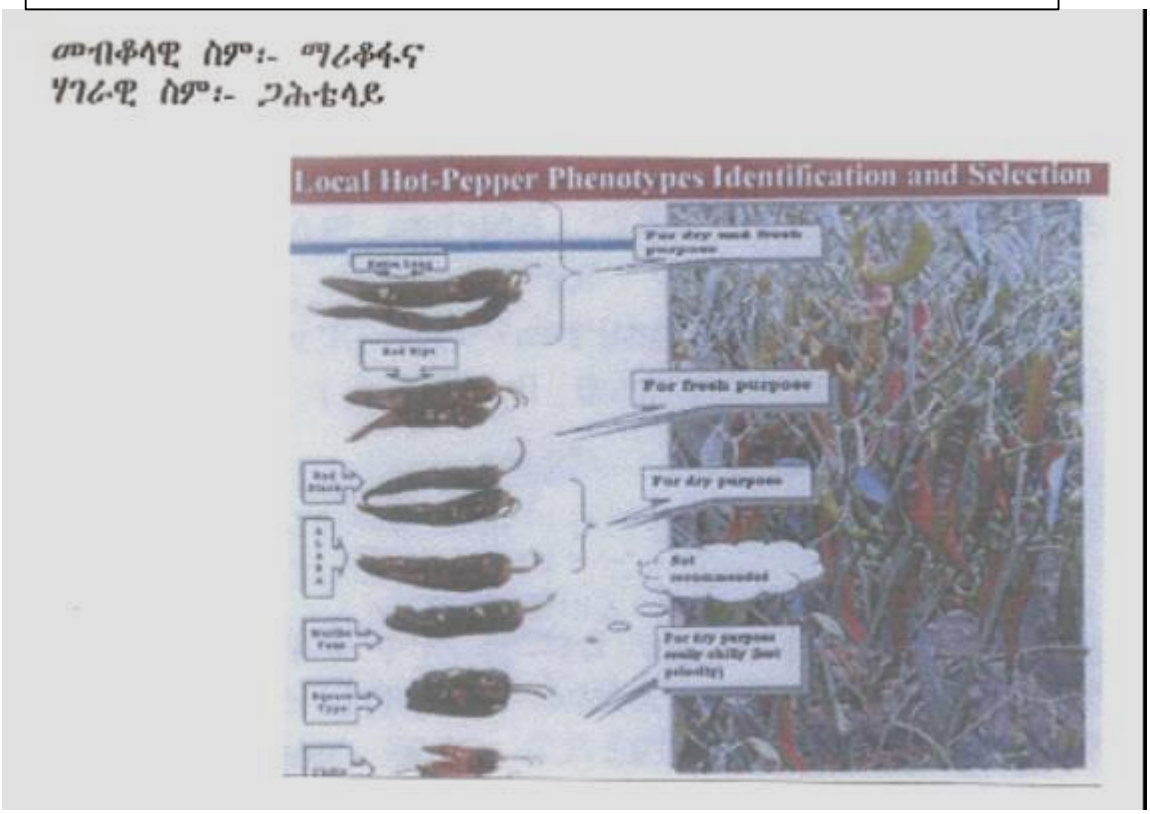
Sorghum varieties for Western lowlands

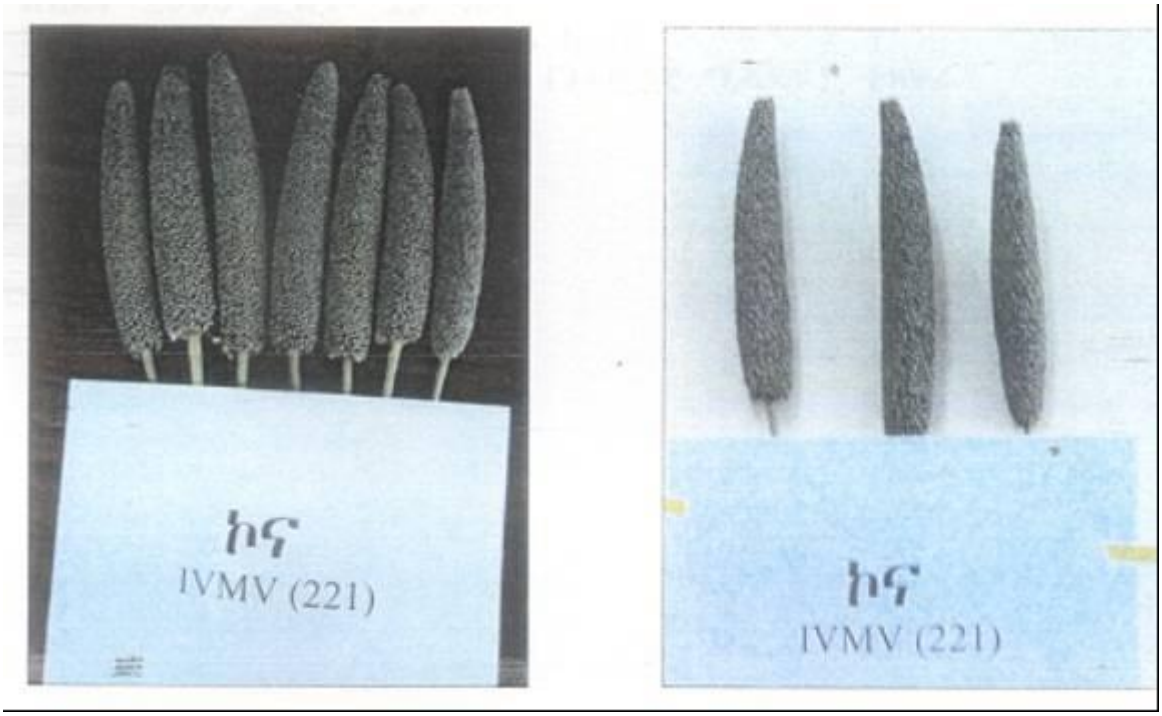


Sorghum varieties for Eastern lowlands



Hot pepper, Pearl millet and Sesame for both agro-ecological zones





Sesame Abunam introduced by extension

Land Race Varieties

The land race varieties had not been studies but for many advantages such as early maturity, less suitable to bird, damage and performance in terms of yields and tillaring capacity, adaptability to an area and rainfall situation the following can be recommended to the specific agro-ecological zones.

Variety	Western low-land	Eastern low land
Dura	Abuseba	Alihiya
Sorghum	Harirai	Hejeri
	Hegertai	Feterita
	Wediaker	Odaka
	Wediferej	Dumburi
	Bazenai	Hartsetsa
	Letemhret	Berih
	Gumbilu	Wedilebabe
	Koden	Chenger
	Amal	Dukum
		Blak & White
Maize		
Pearl-millet	Alwa, Deda, Shila, Tosho and Zubeidi	
Sesame	Abunam, Herher Abdurezak, Abuleben	
Ground nut	Keren	Keren
Cotton		

Exotic seeds introduced by extension

Varieties	Eastern and Western lowlands
Sorghum	- Wedi-Ahmed - Arfa-Gedemek - Tabat - Mailo - Tetron
Maize	- katonomi - H 511 - Awassa

4.3 Improve the existing cultural practices

Rate of seed need to be improved and plant population maintained. These can be improved by the improvement their tools and introducing

Row planting

The system of row planting exists but it is not done in an efficient way. The row is normally not strait and the spacing between rows is not uniform. Oxen driven row planters (drillers) can be introduced and can even be produced locally.

Reduce plant Density

One of the practices requiring improvement is the maintenance of proper plant density in sorghum, which is the most important crop in spate-irrigated fields. The rows are not equally spaced in general, and quite often they tend to be narrow. Within row seeding is too dense to permit the plants to perform to their best potential. The farmers do some thinning of the plants for forage but it is done so late that it cannot minimize the effects of intense intra crop competition within the sorghum stand. As a result, the panicles produced are small in size and the shoots are thin and weak. However, farmers defend dense planting due to a number of reasons and one of which is that dense planting suppresses weeds and farmers also need fodder for the animals.

If forage requirement or weed suppression are the reasons for dense planting, they can be better achieved by having properly spaced rows of sorghum (75x10cm) with an intercropping crop of fast growing legume in the inter row spaces. Such a system would provide forage of greater nutritive value than sorghum, and may enrich the soil with atmospheric nitrogen as well as suppress the weeds similar priorities can be followed in maize also. Moreover, the inter-plant competition between sorghum and legumes would be much less than the interplant competition among the plants of densely sown sorghum.

Inter cultivation

Currently no operation is performed either manually or with implements between planting and harvest. While the weed problems are relatively low in the plots in which "*Mekemet*" is done, it does not mean that the fields are completely free from weeds. Use of multi tine seed drill with proper spacing of rows can facilitate intercultural operations with equally simple harrows as used in the dry land area of the world. Traditionally, the labour force of the household is relatively idle during the time between planting and harvesting. Therefore, possibility exists for better crop management through intercultural operations.

4.4 Increase soil fertility

Farmers in the spate-irrigated area do not apply any manure or chemical fertilizer. Bearing in mind those factors that affect the growth of plants, the agricultural profession requires that all farmers fulfill the following conditions.

- Supply the soil with adequate plant nutrients. There are five ways of accomplishing this.
    a. Prevention soil erosion
    b. Letting the farm lie follow for one or more years during which time the soil nutrients will increase
    c. Good crop rotation
    d. Planting legumes systematically
    e. Applying fertilizers to the soil

- Good preparation of the planting site.

- Planting good quality seeds or better yielding plants that have such characteristics as resistance to disease and pests.

- Proper planting of seed with adequate spacing in between, with a moderate number of crops per hectare of land- not too many and not to few. Planting in row is preferable as it facilitates the easy application of other principles of modern agriculture.

- Provision of adequate water. The supply may be through rainwater or by irrigation providing shades in the farm reduces the evaporation of water and raises the moisture content of the soil.

- Protecting the plant by
    f. Cultivation, uprooting weeds on applying herbicides
    g. Prevention of disease by planting disease-resistant plants or applying relevant pesticides
    h. Prevention or control of destructive insects, birds or animal.

- Proper soil management by
    i. Preventing soil erosion,
    j. Remove of excess water from the farm;
    k. Maintaining of soil structure by applying fertilizers or by seasonally leaving the farm uncultivated

- Crop rotation assists in reducing destructive insects, diseases and weeds.

- Giving incentives to farmers such as good prices for their crops, good marketing arrangement, etc. This motionless the farmers to redouble their efforts and expertise in farming.

A well-fertilized soil is one that has all the nutrients for optimum plat growth organic matter is the principal source of elements in the soil. The role of it is to provide the soil with some plant nutrients and give the soil good structure, facilitate air circulation in the soil, enable the soil to absorb sufficient water and to hold and retain essential nutrients. The amount of elements available for use by plant depends on whether the decomposition on organic matter results in microlisation or not.

There is one component, which is lacking in the spate-irrigation farms; crop residue is generally removed from the fields for feed for animals and also for constructing temporary farmhouses. These means there is no return of nutrient removed by plants back to the soil. Hence, these gap need to be adjust by the application of artificial fertilizers on it is recommended by to the new varieties.

Commonly used fertilizers

Nutrient	Fertilizer	Content %	Quantity of fertilizer (kg) for 1 unit of fertilizer
Nitrogen	Urea Ammonium sulfate Ammonium phosphate Ammonium nitrate	45-46 20-21 17.5-20 35	2.2 5 5-5.2 3.3
Phosphate	Super phosphate Triple phosphate Ammonium phosphate Bi-calcium phosphate Natural phosphate	14-20 40-50 40-52 36-40 25-35	5-7.2 2-2.5 2-2.5 2.5-2.8 3-4
Potash (k_2o)	Potassium chloride Potassium sulphate	60 48	1.7 2.1
Compound fertilizers e.g 10-10.20	Each element to be calculated separately	10 Nitrogen 10 Phosphoric acid 20 Potash	10 10 5

Caution

- The farmer must be very careful in using the fertilizer because it may burn seed, roots or stems on direct contact with them.

- Farmers needs to consider several factors before starting the use a particular type of fertilizer such as the amount of fertilizer needed and the time of application.

- The amount of fertilizer required will depend on one or more of the following factors

1. Climate

2. Examination of soil
3. Crop rotation
4. Weed germination
5. Analysis of the plant
6. Use of natural fertilizers on the farm

- Application of artificial fertilizers.
1. Sprinkling
2. Prior application of fertilizers in pits or furrows
3. Applying the fertilizers in circular form
4. Applying the fertilizers in circular farm
5. Spraying the fertilizer in a planted farm

4.5 Major pests and diseases and control measures

Major pests and disease and control measures weed, pests and disease are major problems of crop production in the spate-irrigated farms yield losses due to these problem is estimated at 30% to 50% and under sever condition there can be a total crop losses.

In order to have a broader view we will see them separately.

Weeds

Various weed species are widespread in the area. According to the survey carried out by the Ministry of Agriculture in 1998, broad leaved and grass weeds commonly affect the crop production under the spate irrigation. The most common broad leaved weed species found in the spate-irrigated fields are *Heliotropium spp*. (*Tsada Rusu*), *Datura spp*. (*Mezerba)*, Argemone spp., Echinocloa spp., *Euphorbia spp*, *Solanum spp* (*Fenchuch*) and *Cucumis spp* (*Hafafulo*), and the common grass weed types are *Cynodon dactylon (Romadi)* and *Echinocloa spp* (*Halawat*).

As a result of the flood a very high weed infestation is prevailing, besides the farmers in the spate irrigated farms do not weed their fields.

Weeds are one of the main factors reduced yield and are often responsible for the very low productivity of certain tropical crops.

The depressing effect on yield is exerted in various ways.

- Direct competition for plant growth substances, or antagonism.
- Light weeds often grow faster than cultivated plants and can overtook them shade them.
- Water: competion for unter between crops and weeds is a mater of life and death.
- Fertilizer: since weeds grow rapidly and vigorously, they use a large proportion of the fertilizer intended for the crop, particular nitrogenous fertilizer.
- It is a breeding and harbours area for pests

Methods of weeding

The hest strategy is often integrated weed management, employing a combination of methods.

Choosing a method

1. Accurately identify and map the location of the major weed problems in each crop.
2. Investigate reasons for the problems, could the farming or planting technique be altered to give the crop a greater competitive advantage?
3. Consider cultural methods of control first, since these are most sustainable with local resources of low cost technology.
4. Where necessary, select chemicals those are both safe and effective.
5. Compare alternative methods on the basis of the optimum timing needed for best effect, cost, lese of application least damage to the environment
6. Any one-weed control treatment must fit into a longer- term weed management strategy.

Manual and mechanical weeding

Until recently, weed control consisted of hand weeding, hoeing, harrowing, ploughing and other farms of tillage.

Hand method

Hand weeding is the cheapest method of control for the small farmers and his/her family simply pulling or rouging trouble some weeds can be done without equipment.

The disadvantage is that the work is seldom done before weeds are large and already seriously competitive with the crop.

- Pulling weeds is hard and tiring work and the area covered per person per day is limited. Hand tools used in weeding is not yet introduced in the spate irrigation farm such as
    - cutlass or machete
    - small hoe
    - hand hoes of different shapes of plades
    - spade
    - sharma hand hoes
    - long –handled hoe- different shapes of blades.

These can be cheap and there fore available to all a most members of the family or community. Hand tools may be made locally rather than imported.

Hand wheel hoes with adjustable blades and hands can also be introduced for they are proved useful. They leave smaller weeds as mulch between the crop rows and are easier to use.

Animal powered weeding

Animal powered system offer the only possible alternative cultural means of controlling weeds. The animal-powered weeding can be carried out using whatever animal is most appropriate to the environment and culture of the people.

Tractor system

Four-wheeled tractors can increase weeding rates around one hundred fold over hand weeding and can, like animals, be made to pull a variety of types of time, attached to multi-purpose toolbars.

Cultural method

1. Burning: - It is widely used especially for destroying scrub on clearing forest for cultivation. It is also used in order to regenerate pastureland.

2. Crop rotations: - it is adopted aimed primarily at maximizing weed control.

3. Covering the soil (mulching): - this technique is practiced with high yielding crops

Herbicides

A distinction is drawn between total herbicides and selective herbicides. Total herbicides, such as sodium chlorate and divron, destroy all vegetation without discriminating, between species. Selective herbicides destroy certain weeds but leave the crop unharmed.

Time of application

- Pre-sowing on pre-planting treatment.
- Post-emergence treatment- is applied after the crop and the weeds have emerged.

There are many compounds of herbicides to use them always check local lows in clearance and use (based on safety and efficacy of the chemicals)

The various types of equipment required for applying herbicides are as follows.

a. Hydraulic sprayers
b. Air-assisted sprayer
c. Ultra-low volume (ULV) sprayer

Chemical weed control in the most important cereals can be summarized as follows.

Variety	Characteristic	Treatment
Maize	It is extremely sensitive to competition from weeds because it emerges more slowly than weeds and doesn't completely cover the soil until two to three months after sowing.	Pre-sowing using paraquat or glyhphosate. Post emergence treatment atrazine, paraquat or 2,4-D
Sorghum	Competition from weeds is made worse by the fact that sorghum grows slowly at first	Inter-row treatment when sorghum is 30-40 heights. Post-emergence 2,4-D Sowing in rows can enable trailed hoes, or chisel ploughs.
Groundnuts	In the early stage, they are slow–growing plants the soil is not completely covered by the crop until late on, about two months after sowing. Pods are formed in the soil, makes weeding difficult.	- Groundnut should be sown only on perfectly clean land. - weeding must be done during the crop cycle - - 2-4-D B(2-3 kg ci/her) may be used post emergency. - .
Cotton	It is during the early stage of their development that cotton plants suffer most	- Prior to planting the crop - Before the weeds emerge pendimethalin, Dipropetryn

Insect pests and diseases

The important insects are locust, stinkbug, termites, lopodopters and hemipterous insects, stembovers, aphids and whiteply.

Description	Pests	Area infested (ha.)	Treated	Pesticide		Farmer participation
				Liquid	Powder	
Cereals		242.5	111.0	66	72	121
pulses	Bugs, ballwarm					
Vegetables	Aphider, Ballwarm, cut warm	278.5	248	212.5	34	44
Fruits	White fly	72.5	48.5	48.5		48
Out break						
Cereals	- Locust	9152	5087	3776		6
	-Grass-hoper	500	450	50		400
	Army warm	231	231	231		231
	Stinking bag	1020	1020	1020		20
	Chaffer beetles	25	25	20		25
Vegetable	- Locust	5	5	5		10
Total		**10,933**	**6818**	**5102**		

Source: *Report of the MoA, 2003 on crop protection activities.*

Updated report can show us the extent and intensity of pest outbreaks in the region. The climate of the spate-irrigated area is favorable for breeding various insect pests, diseases.

So establishment of crop protection system is import.

- Easy warning and prevention system must be in place
- Integrated pest management (IPM) shall be introduces
- Training of farmers to increase their awareness on the major pests
- Farmers have to be organized in a network of plant protection groups.
- Scouts of farmers with special training is essential for continues surveying of the pests
- Farmers must be equipped with equipment used for applying pesticides, which are almost similar for applying herbicides.
- In an outbreak of locust, which is usually associated with good rainy seasons, special contingency planning must be in place. For these purposes all need pests and equipments must be ready a head of time.
- Air runways need to be developed in strategically areas such us Mai-himet and Sheab.
- At the pick producing time stand by of pilots and Aircraft need to be arranged.
- FAO, Desert locust guidelines on
  - Biology and behavior.
  - Survey
  - Control
  - Campaign organization and execution
  - Safety and environmental precaution must be followed.

Equipments needed

1. Micro-ulva + handheld spinning disc sprayer
2. Micro vlva + spray head and optional backpack tank
3. Knapsack misblower fitted with Moromair AV 8000 retary cage.
4. Vehicle-mounted ULV air blast sprayers of different types.
5. Aircraft- mounted sprayers.

Does rates and speed of action of different insecticides for which verified dose rates have been established for the Desert Locust.

Insecticide		Treatment				Speed of
		Over all (blanket		Barrier (hoppers)		
	Class	Hopper	Adults	Within	Overall	Action
Bendio cards	CA	100	100			F.1-2h.
Chlorpyrifos	OP	225	225			M 3-48h
Delkamethrin	PY	12.5	12.5			F 1.2h
Diflubenzuron	BU	60	n.a	100	5	S>48h
Fenitrothion	OP	450	450			M 3-48
Fibronil	PP	4	4	12.5	0.6	M 3-48
Lambda-cyhalothrim	PY	20	20			F 1-2h
Malathion	OP	925	925			M 3-48h

4. 6 Linking with livestock keeping

Animal feed in the spate irrigated areas is one of the problems that limit the keeping up of the amount of livestock during the dry season. Stalks are used for house construction whereby it will also aggravate the shortage of animal feed. This is mainly happening in the Sub Zobas of Sheeb and Afabet. To avoid the shortage of fodder during construction of diversion structures, canals, and other farming activities, farmers grow early growing varieties of sorghum (e.g. *Dura*). However, this may not sustain for the whole year. Other measure as a means of alleviating the shortage of fodder, migration of livestock takes place. For example:

Sub Zoba Ghelalo (Bada Area):

Cattle migrate seasonally to the southern part of Dankalia and to the highlands of Ethiopia (Tigray), but camels, sheep and goats stay in the surrounding area. Since Regali River has year round stream there is no shortage of water both for

domestic and livestock. Since there is year round water, animal fodder with early growth and adaptable variety for the area shall be introduced.

Sub Zoba Sheeb and Afabet:

Another drain of resources and time is to rebuild habitations (*agnet*) each year after returning from highlands. The migration itself is for grazing the animals, to save them and the family from harsh weather, to avail cactus fruits, which are used as food supplementation, and to cultivate small landholdings that some have in the highlands or eastern escarpments.

When the grazing in the non-arable lands becomes scarce, and stock of crop residues, on which the livestock basically subsist, is getting exhausted (April), and when temperature becomes too hot, the households migrate to highlands. All livestock migrate except the hardy breed of oxen, which are required for field operations ranging from flood diversion to tillage and planting. Introduction of different agro forestry practices relevant to the local environment is vital. Such practices would include establishment of shelterbelts and wind breaks at right angle to the wind direction, since wind carrying fine soil particles (*kemsin*) is the major problem in the coastal areas including Sheeb. In addition, substitutes of wood and agricultural residues for house construction shall be also introduced.

Sub Zoba Foro:

In the Sub Zoba Foro, migration of farming community to other areas is practiced with the exception of Zula, Afta and Unga villages. However, during the dry season July to December, animals typically cattle and camels are sent off to Hazemo and highlands of Deot area in search of feed and water, because this is the period when most of the crop cultivation activities are undertaken. Some milking cows and oxen used for land preparation are left behind. Drinking water, school and health centers are under construction. What has been suggested for Sub Zobas of Sheeb and Afabet are relevant for this Sub Zoba also.

Management of livestock and forage resources is an import aspect of animal production. Forage and animals can be brought together in five main ways.

- Free ranging
- Herding
- Pad docking
- Tethering
- Zero grazing

Free ranging, herding and tethering is practiced in the spate irrigation farms. The reasons why farmers choose to herd or to tethering animals must be understood before a change to other farms.

Farmers can take the following strategies to obtain forage for their animals in order of increasing intensity of forage management.

- harvesting by grazing or cutting natural forage
- influencing growth of natural vegetation

- auxiliary use of cultivated plants or plots
- cultivating perennial forage species that persist for several years or even decades
- cultivating animal forage species that must be re-sown each year.
- conservation of forage

Farmers rarely rely on only one of these strategies. They may combine grazing of natural pasture with grazing or feeding of crop residues, use of forage trees, and small areas of planted annual forage crops.

In the spate irrigation forage cultivation must be integrated with crop production. The benefit of forage cultivation includes higher milk and meat production (per animal or per hectare), more manure and possibly better soil fertility for subsequent cropping. Forage crops may also be sold to other livestock keepers, in such case, the procedure for economic calculation does not differ from that for other cash crops.

- Optimizing the use of available forage.
- Optimizing forage use in grazing systems
- Forage conservation practices must be improved and supplementation is necessary for meeting the animal nutritional needs.
- At last is recommended that the output of the research finding of integrated nutritional feeds must be introduced. The research department of the Ministry of Agriculture had already developed 2 formulas for eastern lowland and 2 formulas for western low lands.

Last not list all the recommended activities technologies be implemented needs an efficient extension system. It would be better to build up an extension networks on the existing farmers organization, such as crop and livestock production, and plant and animal health services. A net-work of contact farmers as facilitators in conveying messages to and for concerning farmers issues on different developmental problems.

VII. Literature Cited

1. K.C.Lai, 1996. Special Programme on Food Production (SPFP/ERI/4501), Report of Monitoring and Evaluation consultant, Asmara August 1996.

2. Mehretab Tesfai Hdera 2001. Soil and Water Management in Spate irrigation Systems in Eritrea. Tropical Resource Management Papers. Wagenningen University and Research Center, The Netherlands. 211 pp.

3. Spate Irrigation: Proceedings of the Sub regional Expert consultation on Wadi Development for Agriculture in the Natural Yemen. 6-10 December 1987. Aden, PDRY Yemen. PP 51-57.

4. Poverty in an area of plenty: A baseline study development planning in the Zula plain of Eritrea. Norwegian Church Aid-Eritrea. Working Report No. 1/94: Project ERI-001-02 "Zula Plain Baseline Study". PP 20-36.

5. I.C.Onwueme and T.D. Sinha, 1999. Field Crop Production in Tropical Africa Principles and Practice. Michael health ltd, Reigate, Surrey England. PP 480.

6. Adhanom Negassi, Kidane Negasi and e.tal. 1998. Weed Survey report on Integrated Farming Scheme (IFS) on the different Agroecological Zones of Eritrea. Ministry of Agriculture, Asmara, Eritrea. PP 74-81.

7. M. Natarajan, 1999. Strengthening the agricultural research and extension in Eritrea, GCP/ERI/001/ITA. Report of the consultation on Production/Farming Systems Agronomy. State of Eritrea Ministry of Agriculture, Department of Agricultural Research and Human Resources Development and FAO. PP 48

8. M. Natarajan, 1998. Strengthening the agricultural research and extension in Eritrea, GCP/ERI/001/ITA. Report of the consultation on Production/Farming Systems Agronomy. State of Eritrea Ministry of Agriculture, Department of Agricultural Research and Human Resources Development and FAO. PP 77

9. J.W. Purseglove, 1992. Tropical Crops: Monocotyledon. Longman, London. PP 147-300.

10. Sorghum in the Eighties, 1981. Proceedings of the International Symposium on
    Sorghum. Volume I. ICRISAT Center Patancheru, A.P., India. PP 81-313.

11. Sorghum in the Eighties, 1981. Proceedings of the International Symposium on
    Sorghum. Volume II. ICRISAT Center Patancheru, A.P., India. PP 475-527.

12. M.J.T. Norman, C.J.Pearson and P.G.E.Searle, 1984. The Ecology of Tropical Food Crops. Cambridge University Press. PP 103-163.

13. Tesfay Haile, 1996. Baseline survey report of the Bada irrigated agriculture project. Consultancy report for: USAID-Eritrea, Africare-Eritrea and the Ministry of Agriculture, Asmara-Eritrea.
14. World Bank. (2001) Eritrea: Agricultural Sector Review (third draft). MOA
15. DANIDA, Watershed Development, Proceeding of Fourth International Danida Workshop on watershed development, pp.44
16. Government of Eritrea, 1995 National Environment Plan for Eritrea (NE MP-E) Agency for the Environment Asmara, Eritrea.
17. Pius B.Ngeze, 1998, Artificial Fertilizers and how to use them Nairobi, Kenya pp.2
18. Guy Rouanet, 1987, The Tropical Agriculturalist
19. Wolfagong Bayer and Ann Water-Bayer, 1998, Forage Husbandry. The Tropical Agriculturalist series pp.52-63
20. E.M.Lavobre, 1998 Weed control. The Tropical Agriculturalist Series.

Starkey P, 1998. Integrating Mechanization into Strategies for Sustainable Agriculture, CTA. Wageningen, The Netherlands.