LAND USE PLANNING IN A PERI-URBAN VILLAGE OF ERITREA: THE ADI-SEGDO CASE STUDY

BY

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Declaration

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and has not previously in its entirely or in part been submitted at any other university for a degree.

Signature..... Date 21-01-2002

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ABSTRACT

Land is the basic resource and major production asset of Eritrea. The economy of the country and livelihood of majority of the population in the country depends on agriculture. But, injudicious utilization, over-exploitation and lack of proper management resulted in declining the quality and potential of the land resources. In the past 50 years Eritrea was deprived of any agricultural or non-agricultural development activities especially during the Ethiopian colonial period (1952-1991).

After independence in 1991 the social and economic growth of the country started to revive. As a result different investments were implemented during the last 10 years. But almost all the investments were based on the ambitions and goodwill of the government and the investors. Most of these development activities were done without proper resource surveying for optimum and sustainable resource utilization, hence great competition and losses of good agricultural land to non-agricultural uses were experienced during these 10 years. Resource surveying, land evaluation and land use planning are new concepts to the country.

Dent and Young (1981), pointed out the sharpest conflict in land development occurs in the urban fringe zone where there is competing demand on land for food production, industrial crops, urban expansion and industrial development. This is happening in the study area. The study area, Adi-Segdo, is a village located close to Asmara city, which was incorporated under the city administration in 1994. The people of the village are dependent on land or agriculture for their survival. Due to lack of land resource inventories and determination of the potential use of specific units of land, agricultural lands of the village have been allocated for non-agricultural development activities.

This study was aimed at developing a land use plan for the area by assessing land resources (climate, soil and etc.) and evaluating the potential of these resources for recommending optimum, sustainable and appropriate land utilization for each mapping

unit. It concludes with a provisional land use plan for Adi-Segdo, which could help in allocating land units with no crop production potential for urbanization and other non-agricultural development activities. In addition recommendations are made for possible improvements in farming systems and more efficient utilization of the scarce available agricultural resources, especially water and arable land. At the moment dairy and poultry farm products are more profitable than vegetable crops. Hence these farming enterprises are strongly recommended and should get attention by the community and government institutions.

The new land reform promulgated by the government in 1994 is focused in equitable right of use, optimizing sustainable production, protection of natural environment against degradation and increases the effectiveness of economic growth of rural and urban population. But for different reasons this is not yet implemented. According to this study the delay of its implementation has further aggravated social problems and land degradation. This study has recommended a possible way of implementing the new land tenure system. From experience farmers know the potential of each land unit more than any expert from outside. This indigenous knowledge of farmers with inputs from land resource experts can play a great role in land classification and allocation among households. This recommendation can be tested in the study area, whereby this document could also be used as a base.

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ABBREVIATIONS

AEUs	Agro-ecological units
AEZ	Agro-ecological Zones
ARDA	Agricultural Rehabilitation and Development Agency
CIA	Central Intelligence Agency
CIDE	Center for International Development and Environment
CLI	Canadian Land Inventory
FAO	Food and Agricultural Organization
FSR	Farming Systems research
IIED	International Institute for Environment and Development
IUSS	International Union of Soil Science
KNES	Kenya National Environmental Secretary
LUTs	Land Utilization Types
MH1	Moist Highland 1
MLWE	Ministry of Land, Water and Environment
MOA	Ministry of Agriculture
NEMP-E	National Environmental Management Plan for Eritrea
PRA	Participatory Rural Appraisal
RRA	Rapid Rural Appraisal
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environmental Program
UNESCO	United Nations Education, Scientific and Cultural Organization
USDA	United States Department of Agriculture
WCED	World Commission on Environment and Development
WRB	World Reference Base
WRI	World Resources Institute

CHAPTER 1

INTRODUCTION

1.1 GENERAL BACKGROUND ON ERITREA

Eritrea is a young country with a complex series of landscapes and climatic features, which give rise to a wide variety of agro-ecological zones. The consecutive colonial systems and recent years of drought led to over-exploitation and degradation of the natural resources of the country. This, together with the 30 years of devastating war for independence, has disrupted the social and economic growth of the country. Eritrea is one of the countries of the world not endowed with rich natural resources, but injudicious utilization, over-exploitation and lack of proper management, from the past until today, has further declined its production potential. This may continue to decline unless steps are taken to restore the lost productivity and prevent further losses.

Eritrea covers an area of about 121,320 square kilometers. The population size is about 4 million, of whom about 1 million live abroad, mainly due to political crises that prevailed in the country for several years (New Africa, 1999).

The characteristics of the farming systems in the Eastern and Southern African regions have been influenced appreciably by the physical environment. These regions contain most of the highlands in tropical Africa. The climatic diversity on which farming systems depend, is related to altitude. The area extending from the Red Sea to the horn of the continent, through the plateaux south of Lake Victoria and the Rift Valley to the plains in southern Africa are rather dry (La-Anyane, 1985).

Eritrea is located in the horn of Africa. It is situated between 12 and 18 degrees North and 36 and 44 degrees East (CIA, 1999). It is bounded by the Red Sea in the northeast and east, by Djibouti in the southeast, by Sudan in the north, west and northwest and Ethiopia in the south. The country is mainly arid and semi-arid, and is not endowed with rich water resources. Furthermore, being

part of the Sahelian Africa it has been the victim of recurrent and devastating droughts. It is also a country heavily dependent on rainfed agriculture. Rainfall is torrential, is of high intensity over a short duration, is very unpredictable and occurs sporadically. The geographic variations in rainfall distribution are extreme, with areas of 1000mm annual rainfall and 200mm annual rainfall separated by as little as 15 km (Van Buskirk, 1999). The temperature in the country ranges from hot and arid along the Red Sea coastal line and northwestern lowlands to temperate sub-humid in the micro catchment within the eastern highland escarpments. The topography of the country is dominated by the extension of the Ethiopian north-east running rugged range of highlands, descending in the east to a coastal desert plain and in the west to flat to rolling plains. Natural vegetation is very sparsely scattered. According to the Ministry of Agriculture, cited in Government of Eritrea (1995), the natural vegetation cover of the country is estimated to be as little as 1%, or even less, of the total area of the country. The dominant natural vegetation types include riverine woodland and bushland in some parts along the drainage basins. Dense and open shrub woodland and grassland occupy the southwestern part of the country. Disturbed forest occurs on the eastern escarpments (Government of Eritrea, 1995). Little is known in detail about the soils of the country. According to FAO (1994), twelve major soil units are identified. These are Arenosols, Solonchacks, Leptosols, Lixisols, Luvisols, Gypsisols, Cambisols, Fluvisols, Nitosols, Vertisols, and Regosols. Refer to Weldegiorgis (2000) for information on their characteristics and geographical distribution.

The Ministry of Land, Water and Environment (1997) conducted a general resource survey at a reconnaissance level. According to them, six major agro-ecological zones are identified. The classification was based on similarities of moisture and temperature regime, natural vegetation, soils, land use and farming systems. For detailed information of the natural resources of the country and their distribution, agro-ecological zones and farming systems refer to Berhane (2000) and Weldegiorgis (2000).

1.2 RESOURCE MANAGEMENT PLAN OF ERITREA

After independence in May 1991, the attention of the government was directed towards resource surveying and wise resource utilization for the development and growth of the social and

economic condition of the country. The government turned to the equally challenging task of consolidating national stability and ensuring a firm basis for social and economic growth. In moving to the new challenge of reconstruction, almost from scratch, of the shattered country, and the nation's economic and social infrastructure, it was realized that the environmental and natural capital must be taken fully into account to ensure sustainable growth (Government of Eritrea, 1995).

To achieve the desired outcomes, experts from the Ministries of Agriculture, Mines, Energy and Water Resources, Health, Local Government, Construction, Trade and Industry and Marine Resources drafted the National Environmental Management Plan for Eritrea in 1995. A technical committee of 13 professional members was selected to coordinate the drafting of the substantive management plan (Government of Eritrea, 1995).

The fundamental principles of the National Environmental Management Plan for Eritrea (NEMP-E) are that environmental priorities should be identified through a consultative process between governmental institutions and ministries and the community. Priorities should reflect a consensus by the people, the government, experts and academia. Although there were ready-made available models for environmental management developed in other countries the plan for environmental management of Eritrea was made in reference to the culture and the conditions of the country and population (Government of Eritrea, 1995).

The structure and purpose of the National Environmental Management Plan for Eritrea comprise four parts (A-D), each consisting of several sections:

Part A.

> The overview, considers environmental and development prospects for Eritrea within a broader (i.e. international) context, including the United Nations Conference on Environment and Development (UNCED). It examines the connections between population, resources and the environment; and within the Eritrean context, the relationship between the NEMP-E and other national initiatives (e.g. development

planning and macro-economic policies). The overview concludes with guiding environmental principles to help establish a multi-disciplinary ethos in the national planning process.

Part B.

Addresses the major environmental and development issues confronting the country. These are grouped firstly into those issues that have a direct or indirect bearing on human health and well-being. Other environmental and development issues are grouped into natural resource management issues; and socio-economic, institutional, international affairs and conflict management issues.

Part C.

Defines major steps and responses involved in an integrated environmental and development planning process. It proposes a program strategy and structure for the NEMP-E, and categorizes proposed activities. Key individual program and project activities are defined, and divided into three fundamental categories.

Part D.

Examines in detail the requirements for implementation of the NEMP-E and its associated project activities, institutional prerequisites, financial and human resources.

The National Environmental Management Plan can be summarized as follows: The Eritrean National Environmental Management Plan is the blueprint for coordinating the protection and enhancement of the country's natural resources, so that optimal social and economic development can be achieved in consonance with the rational and sustainable use of these resources, for current use, as well as for future generations (Government of Eritrea, 1995).

For proper and successful implementation of the environmental management plan the technical committee, which was responsible for the substantive drafts of the plan, recommended the following:

1. Upgrading and improvement of the qualification of experts in different disciplines on natural resources and management.
2. Acquiring of the necessary equipment and materials required for resource surveying and related activities.
3. Coordination and proper use of existing human resources in different institutions and ministries.

After the compilation and publication of the National Environmental Management Plan for the country, all ministries and governmental institutions reviewed and modified their policies and strategies according to the recommendations. The aspect of human resources and institutional development was a top priority in all sectors of the government. The government planned a praiseworthy active program of human resources development in different fields of study. The program contains a large training component covering short and long-term (postgraduate) training. A preliminary training needs assessment, in 1996, suggests that the most urgent needs for long-term training exists within the field of resource surveying and management.

D. Berhane and B.W. Weldegiorgis are two of the students who trained in Land Use Planning at master's level. As part of their study they developed methods and techniques in Land Resource Surveying (Berhane, 2000) and Land Suitability Evaluation (Weldegiorgis, 2000) for sustainable development of the country. The general objectives of their studies were to develop appropriate methods and techniques of land resource surveying for collecting the basic data required for effective land use planning and strategies and systems of land suitability evaluation for the situation of Eritrea.

According to Berhane (2000) different levels and intensities of resource surveying for the country are identified. In a country like Eritrea where land is a major natural resource and agriculture is the backbone of the country's economy, the assessment of natural resources is vital for any land development program. The failure of most development programs in most developing countries is

due to lack of proper natural resources surveying or assessment. Therefore proper and efficient land resource surveying is needed and the use of aerial photographs in land resources surveying is essential. At small-scale survey level satellite imagery may substitute aerial photographs. However, in detailed and intensive survey the application of aerial photographs could be vital.

Weldegiorgis (2000) in his study on development of a strategy and structure for land suitability evaluation has identified two alternative strategies depending on circumstances. One is to find a suitable area of land for a specific land utilization type, which requires surveying of natural resources and identifying the limitations. The other is to allocate a suitable land utilization type to a specific area of land, which needs comparison between two or more land uses before deciding on the use of particular land. But he recommended the second alternative, that is 'allocating of alternative areas for specific crops' as the appropriate approach of land suitability evaluation for the country. This is because if there are priority crops that should be planted to secure food self-sufficiency for the masses of the people, there is no choice but to find/allocate areas of land for the production of such crops (Weldegiorgis, 2000). Sorghum, barley and wheat are the priority crops in the country; so areas suitable for the successful production of these crops should be identified.

Even though Berhane and Weldegiorgis have developed methods and techniques for land resource surveying and land suitability evaluation respectively for the whole country practical examining and evaluating of their strategies and techniques is indispensable. Their recommendations on surveying and evaluation should be exercised in pilot areas in different agro-ecological zones of the country.

This research work is done as practical pilot exercise for testing the methodologies and strategies recommended for resource surveying and land suitability evaluation for the country. A pilot village, Adi-Segdo, situated in the western part of Asmara, was selected. The selection of this village as pilot research area is mainly due to the following reasons:

1. Availability of recent aerial photographs at scales of 1:5000 and 1:15000 and topographic maps of 1:50000, showing 50 meter contour intervals.

2. There is a competing demand of land between the villagers for food production and the government for urban expansion and industrial development because this village is located in the urban fringe zone.

The sharpest conflicts in land development occur in the urban fringe zone where there are competing demands on land for food production, industrial crops, urban expansion and industrial development with associated facilities (Dent & Young, 1981). The village is located close to Asmara, the capital city of the country. Plots of agricultural land have been taken from the village for urban expansion and industrial development in the past. These reallocations of agricultural lands for development purposes were not based on quantitative or qualitative physical data on land suitability for alternative uses. No compensation or other significant development opportunities or priorities were given to the village community for the irrevocable loss of land by the government or the developers. Ultimately this reduction in size of agricultural lands resulted in high population pressure, over-exploitation, reduction of fallow periods, from once every three to four years to almost zero fallow period, and decline of productive potential of the land. Efforts to increase crop yields are being negated in the village by the concomitant degradation of soil resources due to population pressure. The evidence for this comes from the declining average yields. Production for subsistence in the village was obtained by cultivating large areas of soil found on steep slopes, which were previously used for grazing. All these resulted in land degradation and soil erosion in the farms of the village.

After independence in 1991, the demand of land for urban expansion and other development purposes increased at a faster rate. When the demand exceeded the supply the government annexed 13 villages in the environs of Asmara to be part of the city. From personal observation and communication with the officers of local government, the communities of these villages are predominantly dependent on agriculture as basis of their life.

Adi-Segdo, the study area, is one of the villages which were included under the administration of Asmara. The government produced aerial photographs of these areas at scales of 1:5000 and 1:15000 in October 1994. The Department of Land, in the Ministry of Land, Water and Environment, was given the responsibility for producing a Land Use Plan map of the area. Due to

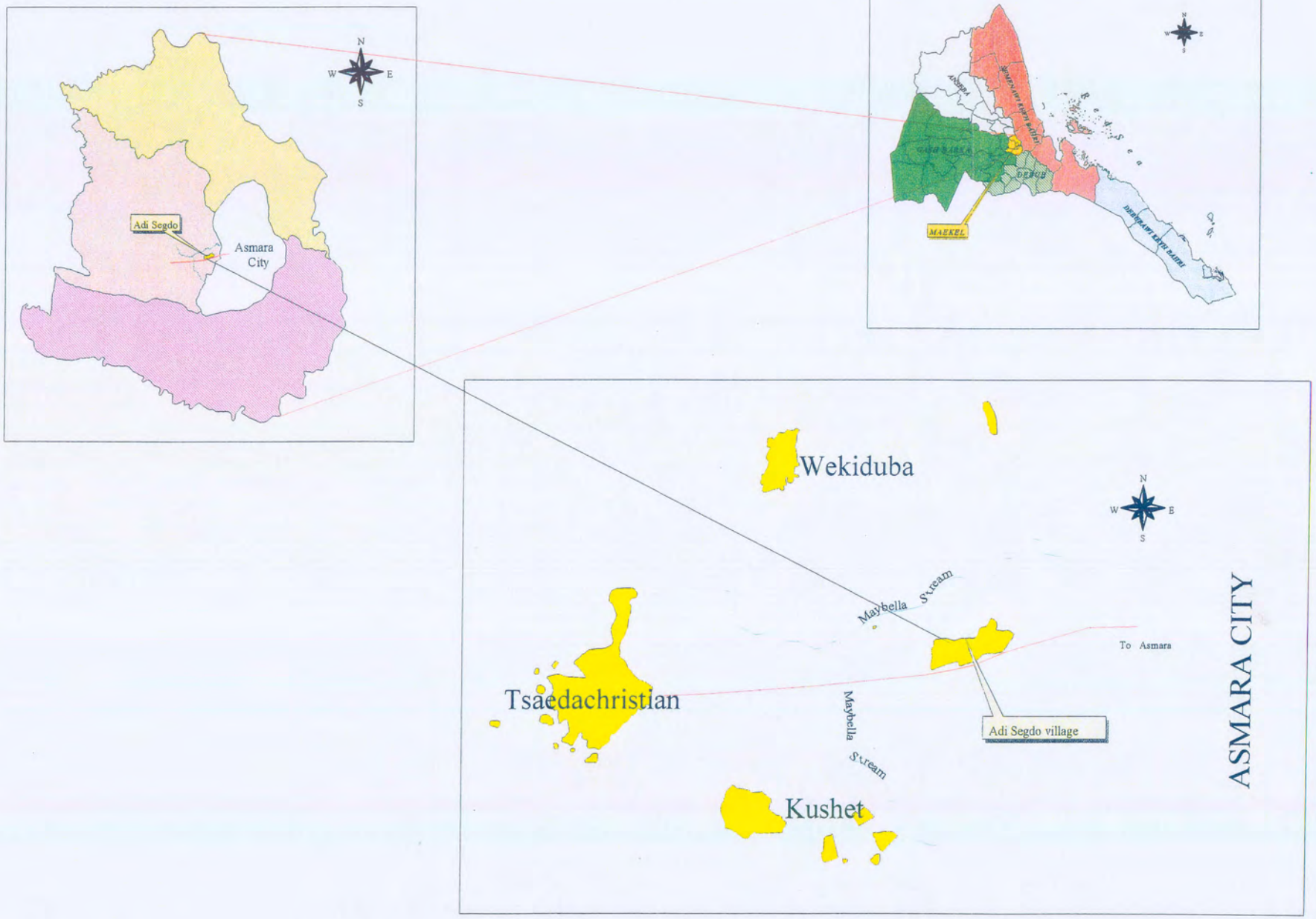
the shortage of qualified experts in resource surveying and land use planning and logistics the land use plan of the area was done based on the USDA system. The produced land use plan maps were of poor quality, because no detailed studies were done on the resources, such as soils, and socio-economic aspects. However degraded and steeply sloping areas were generally recommended for the urban expansion and other non-agricultural development purposes and flat lands for crop production.

1.3 THE STUDY AREA

Adi-Segdo, as explained before, is one of the villages included under the city administration of Asmara by the government in 1994. It is one of the villages of Zoba Maekel province. It is located 3 km west of the city along the gravel road which runs from the west end of the city to the western part of the country (Figure 1.1). The community of the village is predominantly dependent on the productivity of the land both for their crops and livestock. Agriculture, covering all land based activities such as crop production, animal husbandry and irrigated horticulture, is the main source of food and income for most of the population in the village. The land tenure system in the area is communal, where each household has a residential site. Each household is entitled to an arable land area proportional to family size. The rangeland or grazing land for livestock is communally owned.

According to the Agro-ecological zone map of Eritrea (Ministry of Land, Water & Environment, 1997) the research area is classified under the Moist Highland zone. The general characteristics of the moist highland zone are given in Table 1.1.

The classification of this area in the Moist Highland AEZ must be seriously questioned, however, as will be explained in Chapter 4. The area is far too dry to be classified as a moist zone. It should rather be classified under the Arid Highland zone. (See Chapter 4.)



Figurer 1.1 Location map of Adi-Segdo village

Table 1.1 - General characteristics of the moist highland zone (From: MLWE, 1997)

Location	Central and southern highlands; Rora and Hager plateaus
Area (ha)	897920
Landforms	Undulating to rolling plateaux, partly dissected, with hills, valleys, ridges and escarpments
Dominant slope gradient (%)	2-30 (ranges from 0 to 100)
Dominant altitude (m)	1600 – 2600 (maximum 3018m)
Precipitation (mean annual – mm)	500 – 700
Temperature (mean annual – °C)	15 – 21
Potential evapotranspiration (mm)	1600 – 1800
Length of growing period (days)*	60 – 110 (dependable); 90 – 120 (median)
Natural vegetation	Derived bush land and shrub land with remnant *Junipers procera* and *Olea africana.* Acacia bush land and shrub land in the lower part
Dominant soils	Cambisols, Luvisols, Lithosols, Regosols, Vertisols
Dominant crops	Barley, Wheat, Teff, Sorghum, Maize, Finger millet, Pulses
Livestock	Sheep, goats, cattle
Potential productivity	Moderate, Potential yields (barley) 5-20 Q/ha or 0.5-2.0 t/ha (dependable); 10-20 Q/ha or 1.0-2.0 t/ha (median)
Number of Agro-ecological units	10

*The length of the growing period is determined by water supply and temperature

The Moist Highland agro-ecological zone is further divided into a number of agro-ecological units (AEUs), based on more specific differences in regard to landform, soils, land cover and land use (Ministry of Land, Water & Environment, 1997). Based on these, the study area is categorized under agro-ecological unit MH1. The characteristics of this agro-ecological unit are given in Table 1.2.

Table 1.2 – Characteristics of agro-ecological unit MH 1 (From: MLWE, 1997)

AEU (Agro-ecological unit)	MH 1
Landforms	Gentle undulating plateau with few hills
Dominant slope (%)	2 – 8
Altitude range (m)	2200 – 2400
Temperature (mean annual in °C)	16 – 18
Precipitation (mean annual in mm)	500 – 600
Potential evapotranspiration (mean annual in mm)	1600
Soils	Eutric Cambisol (stony), Chromic Luvisol, Lithosols
Growing Period - Dependable (exceeded in 75% of the years) - Median (exceeded in 50% of the years)	 60 – 90 days 80 – 100 days
Natural Vegetation - Cover - typical tree species	 Scrub/ shrub/ scattered trees *Olea africana, Junipers procera, Euphoria candelabrum, Acacia etbaica*
Intensity of cultivation	High
Farming System	Crop based (mixed agriculture)
Recent Land Use - Crops - Livestock	 Barley, Wheat, Sorghum, Teff, Pulses Sheep, Cattle
Geomorphology/Soil Map Units	Rym, Ry4v, Rpm
Reference climatic station -potential evapotranspiration -precipitation	 Asmara Asmara

Table 1.2 Continued

Potential productivity (rainfed crops on good soils)	
-dependable (exceeded in 75 % of the years)	10 – 15 Q/ha (1 – 1.5 t/ha)
-median (exceeded in 50 % of the years)	15 – 20 Q/ha (1.5 – 2.0 t/ha)
Susceptibility to erosion	High

1.4 OBJECTIVES OF THE PRESENT STUDY

The general objective of the study is to apply practically the methods and techniques of Land Resource Surveying and Strategies and Structure for Land Suitability Evaluation for Eritrea developed by Berhane (2000) and Weldegiorgis (2000).

Specific objectives of the study are:

- To describe the characteristics of the soils in the area and classify the soils according to a standard system of classification in order to get to know the different types of soils and their characteristics in the study area.
- To identify socio-economic constraints in the farming systems in the area and recommend some amendments.
- To recommend some appropriate and sustainable techniques for increasing agricultural production in the area and resolving the shortage of food, caused mainly by reallocation of farmland by the government for urban and industrial expansion.
- To help in resolving conflicts caused by the competition for land between the community of the village for agricultural production and the municipality of the city for urban expansion.

1.5 APPROACH OF THE STUDY

The study had ***six*** parts, viz.:

a. A survey of international literature relevant to the research and recommendations required for the study area was conducted (Chapter 2).
b. A study of the dissertations of Berhane (2000) and Weldegiorgis (2000), which give recommendations regarding resource surveying and land use planning strategies for Eritrea, was conducted. (Integrated in Chapter 2.)
c. All the existing available publications and maps on natural resources, culture, land use and farming systems, covering the study area, were collected from the Ministry of Agriculture, Ministry of Land, Water and the Environment and Local Government offices and assessed thoroughly.
d. Detailed resource surveys were conducted in the area, consisting mainly of a detailed soil survey and a survey of the quality of the water used for irrigation. Methods are outlined in Chapter 3 and results presented in Chapter 4.
e. A study of socio-economic and farming system aspects in the area was done, using a combination of RRA (Rural Rapid Appraisal) and PRA (Participatory Rural Appraisal) approaches. Methods are outlined in Chapter 3 and results are presented in Chapter 5.
f. Compilation of recommendations for a proposed development plan for the study area to ensure optimal sustainable utilization of its resources for the best well-being of the local community (Chapter 6).

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The world's agricultural land is deteriorating fast as a result of mismanagement. Fertility of agricultural land is declining, erosion is widespread and production increases are not matching population gains in many areas. Every year more than a million hectares of agricultural land is developed for housing, highways and other non-agricultural uses (Sampson, Hair & American Forestry Association, 1990). Much of this land could be kept in agricultural production if development was more wisely managed (Sampson *et al.*, 1990).

The problems of economic development are complex and often very different in different parts of the world (Sampson *et al.*, 1990). It would, therefore, be unrealistic and misleading to apply a single uniform model to all countries or continents. In agriculture, unfavorable climate and soils; inadequate research, extension and education facilities; insufficient credit facilities; poor marketing and infrastructure; poor attitudes to farming; and lack of well trained experts in transferring development technology have all, to varying degrees, impeded development (La-Anyane, 1985).

For many developing countries, the wise use of the resources and balanced rural development of zones lie at the heart of their national development strategies and programs (UNESCO, UNEP & FAO, 1979). One aspect of these strategies and programs is to search for improved management techniques, as well as ways and means for more effective association between different types of stock raising and arable agriculture, particularly at the village level (Breimer, Van Kekem & Van Reuler, 1986). Several theories have been advanced to explain the process of agricultural development in tropical Africa and developing countries as a whole. Most of these theories have been based on experiences outside Africa and do not provide models required to explain the African situation (La-Anyane, 1985). "However, in most developing countries there is a clear need for much greater information on the quality and availability of the terrestrial biological

resources, and on the ecological and social constraints to successful change in land use and enhanced productivity, as well as on the ecological and social implications of different land use options and management practices in specific situations" (Breimer *et al.*, 1986).

Development economists have always assigned the agricultural sector a central role in development process, but the understanding of that role has evolved with time (Wilber & Jameson, 1992). Early development theories emphasized industrialization, though they counted on agriculture to provide the necessary output of food and raw materials, along with the labor force that would gradually be absorbed by industry. Later thinking moved agriculture to the forefront of the development process. The hopes of technical change in agriculture and the "green revolution" suggested that agriculture could be the dynamo-for-growth, and there were clear gains in this regard (Wilber & Jameson, 1992).

Significant agricultural development cannot occur without cultural and institutional change (La-Anyane, 1985). An immense shift is required from traditional ways of life, in which the same patterns of agricultural life are enforced, to social and cultural environments in which rural people will seek continuous changes in cultural and institutional patterns to better serve them. Without a drastic reorganization and better use of land, meaningful agricultural development will be seriously constrained and economic growth will not benefit the majority (La-Anyane, 1985).

Agricultural development is basically possible in two different ways, which are however, not mutually exclusive: bringing more land under cultivation, and increasing productivity per unit land. Bringing more land under cultivation is possible without changing traditional farming systems, whereas the second is entirely dependent on applying improved farming techniques (Arnon, 1981).

In a country like Eritrea, where dependence on agriculture is heavy, safeguarding the productivity of land is a major concern. Indeed, Eritrea's pressing environmental problems are directly related to land degradation, deforestation, soil loss and the expansion of desertification, especially in the critical areas were agricultural output is vital (Government of Eritrea, 1995). Eritrea is a country not endowed with rich natural resources and yet the limited resources have not been studied

properly, making sustainable agricultural production and economic development hardly obtainable. A detailed assessment of the natural resources, their evaluation for optimum utilization and improvement of the existing farming systems by introducing improved crop cultivars and farming techniques must be the primary focus of the government.

2.2 LAND RESOURCES

Natural resources include all those features and processes of land which can in some way be used to fulfill human needs (Vink, 1975). The principal resources of agriculture are land, labor and capital (Haines, 1982).

According to the FAO (1976) land is defined as "an area of the earth's surface, the characteristics of which embrace all reasonably stable or predictable cyclic, attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and the underlying geology, the hydrology, the plant and the animal populations, and the result of past and present human activity in the event that these attributes exert a significant influence on present and future uses of the land by man". As can be seen from the definition of "land" these resources are numerous and complex. The most important land resources for agriculture are climate, relief and geological formations, soils (including hydrology), water (including geohydrology), artificial elements of a stable nature and vegetation and related biological features.

According to Davidson (1992) from the agricultural point of view these land resources may be grouped into three:

a. Very stable resources: These are climate, major relief features and geological formations. Climate is a very stable resource, in the sense that it is almost completely free from man's influence. Human influence on major relief and geological formations as such is limited to local mining exploitation. Modification of these formations for agricultural land is out of the question, apart from the construction of tunnels for easier communication by road and railroad or for transport of irrigation water.

b. Moderately stable resources: Soils are less stable than climate, relief and geological formation and more easily modified by man. Human activity as one of the soil-forming factors includes modification such as the kind and depth of soil formation. Human activity may lead either to building up of particular soils (plaggen boden), modification of certain soils (paddy soils) or to the partial or complete destruction of soils by erosion or degradation.

c. Relatively unstable resources: These are vegetation and related biological features. Instability and vulnerability are typical characteristics of the biological features of land. These are the natural biological communities of land, i.e. plants and animals. They have different degrees of importance in different areas.

The stability of a particular resource is seen in relation to its period of formation as well as the ease with which human activities can influence it, causing either degradation or improvement.

2.3 RECOMMENDED LAND RESOURCE SURVEYS FOR ERITREA

Land resource survey is basically for the collection of land resource data. Any assessment or evaluation of land resources is impossible without the collection of basic land resource data (Davidson, 1992).

Land resource survey is the description, classification and mapping of the physical environment: climate, water, geology, soils, vegetation and fauna (Young, 1998). Land resource information is necessary in areas where farming experience is not available, when new areas of land are brought into cultivation and when new kinds of use are introduced to existing farms. Survey of natural resources is for delineating map units in the terrain based on differentiating characteristics and diagnostic criteria. These characteristics and criteria are preconceived, following a defined classification system. The classification system is adapted to the aim of the survey, e.g. some type of land classification, technical classification for implementation of planning, etc.

It is clear that detailed topographical, geological, hydrological, soil and ecological surveys are essential prerequisites for meaningful development planning. Their importance for the proper

utilization of land and water resources for agricultural development cannot be overstressed (Arnon, 1981). In the field survey for agricultural development particular reference is made to conventions, procedures and practices applicable to soil surveys. Soil conditions play an important part in the general land conditions (soil is an important attribute of land) and a soil survey is therefore always included in survey of land conditions (Euroconsult, 1989).

Different methods and techniques of land resource surveying have been developed and used for a long time. The effectiveness of each method and technique, however, differs from place to place due to environmental and socio-economic differences. Developing countries have limited capacity for developing their own survey methods and techniques. In most developing countries the problem is in transferring of the technology directly from developed countries. Hence, they have to be very careful in selecting the most appropriate and effective method for the country (Berhane, 2000).

According to Smyth (1981) developing countries should undertake soil surveys in a systematic sequence of surveys of increasing intensity. The logic of this approach is a means of ensuring that the limited specialized manpower, funds and facilities should be concentrated in the most promising areas. After compilation of broad-scale soil surveys, detailed soil surveying in the high potential areas should be given priority.

Systematic resource surveying has not been carried out in Eritrea. Without such survey no meaningful regional planning or sustainable development planning can be done. Hence, the first objective of natural or soil surveying should be for preliminary identification of areas having either high development potential or serious development problems. Since soil surveying in the country is new and not well developed the survey strategy to achieve the objectives must be based on the availability of funds, manpower and equipment required for the survey (Berhane, 2000).

Eritrea has not developed a national soil classification system for many reasons. The importance of conducting soil surveys to achieve sustainable land use planning and development, should not wait until a special unique soil classification system has been developed for the country (Berhane,

2000). According to Berhane (2000) Eritrea should adopt one of the "standard" international soil classification systems, which will best suite the needs of the country. The two main internationally used soil classification systems are the USA's Soil Taxonomy (Soil Survey Staff, 1975, 1999; Young, 1998) and FAO-UNESCO system, which lately has been intensively revised by the World Reference Base for Soil Resources (WRB) Working Group of the International Union of Soil Sciences (IUSS) (WRB Working Group, 1998). The WRB (revised FAO) system is by Berhane (2000) considered the best to be adopted in Eritrea for the following reasons:

- It is less complicated than USDA's Soil Taxonomy (Young, 1998).
- At the IUSS congress in Montpellier, France, in 1998 a resolution was adopted that all countries be requested to adopt the WRB system as reference soil classification system to promote effective communication on soils between countries.
- Most countries of East Africa, e.g. Ethiopia, use the FAO system as basis for soil classification. Hence adopting this system will benefit Eritrea in aspects such as land suitability evaluation and technology transfer.
- The USDA's Soil Taxonomy has major weaknesses in regard to the classification of some important soils of southern and east Africa, e.g. Nitisols.

The intensity and scale of a soil survey are determined by the objectives and purpose of the survey (Dent & Young, 1981). For a small country like Eritrea two levels of scale should be given priority (Berhane, 2000), viz. a broad level survey at a scale of 1:250 000 for resource inventories, identification of high potential areas and determining the country's agricultural potential, and detailed surveys at a scale of 1:5 000 or 1:6 000 in selected high potential areas.

Berhane (2000), in his study for the development of methods and techniques for land resource surveys for Eritrea, concluded that in view of land as a major natural resource and agriculture as a backbone of the economy the assessment of natural resources is vital for any land development program. The failure of development activities in developing countries is often due to lack of proper natural resource surveys or land suitability assessment. Even if the country gives priority to food security, it is not possible to achieve this goal without proper resource assessment.

2.4 LAND EVALUATION

Land evaluation is the assessment of man's possible use of land for agriculture, forestry, engineering, recreation, etc. (Stewart, 1968). Almost invariably a particular possible use of land by man is not dependent on a single parameter or natural resource attribute, but on the interaction of a number of parameters of various attributes. Man's use of land is also very strongly dependent on human resources, technology, finance, and labor. These are not fixed in space, and are time variable in a manner that is not predictable with great accuracy. Thus land evaluation is not something that can be done once for all time, but must be repeated when significant changes take place in any of the human resources (Stewart, 1968).

According to Dent & Young (1981) land evaluation is the process of estimating the potential of land for alternative kinds of use. These include productive use, such as arable farming, livestock production and forestry together with uses that provide services or other benefits, such as water catchment areas, recreation, tourism and wildlife conservation. The basic feature of land evaluation is the comparison of the requirements of land use with the resources offered by land. Fundamental to the evaluation process is the fact that different kinds of use have different requirements.

The objective of land evaluation is to provide an assessment of land that is incorporated into planning, management, or conservation decisions. Land evaluation is an applied science and integrates the management and assessment of environmental information with economic and social analysis (Davidson, 1992). Evaluation takes into consideration the economics of the proposed enterprises, social consequences for the people of the area and the country concerned and the consequences, beneficial or adverse, for the environment (FAO, 1976). The fundamental purpose of land evaluation is to predict the consequences of change (Dent & Young, 1981). The comparison of land use with land is the focal point in an evaluation procedure leading to suitability classification.

An enormous variety of land classification or land evaluation systems have been developed, most of them at local or national scope (Breimer *et al.*, 1986). These include:

a. ***Land Capability Evaluation***: Land capability analysis is probably the best known in land evaluation. This is because it has been widely adopted for over 25 years, the resultant maps are easy to understand, and land use planning policies in several countries now depend upon an assessment of land capability. The origin of land capability evaluation can be traced to the reason for the formation of the United States Soil Conservation Service. The impetus was massive soil erosion, especially in the America Midwest, and the acute need was to identify types of land use that would not lead to environmental degradation (Davidson, 1992). Land capability assessment is based on a broader range of characteristics than soil properties. Information on slope angle, climate, flood and erosion risk as well as of soil properties is required (Davidson, 1992). Davidson (1980, 1992) indicated that the main aim of the method is to assess the degree of limitation for land use or potential imposed by land characteristics on the basis of permanent properties. The outstanding advantage of the land capability classification is its flexibility, its apparent simplicity and it's ease of comprehension by non-specialists. Its main disadvantage is that the uses for which land is classified are defined in very general terms and that a high level of technology is implicitly assumed. These circumstances make the system less suitable for application in developing countries, where great differences in land use technology levels are usually found (Breimer *et al.*, 1986).

b. ***Canadian Method***: It was initiated in Canada by Canadian Land Inventory (CLI), which was established in 1963 as a result of the Agricultural Rehabilitation and Development Act (ARDA) of 1961 (Mather, 1986; Davidson, 1992). The general approach of the Canadian Land Capability Scheme is modeled on the USDA method, although some major differences must be stressed (Davidson, 1992). In addition to the method of land capability classification for agriculture, there are separate land capability schemes for forestry, recreation and wildlife.

c. ***Land Capability Classification in Britain***: The first national assessment of land grades in Britain resulted from the land utilization survey of the 1940s (Stamp, 1962). Accordingly land was ranked on the basis of land use characteristics. By the1960s there was great realization that a more detailed and up to date assessment of land was needed. As Mather

(1986) described, the Ministry of Agriculture decided that a national series of agricultural land classification maps for England and Wales was required in order that good quality agricultural land could be protected against urban encroachment. The British capability classification system adapted the USDA land capability classification by giving higher consideration to climate (Davidson, 1992).

d. ***Dutch System***: In the Netherlands land evaluation has a long tradition and the early work goes back to 1950s, where soil survey was interpreted for crop production and land reclamation and improvement. In the Dutch system the term suitability was used rather than capability. Much emphasis was given to the soil survey in relation to town and country planning with the main contribution in the Netherlands being preservation of soil particularly for horticulture (Davidson, 1980, 1992).

e. ***FAO Land Evaluation***: The initiative for developing some measures for developing a common terminology and procedures for land evaluation was taken by FAO through a series of international discussions from the 1970s onwards. McRea & Burnham (1981) observed some of the major events that contributed to the birth of the FAO framework for land evaluation. These include a background document (FAO, 1972), a draft report (FAO, 1973) and proceedings of two meetings of international expert consultants. In addition to these, reports on various pilot studies in developing countries like Malawi, Srilanka, Mauritius, Sudan, Cameroon, Brazil and Kenya illustrated the development of the framework towards its final format. The framework was designed mainly for use in developing countries, but it can also be used in developed countries.

The FAO framework for land evaluation (FAO, 1976) is not a complete document to be able to conduct a full evaluation procedure by its own. To help evaluators the FAO developed three different Guidelines, which can be used during the process of evaluation. These are Land Evaluation for Rain-fed Agriculture (FAO, 1983), Land Evaluation for Irrigated Agriculture (FAO, 1985) and Land Evaluation for Extensive Grazing (FAO, 1991). All these Guidelines put more emphasis on the need to evaluate (a) crop requirements, (b) management requirements and

(c) environmental and conservation requirements. At the same time they put more emphasis on the use of local criteria, where available, rather than outside criteria.

The first step in the land evaluation system proposed by the FAO, is the selection and definition of possible relevant land use alternatives for which the land should be classified. Land in this context includes the vegetation on the soil, the air above the soil (climate), relief, hydrology and fauna, either natural or domestic. All the characteristics should be taken into account in the land evaluation exercise, insofar as they are relevant to the land use under consideration (Breimer *et al.*, 1986).

2.5 RECOMMENDED LAND EVALUATION STRATEGIES FOR ERITREA

As mentioned earlier, there are different types of land capability and suitability evaluation systems in the world. Though they are different in their approaches and procedures, all have the objective to evaluate and classify land to determine the most capable and suitable use it can offer on a more or less sustainable basis. Eritrea as a new nation has the chance to learn from past experience of other countries in planning and allocating resources to optimal and sustainable uses. With the limited and less experienced manpower and logistics it has started to classify land in limited areas using the USDA system of land capability classification. The limited natural resources in the country, especially moisture, and extensive land degradation call for effective, efficient and careful planning.

Weldegiorgis (2000) recommended two alternative land suitability evaluation strategies for Eritrea. These strategies can be applied in different circumstances. The choice of the strategy depends on the overall objectives and available resources for a specific case. These strategies are as follows:

a. Allocation of alternative crops for specific areas.
b. Allocation of alternative areas for specific crops.

The first strategy is applicable where the potential of a specific area is known and different land uses compete on the basis of their economic importance or their overall importance to the fulfillment of the general objectives of the country, etc. For instance, in the southwestern lowlands of Eritrea where the potential fertility of the soils is relatively high, the land uses (crops) that should be allocated must be those which are important for the attainment of the food security objectives of the country. The second strategy is employed to prevent crop failure by applying the principle of selecting the right crop for the right area of land. As the priority and specific objective of the country is to be self sufficient in food production, therefore the second strategy, allocating of alternative areas for specific crops, is more applicable. There is no choice but to find or allocate areas of land for the production of the common staple crops (Weldegiorgis, 2000).

Weldegiorgis (2000) recommends that when economic and other factors allow, the procedure of land evaluation for specific purposes recommended by FAO (1976) and Dent & Young (1981) could be adopted after few modifications to the situation of Eritrea. These procedures are:

a) Initial consultation (on objectives, data and assumptions and planning of the evaluation).
b) Description of the relevant kinds of land uses (major kinds or LUTs).
c) Ascertain the requirement of each land use type.
d) Description of land mapping units through soil / land resource surveys.
e) Rating the land qualities relevant for the land use type concerned.
f) Comparison (matching) of land use requirement with land quality.
g) Land suitability classification (quantitative or qualitative).
h) Presentation of land evaluation results.

According to Weldegiorgis (2000) the most important land qualities that should be assessed in relation to rainfed agriculture in Eritrea are water availability, nutrient availability, rooting condition and erosion hazard. The erratic nature of the rainfall of the country calls for different strategies to avoid crop failures. One way of avoiding crop failure due to drought stress is to select short season varieties or to adjust the appropriate planting date. Fertilizer distribution is limited in the country and the buying power of the farmers is low. The main focus should therefore, be on the natural fertility of the soils and ways to improve it through addition of

manure and fallowing. Lack of a well-established soil laboratory in the country is a major problem, hence certain indicators that show favorable or unfavorable characteristics for high soil fertility developed by Young (1976) can be used.

According to Weldegiorgis (2000) the following points should be considered in land allocation for particulat use in Eritrea:

A. The use in question must be very important to the general objective of the country.
B. The use must ensure income to the land user or community.
C. The use should comply with the real situation of the local community.
D. The use must be sustainable, i.e. it must not result in degradation and erosion of the natural resources of the country.

2.6 FARMING SYSTEMS

A farming system is a collection of distinct functional units, such as crops, livestock, processing, investment and marketing activities, which interact because of the joint use of inputs they receive from the environment, which deliver their outputs to the environment and which have the common objective of satisfying the farmer's (decision maker's) aims (Ruthenburg, MacArthur, Zandstra & Collinson, 1980). The definition of the borders of the system depends on the circumstances. Often it includes not only the farm (economic enterprises) but also the household (farm household system) (Ruthenburg *et al.*, 1980).

The farm as a system consists of a set of related subsystems, which form a hierarchy of systems: microorganisms in the soil are a subsystem of the soil system. The soil system again is a subsystem of the crop-producing system (activity) and the crop system is a system of the farm system (Ruthenburg *et al.*, 1980). According to Reijntjes, Haverkort & Waters-Bayer (1992) farming systems are open systems: they receive inputs (nutrients, water, information, etc.) from outside the farm, and some of the outputs leave the farm, e.g. are sold.

A farming system is a function of environmental and socio-economic factors. According to Webster & Wilson (1980) the wide ecological variation in different parts of the tropics is paralleled by a great diversity of farming systems. Farming systems are determined partly by the environmental factors of climate, soil, natural vegetation and topography and partly by socio-economic factors such as the custom of the people and the level of technology they have attained, population density, the availability of financial resources for acquiring the required capital and recurrent inputs, and the family or market demand for food and cash crops (Webster & Wilson, 1980).

During the 1970s the concept of farming system was applied to several activities, which focuses on the small-scale family farmers who almost always reap a disproportionately small share of the benefit from the organized research and extension (Bembridge, 1991).

2.7 FARMING SYSTEMS IN THE TROPICS

The tropics are characterized by enormous variability. Climate, soil and altitude differ widely, and markedly differing conditions can occur even over short distances (Webster & Wilson, 1980). It is therefore even more difficult to generalize about farming in the tropics. However some generalizations can be made which help understanding of the possibilities for agriculture and of difficulties facing farmers – small-farmers especially – which influence and are reflected in the complex and specialized farming systems that have been developed. Despite the differences of the natural environment and the limitations that arise from unfavorable price relations, unstable markets and the traditional socio-economic conditions of agricultural production in the low income countries, tropical farming, which consist mainly of small-holder farming systems, is a dynamic business, in which small but numerous adjustments are continually being made to the production processes (Ruthenburg *et al.*, 1980).

According to Ruthenburg *et al.* (1980) there are seven basically different main types of farming systems in the tropics:

1. ***Shifting Cultivation***: Shifting cultivation is an agricultural system that involves alternation between cropping for few years on selected and cleared plots and a lengthy period when the soil is rested. According to FAO (1983) shifting cultivation is defined as "a farming system in which relatively short periods of cultivation are followed by relatively long periods of fallow". Shifting cultivation is practiced not only by migrating cultivators but also by sedentary cultivators. In each case, however, cropping and fallowing alternate and this alternation can be irregular or regular. The 'shifting' cultivator has an understanding of his environment suited to his needs. He can rate the fertility of a piece of land and its suitability for one or other of his crops by the vegetation which covers it and by the physical characteristics of the soil; and he can assess the 'staying power' of a soil, the number of seasons for which it can be cropped with satisfactory results, and the number of seasons for which it must be rested before such results can be obtained again. His indicator of initial fertility is the climax vegetation and his index of returning fertility is the succession of the vegetation phase that follows cultivation. In many cases his knowledge is precise and remarkably complete. He has a vocabulary of hundreds of names of trees, grasses and other plants and identifies particular vegetation association by specific terms. This fund of ecological knowledge is the basis of 'shifting' cultivation.

2. ***Fallow Systems***: Expanding cash crop production and the growing subsistence needs of an increasing population lead to gradual extension of arable farming at the expense of fallow, and short-fallow systems replace long-fallow systems. The length of fallow is mostly insufficient for fallow vegetation of forest to regenerate. Fallow systems are usually characterized by clearly defined holdings with largely permanent field divisions. Families generally have registered ownership of land, in contrast with most shifting systems, in which the holding boundaries are usually not clearly defined, housing is more or less of migratory nature and land rights are less precisely defined. Fallow systems can be found under a wide range of natural and social conditions; but the underlying reasons are generally the same: the extension of cash crop production and the increasing demand of the growing population for food compel farmers to move away from shifting to fallow systems.

3. ***Ley and Dairy Systems***: The word 'ley' is used whenever several years of arable cropping are followed by several years of grass and legumes utilized for livestock production. Ley systems show a more or less regular alternation between arable farming and ley periods. Ley systems are widespread in the subtropics in the northern and southern hemisphere but are rare in the tropics. The fact that ley systems have been able to hold their own in the tropics only in rare areas indicates that the expansion path of tropical rainfed farming usually leads directly from fallow systems to permanent farming systems.

4. ***Permanent upland cultivation systems***: A continual expansion of arable farming at the expense of fallow or ley leads to systems with permanent cultivation. This class includes those farming systems in which fallow or leys are used only rarely and for short terms. In contrast with fallow or ley systems, farming systems of this kind are normally characterized by:

    - A permanent division within the holding between arable land and grassland, which is seldom or never cultivated.
    - Clearly demarcated fields.
    - A predominance of annual and biennial crops.

    The evolution path of arable land use in densely populated tropical highlands is similar to that of temperate climates: shifting cultivation - unregulated ley systems - permanent arable cropping.

5. ***Irrigated arable systems***: 'Irrigation' describes those practices that are adopted to supply water to an area where crops are growing so as to reduce the length and frequency of periods in which a lack of soil moisture is the limiting factor to plant growth. Most irrigation systems are the result of land development, which occurs gradually over time. The transition is from permanent upland rainfed farming to irrigated farming. Irrigation is man's major response to the challenge offered by increasing population densities in the degraded system with permanent farming. Irrigation systems, because they involve increasing control of water and reliability of water supplies, are characterized by a 'control of nature'. Both water supply and soil conditions become increasingly subject to human control. Therefore irrigation farming

systems are classified according to the water supply system, cropping system and exploitation system. The main problems of irrigation systems are not inherent in the system as such, as in the case in shifting cultivation systems and generally to a lesser extent in upland farming. The major weakness lies in the inadequacy of water control, husbandry practices and irrigation institutions.

6. ***Perennial cropping systems***: A form of land use in the humid and sub-humid tropics is the cultivation of perennial crops, primarily trees and shrub crops with growth cycles of several decades. Plantations of perennial crops may come into existence in various ways. Where land is ample, estates tend to shift their plantations either within the estate's boundary or by acquiring virgin land. But as land becomes scarce, plantations tend to become stationary within the estate boundary. Although perennial crops are a heterogeneous group, grown under various circumstances by various types of farmers, some common characteristics exist, which are mainly relevant to shrub and tree crops and which to a lesser degree apply to several perennial field crops. As a first step, the farm management characteristics of perennial cropping can be compared with those of arable farming, and then some general principles, applied by farmers to fit perennial crops in to their farming systems, can be outlined.

7. ***Grazing systems***: Most of the livestock in the tropics are kept by arable cultivators, and in some of their systems livestock densities are very high, much higher than in extensive grazing systems under similar conditions. Most additional animal production in the tropics will in the future have to come from fertilizer-based land-use intensification in sedentary smallholdings.

2.8 FARMING SYSTEMS RESEARCH

In the mid-1960s there was little interaction between technical scientists (who were mostly on experiment stations) and social scientists (who tended to be concentrated in planning units) (McCracken, Pretty & Conway, 1988). The Green Revolution was beginning to have a great deal of success in Asia and Latin America, being based on good climate, soil, homogeneous and favourable production environments and adoption of improved seed cultivars responsive to fertilizers. However, in most sub-Saharan African countries and certain parts of Latin America

and Asia, there was no Green Revolution. This is because of unfavorable climate, poor soil, and production environments that are very heterogeneous and poor (Norman, Siebert, Modiakgotla & Worman, 1994). Not surprisingly there have been great difficulties in developing improved technologies that are attractive to farmers in such areas. Thus, it appears that in the Green Revolution areas, because of the spectacular nature of the technology, experiment station based technical scientists were very successful in their work. However, similar approaches in the areas with poorer agricultural resources failed (Norman *et al.*, 1994). Attention then turned to the problem of farmers in poorer and more heterogeneous environments. Because of the great diversity and complexity encountered it soon became apparent that there was a growing need to understand the whole system in which farmers operate and to develop technologies that would fit these different systems. Out of this perception was developed the approach known as Farming Systems Research (McCracken *et al.*, 1988). The FSR concept started with the realization that certain technologies were not accepted by farmers because it did not fit in with cultural norms (Bembridge, 1991). Since the experiment station had been there for almost 50 years, the question that immediately came to mind was why none of the results or lessons from the research stations had "rubbed off" on neighboring farms (Collinson, 2000).

Farming systems research is defined as a diagnostic process; a basket of methods for researchers to elicit a better understanding of farm household (family) decisions and decision-making processes. Its applications use these understandings to increase the efficiency in the use of human and budgetary resources for agricultural development, including research, extension and policy formulation (Collinson, 2000). Its general aim was to describe and analyze farming systems, identify problems and plan research and extension activities (McCracken *et al.*, 1988). The term FSR is used to describe a range of activities with varied objectives and approaches, although they have usually been associated with agricultural research. FSR refers to the application of a systems perspective in identifying techniques appropriate for location-specific farm situations or systems (Cernea, Coulter & Russell, 1985). According to Euroconsult (1989) farming systems research and development refer to recent efforts to bundle a wide spectrum of land-related sciences and professionals towards devising rational, long-term production systems in which farming families with specified, similar socio-economic opportunities and bottlenecks produce food, fuel, shelter, cash etc. for their own stated needs and for well surveyed markets.

Farming systems research is a process that identifies problems limiting agricultural productivity and then searches for solutions to these problems. This process reorganizes the resources and constraints of the farming families (who are both producers and consumers) and seeks solutions that are relevant, useful and acceptable to these families. Multidisciplinary teams of scientists that interact continually with the farmers for whom the research is intended, undertake the research. This approach should insure that the research produces appropriate technologies and, therefore, will be more easily and quickly adaptable (Cernea *et al.*, 1985).

Both experiment station research and farming systems research are needed in rural development planning. This is because they focus on different things that are complementary to each other. According to Norman *et al.* (1994) the major differences between experiment station and farming systems research are the following:

- On the experiment station, ***applied*** research is usually undertaken, in which new technologies are created.
- FSR, on the other hand, concentrates mainly on ***adaptive*** research, which involves helping to adjust technologies to specific environmental conditions. FSR also helps feedback of information about future priorities for applied research to experiment stations.

Table 2.1 gives comparisons between station-based research and farming systems research.

Table 2.1 – Comparisons between experiment station based research and farming systems research (From: Norman *et al.*, 1994)

Characteristics	Station – based Research	Farming System Research (FSR)
Location of trial	Usually experiment station	Usually on-farm
Disciplines involved	Often single Mostly technical	Usually several Technical and social
Priority setting for trial: Researcher Farmer	 More involved Less involved	 Less involved More involved
Experiment design: Complexity Management Implementation	 Usually more Researcher Researcher	 Usually less Researcher or Farmer Researcher or Farmer
Degree of experimental control	More	Usually less
Evaluation of trial results—factors taken into account: System perspective Technical feasibility Economic reliability Social acceptance Farmer opinion	 Less likely Yes Less likely Less likely Not likely	 More likely Yes More likely More likely More likely
Expense of experimental program: Fixed (overhead) cost Variable (recurrent) cost	 Likely to be higher Likely to be lower	 Likely to be lower Likely to be higher

Farming systems research rapidly became popular and was strongly supported by many donor agencies. By the mid-1980s about 250 medium and long-term projects worldwide were carrying out farming system research type work. Thus the farming systems approach evolved primarily as a result of lack of success in developing relevant improved technologies. The strong technical focus in station-based research resulted in the evolution of farming system research. Today many

are advocating that the approach of farming systems research can be constructively used in addressing not only technological solutions but also those relating to policy / support systems (Norman *et al.*, 1994).

2.8.1 Farming Systems Research and Agricultural Extension

Agricultural extension is a system of non-formal education for adults in rural areas which is based on relevant content derived from agricultural, social and communication research synthesized into a body of concepts, principles and operational procedures (Bembridge, 1991). Extension is a process of working with rural people in order to improve their standard of living (Bembridge, 1991).

The primary objective of both the research and extension should be to increase the farm productivity and to enhance farm incomes, at least cost to the farmer. To achieve this objective in ways consistent with national priorities, the extension system must feed research workers information about the constraints farmers have experienced in adopting research recommendations. The role of extension is one of adopting research recommendations to suit varying needs of farmers and providing delivery service to speed up farmers' access to and adoption of new technology (Cernea *et al.*, 1985).

According to Bembridge (1991) extension education has four major functions in agricultural development:

1. The first serves to assist farmers in adopting an attitude conducive to acceptance of technological changes. As generally known, most farmers in less developed countries are still largely tradition-bound and afraid to take risks that will involve them in great financial loss unless they are convinced beyond all doubt that the improved technology which the extension agents are asking them to adopt is economically viable, technically feasible and compatible with their farming system.
2. The second function is the dissemination to the farmer of results of research and the transfer of farmers' problems back to the research organization through subject-matter specialists. In

order to perform this function properly, effective lines of communication must exist among the research organization, the extension service and the farmer.

3. The third function is to help farmers gain managerial skills to operate in a commercial economy through the provision of training and guidance in problem solving and decision-making.
4. The fourth and often neglected function of agricultural extension is to promote the conservation and best use of natural resources, especially soil, vegetation and water, and to inculcate a conservation consciousness among both urban and rural communities.

Researchers must know what is occurring at the farm level in order to formulate valid and useful questions for their research. They must be aware of the biotic and physical environment, and the economic, sociological and cultural context in which rural people produce and market. For this there should be strong linkage between the extensionists and the researchers, as the extension service is in close contact with the farmers throughout the country (Cernea *et al.*, 1985).

According to Norman *et al.* (1994) the value of the interaction between FSR workers and extension staff can be summarized as follows:

- Extension staffs possess substantial knowledge about the area where they are posted and know many of the farmers personally. This local knowledge is invaluable to FSR teams in their diagnostic, design and testing work.
- FSR workers interact with small numbers of farmers – hopefully representative of much larger numbers of farmers – whereas extension staff have a mandate to work with all farmers. In a sense, the extension service provides a conduit for FSR teams to reach farmers as a whole. Therefore, interaction between FSR teams and extension staff can help provide a multiplier effect for FSR work, can assist in providing extension staff with relevant messages to disseminate, and can help extension staff in developing appropriate methods and systems for dissemination of technologies to farmers.

Research is needed to respond to the practical problems that farmers are facing in their agricultural production systems. Unless research is responsive to farmers' problems, it soon loses its credibility among both farmers and extension workers. If it is to become more responsive,

researchers have to recognize that the social and economic aspects of the problem are as essential as the biological aspects (Norman *et al.*, 1994). It is generally recognized that to increase farmer productivity and incomes require access to new technology, much of which will be developed by researchers. The role of extension is one of adopting research recommendations to suit the varying needs of farmers and providing a delivery service to speed up farmers' access to and adoption of new technology (Cernea *et al.*, 1985).

To achieve this objective in ways consistent with national priorities, the extension system must feed research workers information about the constraints farmers have experienced in adopting recommendations, and research systems must have the capacity and readiness to respond with problem-specific recommendations. Research should also seek to obtain direct feedback from the field itself, through field visits undertaken by research scientists, preferably accompanied by the extension workers. Hence, a close linkage between the farmer, extension and research is required to solve farmer problems and increase farm productivity and incomes (Cernea *et al.*, 1985).

2.8.2 Identification of farmers' production problems

The production problems that farmers face are always interrelated. Attempts to solve a specific technical problem may create new problems if the whole complex of farmers' constraints is not understood. Farmers' production problems must be viewed in the context of the whole farming system and the needs and priorities of the farm family. Problems must be identified jointly by farmers, extension staff and researchers whose mandate to generate technology does not end at the research station but requires follow through with the farmers. Problems requiring further research should be ranked according to their potential to increase incomes for the largest number of farmers and the ability of researchers to deal with them (Cernea *et al.*, 1985).

A central problem in identifying farmers' problems is that farmers are stratified and farms with different levels of resources respond differently even in the same agro-ecological zone (Cernea *et al.*, 1985). Collinson (1980), cited in Cernea *et al.* (1985), argues that grouping the farmers on the basis of their farming system will help define target populations for which the same research effort and the same extension development program will be appropriate. He also pointed out that

agricultural research needs to understand the structure of the farm household, its organization, labor resources, division of tasks and resource allocation regarding the production of different crops on various land parcels. To be more effective, extension staff in turn need to have a perception of the sociology of the farm family and its rationale and strategy for implementing the existing farming system.

2.8.3 Farming systems research approach

A preliminary step in the farming systems research approach is to understand an existing small-farm system and acknowledge geographical and hierarchical specificity and to identify a group of farmers operating the same system (Cernea *et al., 1985).* The approach is most easily applied in a single farming system and is applied in four stages according to FSR:

1. Understanding the main management challenges for local farmers by investigating the circumstances of their production environment. Farmers use their knowledge and environment and management skills to exploit their natural, economic and social circumstances to satisfy their family needs. Farming systems researchers investigate farmers' circumstances from the perspective of natural, economic and social circumstances.
2. Describing farmers' activities and methods. This shows ***what*** farmers are doing, and ***how*** they do it, to meet their priorities within this environment. Describing the crop, livestock and off-farm activities pursued by farmers in the system. Drawing up a monthly calendar of the operations involved in managing each production activity, including the methods and purchased inputs related to each operation.
3. Understanding a local farming system, i.e. understanding **w*hy*** the farmers do these things in the way they are doing them to meet their priorities.
4. Problem identification. This stage identifies two sets of problems, viz. management compromises and resource constraints.

According to Norman *et al.* (1994) there are four fundamental stages in the farming systems research approach:

1. Descriptive or diagnostic stage, in which the actual farming system is examined in the context of the total environment—to identify constraints farmers face and to determine the potential flexibility in the farming system in terms of timing, unused resources, etc. An effort also is made to understand the goals and motivation of farmers that may affect their efforts to improve the farming system.
2. The design stage, in which a range of strategies are identified that are thought to be relevant in dealing with the constraints determined in the descriptive or diagnostic stage. Information for designing such strategies comes from experiment station work, researcher managed and researcher-implemented type of research in farmers' fields, and from other farmers.
3. The testing stage, in which a few promising strategies, arising from the design stage are examined and evaluated under farm conditions to determine their suitability for producing desirable and acceptable changes in the existing farming system.
4. The dissemination stage, in which the strategies that were identified and screened during the design and testing stages are extended to farmers. Adoption studies can be very important at this stage, not only in giving some idea of impact of agricultural research, but also in giving some idea of future priorities for agricultural research and indicating what adjustments are required in the policy / support system to ensure better rates of adoption.

2.8.4 Methods for implementing FSR

According to Cernea *et al.* (1985), there are two interacting areas of controversy over alternative research methodologies. First, the objective functions of small farmers are strongly influenced by subsistence and risk consideration and are very complex. The production environments of small farmers are fraught with uncertainties and farmers' reactions to these environments are often conditioned by social and cultural circumstances. Under these conditions the economic principles on which most analytical tools in farm management depend have limited relevance. Second, data collection among a wholly literate population accustomed to recording information about their farm activities is relatively easy. This task becomes both complex and expensive among illiterate populations. Enumeration of verbal response or direct measurement by the research team is the only means of recording. The World Bank's experience in detailed data collection for monitoring and evaluation of projects such as the Lilongwe Development program in Malawi, the Regional

Integrated Development Project in Tanzania and Northern Nigerian Agricultural Projects- demonstrates the bottlenecks in processing and analyzing detailed data, which compound the time and expense of collecting them. Furthermore, a sound understanding of the system is needed before the parameters requiring detailed measurements can be specified (Cernea *et al.*, 1985).

2.8.5 Survey methods in farming systems research

Surveys are obviously a very useful and efficient means of collecting data. There are two major types of surveys, namely informal (unstructured) and formal (structured) surveys.

Table 2.2 presents, in general terms, some of the distinguishing characteristics of the two types of surveys.

According to the table (Table 2.2) all informal surveys have five important features or distinguishing characteristics:

- There is a direct researcher-farmer interaction because the interviews are conducted by the researchers themselves, with researchers directly learning from the farmers. Existing information and direct observation are also important sources of information in an informal survey.
- Interviews are basically unstructured and semi-directed. As a result learning is rapid and progressive with a flexible use of methods to explore relevant issues as they arise with improvisation, iteration and probing. ***Questionnaires are not used***, although often researchers use topic guidelines to make sure all relevant topics, on a given subject, are covered.
- The data collection system is dynamic and iterative because researchers evaluate the data collected, and reformulate data needs on a regular basis.
- Interdisciplinary teams often conduct the interviews, with each discipline contributing to the identification of problems and identifying and evaluating potential and actual solutions.
- Informal surveys ***do not permit statistical analysis*** because they are undertaken without formal sampling procedures, do not involve obtaining responses to standard sets of questions, etc.

Table 2.2 Comparisons between general characteristics of formal and informal surveys (From: Norman *et al.*, 1994)

Characteristics	**Informal**	**Formal**
Background information required	Minimal	Substantial
Time allocation by researchers		
Preparation	Less	More
Implementation	More	Less
Analysis / writing up	Less	More
Total time	Less	More
Hypothesis: Required beforehand	Not essential	Essential
Created during	Yes	No
Likely discipline interaction	More likely	Less likely
Implementation:		
Questionnaire used?	No	Yes
Interviews	Researcher(s)	Mainly enumerators
Potential for creativity/iteration	Maximum	Minimal
Potential for learning/verification	Mainly learning	Mainly verification
Potential for representative sample	Less likely	More likely
Potential quality of information		
Attitudinal	Better	Poorer
Qualitative	Better	Poorer
Quantitative	Poorer	Better
Probability of high: Sampling errors	Higher	Lower
Measurement errors	No difference	No difference
Value of statistical techniques in analysis	Little	Great

According Norman *et al.* (1994) in FSR informal surveys have developed as a result of:

- Increasing realization by scientists that a relationship with the farmer based on treating her/him as a person whom one could interact with constructively was much more fruitful than one based on treating her/him as an object from whom one collected data and analyzed independently.
- The increasing need by scientists to become acquainted with, and learn from, farmers.
- The need to find a method for rapidly obtaining technical and socio-economic information to help researchers in developing relevant improved technologies.
- The need to identify a cost effective survey procedure.

In recent years there has been a methodological explosion in terms of how to undertake informal surveys. Informal surveys are considered as semi-structured interviews. It means having a mental or written checklist but it is open-ended in approach, allowing following up on anticipated issues and/or responses (Norman *et al.*, 1994). Very simply, these new survey methods can be classified in to two major groups, viz. Rapid Rural Appraisal (RRA) surveys and Participatory Rural Appraisal (PRA) surveys.

2.8.5.1 Rapid Rural Appraisal (RRA) Surveys

RRA is a relatively new and quite different approach for conducting action-oriented research in developing countries and until now it has been used in assisting agricultural development works. RRA evolved during the 1970s partly from and partly alongside the development of farming system research development (McCracken *et al.*, 1988). RRA surveys are sometimes called with a variety of names including Sondeos, Rapid Reconnaissance surveys and/or Exploratory surveys (Norman *et al.*, 1994). According to CIDE, KNES & WRI (1990) RRA is one of the several approaches for rapid design, implementation, monitoring and evaluation of rural development.

Gordon Conway and Robert Chambers developed RRA with support from the International Institute for Environment and Development (IIED). The philosophy, approaches and methods of RRA began developing into a coherent and identifiable form in the late 1970s and RRA was

considered constructive in the sense that outside professionals go to the rural areas, obtain information and then take it away to process and analyze (Norman *et al.*, 1994).

Over the years, properly executed RRA surveys have proved to be low cost ways of obtaining information and opinions from farmers, of tapping the indigenous knowledge and wisdom that exists on agricultural matters, and of developing a rapid understanding of farmers' circumstances, practices and problems. RRA is thus a semi-structured activity carried out in the field, by a multidisciplinary team and designed to acquire quickly new information on, and new hypotheses about, rural life (McCracken *et al.*, 1988).

According to McCracken *et al.* (1988) there are five key features of good RRAs. These are:

1. **Iterative**: The process and goals of the study are not immutably fixed beforehand, but modified as the team realizes what is or is not relevant. This involves "learning as you go", whereby newly generated information helps to set the agenda for the later stages of the analysis.
2. **Innovative**: There is no simple and standard methodology. Techniques are developed for particular situations, depending on the skills and knowledge available.
3. **Interactive**: All team members and disciplines combine together in a way that fosters unexpected discoveries and interdisciplinary insights. A system perspective helps to make communication easy.
4. **Informal**: The emphasis is, in contrast to the formality of other approaches, on partly structured and informal interviews and discussion.
5. **In the community**: Learning takes place largely in the field, or immediately after, in short duration intensive workshops. In particular, farmers' perspectives are used to help define differences in field conditions.

RRA type surveys can serve five main functions in farming systems research-type work (Norman et. al, 1994). These are as follows:

a. ***Feasibility Surveys***. RRA surveys can be useful in planning a project in a region, particularly in cases where relatively little is known, such as obtaining an understanding of the target area and in selecting the research area.
b. ***Reconnaissance Surveys to Prepare Formal Surveys***. The objective of these surveys is to quickly obtain basic information for designing and executing formal surveys or more in-depth investigations that may lead to on-farm experimentation. Such surveys help in developing an understanding of the area and can help ensure that the formal questionnaire is designed in a manner understandable and relevant to the farmers' circumstances and sensitive to local issues.
c. ***Informal Survey for the Direct Planning of On-Farm Trials***. The formal survey stage is skipped and on-farm experiments are undertaken on the basis of an informal survey, which identify problems that need to be addressed.
d. ***Informal Group Interviews on Selecting, Monitoring and Evaluation On-Farm Trials***. Conventionally, much of the literature usually emphasizes the use of RRA techniques in the planning stage of FSR work. However, in Botswana, such techniques have also been used in the monitoring and evaluation of on-farm trials.
e. ***Assessing Impact and Adoption***. The recent increased emphasis on looking at the impact of research resources in terms of success and problems of adoption provides another potential role for RRA type surveys. As yet this has rarely been done but it could provide a quick and cost efficient way of feeding back issues to station-based researchers and planners. Such surveys could also provide valuable insights in the design of more formal surveys addressing adoption.

The techniques used in RRA study will depend to a large extent on the agreed objectives and the available resources. The "core" techniques common to almost all RRAs are as follows (McCracken *et al.*, 1988):

i. Secondary Data Review: These are published or unpublished data, acquired by other people at an earlier time relevant to the topic or agro-ecosystem, which is the target of RRA. These

are obtained from government agencies, universities, research, centers etc. They take a great variety of forms, including project documents, research papers, annual reports, maps, photographs, newspaper articles, etc.

ii. Direct Observation: Any direct observation of field objects, event processes, relationships or people that is recorded by the team in note or diagrammatic form. Some of the more innovative forms of direct observation rely on carefully chosen indicators. These are events, processes or relationships which are easily observed or measured but can be used as an indicator of some other variable that is more difficult or impossible to observe.

iii. Semi-Structured Interviews: This is probably the most powerful of RRA technique. It takes place in informal, guided interview sessions where only some of the questions are predetermined and new questions or lines of questions arise during the interview, in response to answers from those interviewed. The interviews are associated with farm, field or village visits and the interviewees may be individual farmers or households.

iv. Analytical Games: These include techniques, such as ranking, which are used in interview sessions as a quick means of finding out an individual's or a group's list of priorities or preferences. Ranking can also help in the investigation of the seasonal changes in the lives of the villages or farmers.

v. Stories and Portraits: These are short, colorful descriptions of situations encountered by the team in the field or stories encountered by the people met there. They describe information that is difficult to incorporate into diagrams, and help to bring life to the condition of rural people. In particular they draw attention to the ways in which rural people themselves perceive local conditions, notably problems and opportunities.

vi. Diagrams: It is the second most powerful technique. It uses conceptual and, in particular, diagrammatic models. It can be defined as a simple, schematic device, which presents information in a readily understandable visual form. Diagrams are particularly useful tools in semi-structured interviewing, as a means of bypassing the need for interpreting and clarifying field information such as intercropping patterns in the field or relay cropping sequences through the year. Diagrams are also important in the team's daily analysis of the interviews and in the later workshop analysis session.

vii. Workshops: This is a means of bringing people together, including the field team and outsiders introduced for their skills and experience, to participate actively in reviewing, analyzing and evaluating the information gathered.

Some important points to be considered in RRA surveys are (Norman *et al.*, 1994):

- Determining the major objectives of the survey. These should be finalized after taking into account the needs and inputs of the relevant authorities and interested parties such as FSR, extension and experiment station based personnel.
- Size of the survey team should be decided, which is determined by the objectives or focus of the survey. In general both social and technical scientists should be included in the team.
- Background information regarding the objectives and area to be surveyed needs to be assembled and digested. Such information can be obtained from reviewing secondary data - both published and unpublished.
- Acquiring maps and interviewing key information.

2.8.5.2 Participatory Rural Appraisal (PRA) Surveys

Improving the quality of life in rural communities is a primary goal of development. While many efforts, such as introduction of hybrid seeds, fertilizer and pesticide packages, or irrigation systems have been effective in some areas, their benefits, unfortunately, have bypassed the rural people. Part of the dilemma lies in the fundamental approach to the development (WCED, 1987). This failure of "top-down' or "blue-print" approaches to rural development leads to other alternative approaches such as Rapid Rural Appraisal and Participatory Rural Appraisal (CIDE *et al.*, 1990).

PRA is one alternative to the conventional top-down approach to rural development. PRA methodology assumes that popular participation is a fundamental ingredient in project planning; that locally maintained technologies as well as sustainable economic, political, and ecological systems are fundamental to reverse Africa's decline; and that truly sustainable development

initiatives will incorporate approaches that local communities themselves can manage and control (CIDE *et al.*, 1990). The philosophy, approaches and methods of PRA techniques developed later, after the development of RRA techniques. PRA is a participatory technique in the sense that its role is more to facilitate the collection, presentation and analysis by farmers themselves. PRA methods, which have visual strengths, include: participatory analysis and trend diagramming, matrix scoring and ranking, flow and linkage diagrams (Chambers, 1992).

PRA, like its parent methodology of RRA, is a "systematic yet semi-structured activity carried out in the field by a multidisciplinary team and designed to acquire quickly new information on and new hypotheses for rural development. Its goal is socially acceptable, economically viable, and ecologically sustainable development. PRA assumes that communities need committed local leadership and effective rural institutions to do the job. PRA helps communities mobilize their human and natural resources to define problems, consider previous successes, evaluate local institutional activities, priorities, opportunities, and prepare a systematic and site specific action plan. PRA enables multi-disciplinary teams of specialists and rural leaders to work more closely together and to understand better their problems, needs, and opportunities. PRA is an excellent tool to bring together, on the one hand, development needs defined by community groups and, on the other hand, the resources and technical skills of the government, donor agencies, and non-governmental organizations. In so doing it integrates traditional skills and external technical knowledge in the development process. The composition of a PRA team greatly influences the quality of information, analysis, and the subsequent management plan" (CIDE *et al.*, 1990).

PRA techniques are evolving rapidly. Four important key points to note about the use of PRA techniques are as follows (Norman *et al.*, 1994):

- All involve a group of respondents who together, after discussion, come to a consensus on the subject being considered. Thus care must be taken that the respondents selected for the exercise are knowledgeable about the subject being discussed, and where results are likely to differ by recommendation domain, gender, etc., that those in a specific group are of the same 'type' or 'class'.
- They can be effectively used where the level of literacy is low. Lack of reliance on the written word appears to positively influence memory or visual retention. Such information can be

effectively transmitted to others in pictorial form through drawing outlines on the ground, supplemented with different objects or symbols reflecting different things / events / orders of magnitude, etc.

- Since the respondents are the major 'actors' in the activity, and primarily interact amongst themselves they become very enthusiastic in, and derive considerable enjoyment and satisfaction form, undertaking the exercise.
- For those who doubt the result of a particular exercise, it can be repeated with another group of respondents who have similar attributes, and the results compared.

Techniques and potential uses of PRA as indicated by Norman *et al.* (1994) are:

a. **Mapping**: Mapping of farms, residences, and/or points of major interest (e.g. wells, cooperatives, etc.) in a village. Names of individual farms or each plot of land can be identified, and characteristics of households living in each residence can be obtained. The potential value of such an exercise is obvious in providing a low-cost and quick way of assembling a sampling frame from which stratified random samples can be selected for random surveys.

b. **Trend Analysis**: This involves the use of historical perspectives and provides a way of relating changes and their causes to specific major events, which in turn can be related to specific years. Such trends, together with information related to their causes, can obviously be a useful input into addressing ecological sustainability issues, designing solutions that will overcome undesirable trends, providing some idea on how desirable trends can be encouraged, etc.

c. **Seasonal Diagramming**: Amount and distribution of rainfall; specific operations by crops; level and distribution of labor by crop and livestock enterprises, total agricultural, off-farm, domestic household related; level and composition of food consumption through the year; level and composition of animal fodder throughout year, etc. Seasonal diagramming is potentially very important in highlighting problems that need to be addressed by an FSR team and in helping to evaluate the value or relevance of potential solutions.

d. Matrix scoring and ranking: This is used in farmer assessments of: different varieties of crops, livestock, fodder crops, trees; treatments in researcher managed and researcher implemented (RMRI) trials; types of soils; methods of soil and water conservation, etc. The idea is to encourage and enable farmers to debate, decide and weight the characteristics of the different alternatives and perhaps also indicate what they would ideally like to have. The weighting is constrained, forcing them to make judgments and trade off decisions.

According to Chambers (1992) the procedure for matrix scoring and ranking is as follows:

- Decide what you want scored or ranked (e.g. varieties of sorghum, different treatments in a tillage trial, etc.).
- Find one or more (preferably more than one) informants who are knowledgeable and willing to discuss - preferably from the same recommendation domain.
- Decide with them which items (i.e. under the first point above) to rank or score - for example, if they know nothing about a particular variety it should not be included.
- For each in turn, ask them what is good about it, what else (i.e. any other point that is relevant in ranking / scoring) - their ideas not yours.
- List the criteria and make negative ones positive. For example, 'attracts pests' becomes 'does not attract pests'
- Ask informants to rank or score each one (i.e. 1=best, 2=second best, etc. or score each out of 10, 5 or 3). This could be done visually with a matrix drawn on the ground and asking farmers to select their preferences by, for example, distributing 10 identical objects (e.g. cowpea seeds) between the various choices.
- At the end ask the informants to rank them according their preferences if they could have only one. At that time they are aggregating the different criteria according to some weighting system. In fact it might also be useful to ask them to rank the importance of the different criteria. This could be done in a way Chambers (1992) called 'wish list' through distributing the objects according to the relative importance of the different criteria. This could provide very useful information for researchers.

This is one of the most exciting of PRA techniques in the sense that it has tremendous potential for obtaining farmer assessment during design and testing activities and possibly even relating to

adoption in the dissemination stage. However, this has not been exploited up to now. A recent experience in Botswana confirmed its potential value. In assessing different varieties of sorghum, the respondents indicated that, apart from palatability the criteria farmers used to evaluate the sorghum related to those reflecting yield stability. In a sense these PRA methods provide a way of quantifying qualitative data and therefore potentially could be more appealing to technical scientists not associated with FSR teams. This is particularly likely to be the case once they have observed these methods in operation. These methods as well as adding an extra dimension to RRA-type surveying during descriptive / diagnostic work, could, as mentioned above, be important during the other stage of FSR work in evaluating technologies (Norman *et al.*, 1994).

2.8.5.3 Comparing RRA and PRA Types of Informal Surveys

In considering the two types of informal surveys, a number of points can be made as follows (Norman *et al.*, 1994):

1. The philosophy, approaches and methods of RRA began to develop into a coherent and identifiable form in the late 1970s, while most of the PRA techniques developed later.
2. RRA is often considered extractive in the sense that outside professionals go to the rural areas, obtain information and then take it away to process and analyze. PRA, on the other hand, is participatory in the sense that its role is more to facilitate the collection, presentation and analysis by the farmers themselves.
3. Although there is a difference in approach between RRA and PRA, the distinction is becoming increasingly blurred since much of the methodology is shared. However, according to Norman *et al.* (1994), RRA is distinguished from PRA in the sense that RRA's are considered as semi-structured interviews. This has often been viewed as the 'basic foundation' of good RRA. It means having a mental or written checklist but that is open-ended in approach, allowing following up of unanticipated issues and / or responses.
4. RRA and PRA have a number of features in common. However PRA has a number of features that have not been prominent in RRA including:
   - Getting the farmers themselves to do it (i.e. investigation, analysis and presentation) with the outsiders simply playing a facilitative role.

- Outsiders emphasizing self-critical awareness (i.e. examining their own behavior) so that they play a truly facilitative rather than interventionist role, including that of relaxing and not rushing the farmers.
- Outsiders using their own best judgment at all times rather than relying on a manual or a rigid set of rules, and learning to welcome any errors as an opportunity to do better.
- Greater sharing of information among farmers and between farmers and outsiders.

Point 4 above is also emphasized by the CIDE *et al.* (1990).

CHAPTER 3

RESEARCH METHODOLOGY

3.1 COLLECTION OF AVAILABLE EXISTING INFORMATION ON THE STUDY AREA

Resource surveying for land evaluation is a new science for Eritrea. Detailed surveying for the purpose of land evaluation has not been practiced in any part of the country before. Hence, hardly any specific publications, documents or reports in relation to resource surveying and land evaluation are available. During the study much effort was spent to collect essential information on the study area. Except few documents and reports on resources and farming systems at small scales (national level), information at a sufficiently detailed level for development planning was not obtained for the study area. The reports and publications studied and personnel consulted during the study are as follows:

- Berhane, D., 2000. Development of Methods and Techniques for Land Resource Surveying for Eritrea. M.Inst.Agrar. dissertation, University of Pretoria, South Africa.
- Weldegiorgis, B., 2000. Development of a Strategy and Structure for Land Suitability Evaluation for Eritrea. M.Inst.Agrar. dissertation, University of Pretoria, South Africa.
- Ministry of Land, Water and Environment, 1997. Agro-ecological Zones Classification and Legend. Unpublished report. MLWE, Asmara.
- Ministry of Agriculture & University of Asmara, 1998. Eritrean Soil Fertility Initiative Draft Paper. Unpublished report. MOA, Asmara.
- Ministry of Land, Water and Environment, 1996. Land Use Plan of Asmara and its Environs. Unpublished report. MLWE, Asmara.
- Ministry of Agriculture Central Zoba, 1995. Agricultural Practices in Central Zoba. Unpublished report. MOA, Asmara.
- Ministry of Agriculture, Department of Animal Science, 1998. Animal Population of Eritrea.

Unpublished report. MOA, Asmara.

- Ministry of Agriculture, 1999. Soil Conservation Practices in Eritrea by Students on Summer time. Unpublished report of 1994-1999. MOA, Asmara.
- Bein, E., Negassi, A., Tengnas, B. & Ghebru, K. 2000. Soil Conservation in Eritrea, case study, RELMA / SIDA, Nairobi, Kenya.
- Ministry of Transportation and Communication, 2000. Climatic Data of Different Weather Stations. Unpublished Report. Asmara.

In addition personal communication with experts from the Ministry of Agriculture, Ministry of Land, Water and Environment, University of Asmara: College of Agriculture and Aquatic Science and Department of Earth Science, Office of Local Government, Local Office of MOA and Extension Experts in the province was done.

3.2 DETAILED RESOURCE SURVEYING

Recent aerial photographs, for use as field sheets and base maps for a detailed soil survey of the study area, were obtained from the Ministry of Land, Water and Environment. The photographs were flown in October 1994 at a scale of 1: 15000 and developed at scales of 1: 5000 and 1: 15000. The photographs at a scale of 1: 5000 were used as field sheets and those at 1: 15000 scale for final publication of the soil map. Soil augers, chemicals such as 10 % HCl and materials such as a Munsell color chart, tape, etc. were obtained from the Ministry of Agriculture.

Before the beginning of the survey 4 people from the village elders were selected. With the help of these people the village land boundaries were demarcated on the aerial photographs. A detailed survey on land use and land cover of the area was done.

Information on climatic characteristics of the area was gathered from Asmara Airport Weather Station and other stations around the research area.

3.2.1 Actual field soil survey

The actual soil survey was done predominantly using a fixed grid method. Auguring was done at intervals of 30-40 meters in areas with uniform topography and similar topsoil color. Intensive auguring of up to 10 meters interval was carried out near landform and/or topsoil color change for more accurate demarcation of delineation boundaries. Different diagnostic horizons and the depth of each horizon were recorded. Surface stoniness was estimated and recorded as percentage coverage of the area. Slope percentage of the area was measured using clinometers. Information on rock types and parent materials was identified with the help of junior experts in geology from the Ministry of Land, Water and Environment who participated in the survey.

3.2.2 Modal profiles

Representative modal profiles for detail analysis of the soils in each mapping unit were selected. The site for each modal profile was selected very carefully to ensure that it was as much as possible representative of the particular mapping unit. For some similar mapping units in different localities two modal profiles were dug. The dimension of each modal profile was 1.5 meters by 2 meters and depth of up to 2 meters. All information on every modal profile was collected and recorded carefully. Diagnostic horizons were identified and the thickness of each horizon was recorded. Samples from the top 50 centimeters were collected in cotton sacks for laboratory analysis. The soil depth limit for sampling was determined in consultation with the Soil Science Laboratory and senior land use experts. The argument given by them is that the root depth of the crops grown in the study area extends to maximum of 50 centimeters. The soil samples were taken to the Soil Science Laboratory, Ministry of Agriculture for analysis.

3.2.3 Laboratory analyses

The soil samples were air dried for almost a week in the laboratory and passed through a 2 mm sieve. The soil scientists of the Ministry of Agriculture determined the different physical and chemical characteristics of the soils, employing the routine analytical methods used in the soils laboratory of the ministry.

3.3 RAPID RURAL APPRAISAL AND PARTICIPATORY RURAL APPRAISAL SURVEY

Socio-economic aspects are very important in planning any development project or making recommendations for the implementation of any technology. The socio-economic component of this study was done using a combination of rapid rural appraisal and participatory rural appraisal. Before the actual survey on social aspects, information on culture, land tenure systems and farming systems in the study area was studied from previous reports and personal communication with experts from different government institutions. From the information obtained a small number of points were extracted on general aspects of the farming systems of the community as a starting point for the study.

Before the beginning of the study the local government office organized a meeting with the village elders and representatives. During this meeting a general brief was given to the community representatives on the objectives of the study. The representatives of the community were asked to select farmers of both genders and involved in different farming activities, i.e. in dairy farming, crop production and those with additional jobs in the city and nearby places. They were very cooperative and nominated farmers to provide information regarding the situation in and concerns of the community. The segregation based on gender, level of production and additional income sources was to gather information relevant to the different groups. The representatives of the community selected 15 farmers from the village. Out of these seven farmers are completely dependent on crop and vegetable production for their living. Five are involved mainly in dairy production, even though they also practice field crop and vegetable production on a small scale. The remaining three are women who recently started practicing poultry farming for commercial purposes as a subsidiary with the help of the government and National Union of Women of Eritrea in addition to crop and vegetable production. A specific day was selected which was suitable for all of them. The day agreed upon was a public holiday in the area. The place for meeting was chosen to be inside the church compound under the shade of a big tree where the community of the village always gathers regarding issues concerning the village.

A short introduction and briefing was given on the objectives and aims of the study. This was mainly to clear the atmosphere from direct expectations and suspicions regarding the result of the study. Some refreshments were ready and utmost efforts were made to make the participating farmers feel relaxed. A tape recorder was ready to record every thing said during the survey. Some notes were also taken during the discussions. The discussion started on the history of the village, the way they have been living and the ups and downs experienced in life, especially in their farming systems. Interesting points from the information given by the farmers were identified for further discussion. The study was a sort of discussion and brainstorming. The farmers were moving forward and back and scratching on the ground during their comments, explanation and discussion. Special attention and priority was given to the women participants, because culturally women are not allowed to speak when men are nearby. Maximum effort was taken to minimize interruption by any member of the study team during discussions. Questions were asked to individuals at the end of every discussion to clear up matters before proceeding to the next point.

The participants were asked to put their community problems in priorities. At this point the representatives were divided, basically because of their different interests and expectations. This was the most difficult issue for the farmers to reach consensus on. Some put the tenure system as the main problem and the starting point of all the other problems and others put lack of credit and extension facilities as the main one. Those who supported the latter issue did so in comparison to the situation in other villages. Accordingly villages Lamza and Adi-Hakefa have a better extension service and support systems compared to Adi-Segdo. They blame the local and central office of the Ministry of Agriculture for the situation. The response of the local office of the ministry on the issue is that the situation in Adi-Segdo unlike other villages, since most of the people of this area have supplementary incomes. Hence this village is not in one of the priority lists of the extension services.

In general the discussion concentrated on the issue of the land tenure system and lack of attention from the Ministry of Agriculture, especially in accessing and giving opportunities in credit facilities and other agricultural equipment. In general the problems of the community in regard to

social services, the issue of land reallocation for non-agricultural uses to investors from outside and the consequences to the community also received attention.

At the end of the first full day discussion another short meeting was arranged for a week later. The recorded information was replayed and sorted out with the notes taken during the discussions and a summary of the issues that were raised, was made. At the second meeting the summarized points were presented to the participants for further comment and addition of any forgotten issue. Some explanations were given and the eldest one from the participants made a closing speech.

CHAPTER 4

NATURAL RESOURCES OF THE STUDY AREA

4.1 GENERAL

The study area, Adi-segdo, is situated 3 km west of Asmara, the capital of Eritrea, and is approximately **757.0** ha in size. It borders on Weki-Duba in the north and northwest, Tsaedachristian in the west, Asmara in the east and Queshet in the south and southwest (See Figure 1.1 given in Chapter 1).

Two streams, called *Maibella,* form the northern and southwestern boundaries of the village land. All the sewage and domestic wastes of the city of Asmara and effluents from the various factories within the city drain into these streams. The streams join at a junction in the west end of the village and finally drain into one of the main drainage basins of the country, the *Anseba drainage basin.* The village community of the study area and other neighboring villages traversed by the streams have been using water from the streams to irrigate vegetables and other food crops for many years and recently also animal fodder crops. Even though detailed analyses of the chemical contents of the streams have not been done, it is believed that the streams are highly polluted and hazardous to life.

According to the Agro-ecological Zones (AEZ) map of the country the area is classified under the Moist Highland zone (Ministry of Land, Water and Environment, 1997). In view of the low rainfall figures for the weather stations around the study area (Tables 4.2 and 4.3), this AEZ classification must be questioned, however. According to these figures it should instead have been classified in the Arid Highland zone. In mitigation it must be said that only limited data were available for AEZ classification and that the Ministry for Land, Water and Environment (1997) stated clearly that for "some of these data accuracy is questionable" and in places the AEZ classification may, therefore, be incorrect. The landform of the study area is dominantly flat along both *Maibella* streams that bound it and gently to moderately undulating, with few low

hills, in the rest of the area. The minimum and maximum altitudes are 2214 and 2276 meters above sea level respectively. The small difference of only 62 meters in elevation between the lowest and highest points means that elevation does not have a significant effect on aspects such as rainfall and temperature in the study area.

4.2 CLIMATE

There is no weather station in the study area. Hence data on climate was collected from four weather stations close to the area. Unfortunately three stations have been installed only recently and consequently no long-term records are available. In addition to they have records of rainfall only available on annual basis. These three stations at Tsaedachristian, Tseazega and Hazega are located within 9-17 km from the study area and they are at approximately the same altitude as the study area. But the fourth station, Asmara airport weather station, has long-term records. This station is situated at an altitude of 2350 meters above sea level and at a distance of 12 km away due south of the area. Data on temperature, relative humidity and sunshine hours were obtained from Asmara airport weather station for the last 11 years (1990-2000) on a monthly basis. But also rainfall data on a monthly basis from 1923 to 2000, with missing records in some of the years inbetween, were obtained. Climatic data on a monthly basis is more preferable than on annual basis for land use planning purpose. But the other three stations have records of rainfall only on an annual basis.

The location of these four weather stations in reference to the research area is given in Figure 4.1.

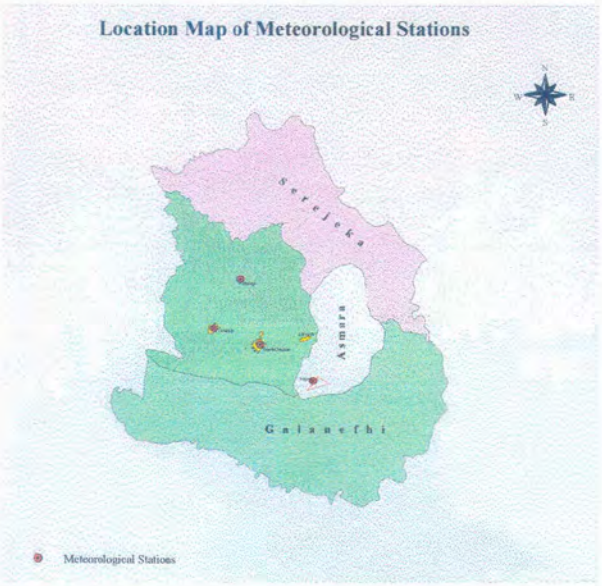


Figure 4.1 Location map of weather stations

4.2.1 Temperature

According to the data for Asmara airport weather station April to June is the hottest and December to February the coolest season (Table 4.1). The mean monthly maximum temperatures from April to June range between 25.3°C and 25.5°C. The mean monthly minimum temperatures from December to February range between 4.3°C and 5.5°C. Frost occurs during December and January. The rain months of July and August interestingly have both the highest mean monthly minimum temperatures and the lowest mean monthly maximum temperatures. This is brought about by the cloud cover, which reduces radiation losses during the night and creates a shield during the day.

4.2.2 Rainfall

Eritrea, as part of the Sahelian Africa, has been victim of recurrent and devastating droughts lately. The rainfall of the country characteristically is torrential, of high intensity over a short duration, very unpredictable and occurs sporadically. The rainfall data from Asmara airport weather station (as indicated in Table 4.2) is on monthly basis for the years from 1990 to 2000

and monthly averages from 1923 to 2000. According to the available rainfall data, the study area must be classified as semi-arid to arid. The average annual rainfall for the Asmara airport weather station is 456 mm (Table 4.2). For the other three weather stations it ranges from 380 mm at Tseazega to 421 at Hazega, with an average of 399 mm for the three stations (Table 4.3).

Table 4.1 Mean monthly minimum and maximum temperatures for Asmara airport weather station

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Ave
Jan	**Min**	3.2	3.9	4.2	4.9	6.5	5.7	1.6	3.5	4.7	4.8	4.6	**4.3**
	Max	22.3	23.9	22.0	22.1	22.7	22.4	23.5	23.1	23.3	22.3	22.7	22.8
Feb	**Min**	2.8	3.8	4.1	6.5	6.4	6.1	2.5	5.7	4.8	5.5	6.1	**4.9**
	Max	23.2	24.1	23.5	23.1	24.6	24.4	24.9	24.8	24.2	25.4	24.1	24.2
Mar	**Min**	7.0	6.4	8.5	8.7	6.3	7.6	4.2	9.4	8.5	5.7	8.1	7.3
	Max	25.2	25.0	26.1	25.3	25.9	24.8	25.2	25.4	26.1	24.7	26.0	**25.4**
Apr	**Min**	9.4	9.5	11.4	10.5	10.7	6.3	6.7	9.8	10.6	10.2	9.7	9.5
	Max	24.2	25.2	25.4	24.0	26.0	25.3	25.6	25.1	27	25.8	23.8	**25.3**
May	**Min**	9.8	NA	12.3	10.8	11.6	11.8	9.4	11.5	11.6	10.8	13.6	11.3
	Max	26.5	25.2	26.0	24.2	26.0	25.3	25.6	25.1	27.0	25.8	23.8	**25.3**
Jun	**Min**	9.9	NA	12.0	11.0	11.1	12.0	9.2	11.5	12.6	11.4	12.2	11.3
	Max	25.7	25.3	25.5	25.1	24.6	26.7	24.4	25.5	26.5	26.1	25.6	**25.5**
Jul.	**Min**	11.2	13.5	12.1	11.7	11.8	12.6	10.2	12.2	13.7	12.5	12.6	**12.2**
	Max	21.7	22.5	22.0	21.6	20.9	21.9	22.4	21.6	22.1	21.1	22.4	**21.8**
Aug	**Min**	11.0	12.8	12.7	11.6	12.4	13.5	10.3	11.6	13.3	12.2	13.2	**12.2**
	Max	22.7	21.8	20.4	23.0	21.1	21.9	22.9	22.6	21.7	21.7	21.5	**21.9**
Sep.	**Min**	9.2	11.1	9.7	9.7	8.9	9.8	7.8	9.0	11.1	9.9	8.9	9.6
	Max	24.4	24.1	22.0	24.0	21.9	23.0	24.6	25.0	23.4	23.5	23.0	23.5
Oct.	**Min**	9.0	10.6	9.6	10.9	7.9	10.2	7.5	10.0	8.7	8.6	8.9	9.3
	Max	22.6	22.1	20.9	22.3	22.2	22.0	22.3	22.6	22.1	21.9	21.4	22.0
Nov	**Min**	6.7	8.1	7.0	8.3	7.8	8.1	6.1	8.6	6.5	6.8	7.6	7.4
	Max	23.0	21.2	21.5	22.4	22.4	22.4	21.0	22.5	21.7	21.6	22.8	22.0
Dec.	**Min**	3.2	6.4	6.7	4.2	7.1	4.6	5.1	6.6	3.9	7.5	5.4	**5.5**
	Max	22.3	22.5	22.6	22.9	22.7	23.9	21.6	22.6	21.6	20.9	22.6	22.4

Source: Ministry of Transportation and Communication, Civil Aviation Department

As in most parts of the highlands, the study area has one short, intense "main rain" season during July and August (Table 4.2 and Figure 4.2). At the Asmara airport weather station nearly two-thirds (62.9 %) of the total annual rainfall is recorded during these two months.

Table 4.2 Monthly rainfall data for the Asmara airport weather station

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1990	0.8	0.0	33.3	1.6	0.0	26.4	110.8	23.9	18.2	0.0	0.0	0.0
1991	0.0	0.0	2.8	36.1	NA	NA	47.9	60.4	1.2	30.1	0.0	0.0
1992	0.0	0.0	4.8	5.8	14.0	38.6	127.8	158.7	1.3	15.8	5.3	3.2
1993	0.0	0.0	0.0	0.0	10.0	10.0	156.0	79.0	22.0	26.0	0.0	0.0
1994	0.0	0.0	3.0	17.0	46.0	16.0	104.4	135.0	61.0	10.0	0.0	15.0
1995	0.0	0.0	0.0	59.0	31.0	0.0	165.0	111.0	34.0	0.0	0.0	0.0
1996	0.0	0.0	16.0	26.0	28.0	40.0	67.0	80.0	0.0	0.0	44.0	0.0
1997	0.0	0.0	9.6	6.4	101.4	44.4	242.7	98.0	0.0	117	69.0	0.0
1998	0.0	0.0	68.4	40.9	30.8	12.6	141.7	255.2	5.8	7.0	0.0	0.0
1999	27.7	0.0	0.0	28.2	8.2	21.6	199.3	199.5	6.2	1.4	2.2	0.0
2000	0.0	0.0	3.9	97.0	15.8	32.2	259.4	106.6	19.0	26.8	12.2	0.0
Mean	2.6	0.0	12.9	28.9	28.5	24.2	147.7	118.8	15.3	21.3	12.1	1.7
LTM*	1.7	0.4	8.5	24.4	28.5	28.9	164.1	122.6	22.5	13.7	7.8	3.3

LTM* = Long term means for 1923 – 2000

Annual means:

1. 1990 – 2000: 414mm
2. 1923 – 2000: 456mm

Source: Ministry of Transportation and Communication, Civil Aviation Department

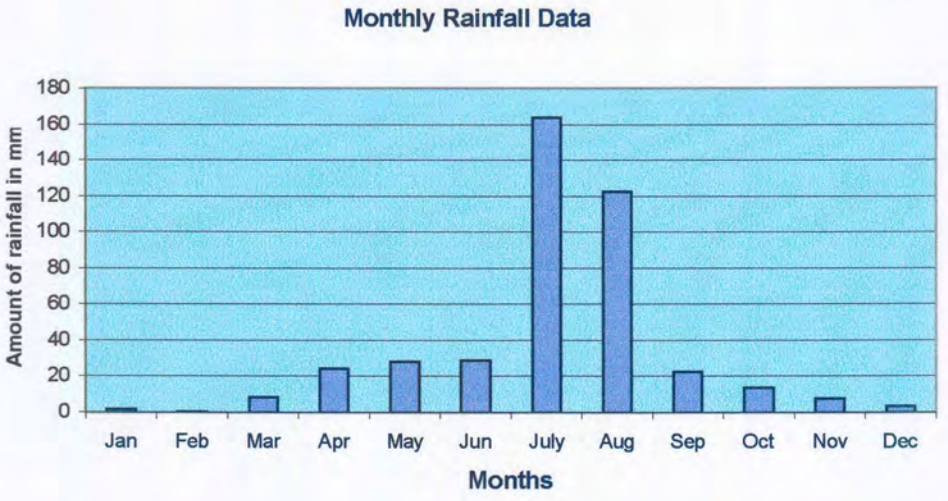


Figure 4.2 Graphic representation of mean monthly rainfall data for Asmara airport weather station

According to the farmers wind blowing from south to north brings rain but when it blows from north to south there is no rain. As for most of Eritrea there is a belief that the area has a useful "small rain" season during April and May. The usefulness of these rains is rather suspect. The rains during these months are extremely variable. Only in rare years will one of the months get good rains, e.g. May in 1997 and April in 2000 (Table 4.2). The averages for both months are less than 30 mm at Asmara airport. The efficiency of these rains is further reduced because these are amongst the warmest months with the lowest relative humidities, and thus probably are the months with the highest evapotranspiration.

In reference to the last 11 years' rainfall data; a third feature of the rainfall pattern is the long very dry period from September to March (Table 4.2). December to February are throughout exceptionally dry. December and January recorded no rain for nine out of eleven years, whereas February recorded no rain throughout the whole 11 year period. September, October, November and March recorded significant rain only in one or two odd years. November, in fact, recorded no rain in six of the eleven years and more than 10 mm in only three of the years.

Overall it is clear that not only the low total rainfall, but especially the very short duration of the main rain season (Table 4.2), pose serious problems for crop production in the study area.

Table 4.3 Annual rainfall data for three weather stations in the vicinity of the study area

Year	Tsaedachristian	Tseazega	Hazega	Average
1992	N / A	380.0	N / A	380.0
1993	N / A	355.0	N / A	355.0
1994	374.0	473.0	402.0	416.0
1995	382.0	308.0	445.0	378.3
1996	464.0	378.0	446.0	429.3
1997	717.0	556.5	591.0	621.6
1998	439.8	343.3	344.0	375.0
1999	332.4	243.1	295.1	290.0
Mean	**396.1**	**379.6**	**420.5**	**398.7**

Source: Provincial Office, Ministry of Agriculture.

4.2.3 Relative humidity

Relative humidity, amount of moisture in the atmosphere, is high only for two months of the year, i.e. during the main rain season in July and August (Table 4.4). During the rest of the year it is low, dropping below 60%, the danger zone for many crops, during the whole period from January to June, i.e. including the perceived "small rain" season.

Table 4.4 Mean monthly relative humidity (%) at the Asmara airport weather station

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1990	63	52	59	50	42	52	79	74	56	54	66	56
1991	60	55	44	56	NA	NA	NA	81	56	59	60	62
1992	51	41	40	48	48	44	73	85	60	63	69	62
1993	54	43	50	62	53	53	80	71	58	62	66	54
1994	50	55	39	54	49	50	80	84	71	62	65	66
1995	50	55	39	54	49	55	80	84	70	62	65	66
1996	54	44	46	58	51	40	81	84	62	58	64	64
1997	54	48	54	59	57	67	78	81	55	56	67	63
1998	51	38	39	39	37	43	83	83	59	56	58	71
1999	55	42	45	42	47	44	80	86	71	45	58	56
2000	52	47	40	54	46	46	72	84	57	54	64	59
Mean	54	49	47	51	49	49	78	81	61	62	66	62

Source: Ministry of Transportation and Communication; Civil Aviation Department

4.2.4 Sunshine hours

The sunshine hours of the area is high for most of the year, with maximum values during November to February (Table 4.5). It is much lower during July and August, the main rain season, when the sky is covered with cloud for much of the time.

Table 4.5 Mean daily sunshine hours at Asmara airport weather station

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1990	9.1	8.5	7.9	9.4	9.5	7.6	5.3	5.6	5.3	8.6	10.2	10.1
1991	9.2	10.0	7.9	7.6	NA	NA	3.7	3.6	6.8	8.5	9.1	8.6
1992	8.9	9.2	9.1	9.1	8.8	7.1	4.3	4.2	7.8	7.7	7.7	9.0
1993	9.8	9.1	9.2	8.2	9.1	8.1	5.9	7.3	8.9	8.6	10.1	9.9
1994	10.0	9.5	10.2	8.4	8.9	7.6	7.6	6.2	8.0	9.3	9.7	9.1
1995	10.1	9.3	9.7	8.7	9.3	10.0	5.5	6.2	8.7	10.4	9.7	9.4
1996	9.9	10.1	8.9	8.0	7.0	6.6	7.2	6.2	8.8	9.6	8.5	9.1
1997	9.7	9.1	8.6	8.8	6.2	8.1	4.9	7.3	9.7	7.6	8.3	9.6
1998	9.4	10.1	9.2	9.3	9.2	8.5	5.5	4.8	8.3	9.9	10.4	10.5
1999	9.6	9.9	10.5	10.8	10.1	9.4	4.0	6.2	8.6	9.0	10.2	9.2
2000	10.1	9.9	10.0	7.7	9.7	9.3	6.4	6.6	8.7	9.1	9.5	9.9
Mean	9.6	9.5	9.2	8.7	8.8	8.2	5.5	5.8	8.1	8.9	9.4	9.5

Source: Ministry of Transportation and Communication; Civil Aviation Department

4.3 GEOLOGY AND SOILS

General information on geology of the area was obtained from the Earth Science Department, Asmara University. The following description is based upon personal communication with the department's staff and personal observation with junior geologists during the field survey. According to Dr. M. Tecklay the rocks in the area form part of the Precambrian basement of Eritrea. They consist of schist, a metamorphic rock which was originally intermediate to felsic volcanic rocks. The numerous quartz veins seen throughout the area may be evidence of the high silica content of the rocks. The rocks in the area have also undergone a period of laterization.

The soils of the area were classified using the South African soil classification system (Soil Classification Working Group, 1991) at the higher of its two levels, i.e. at the form level and, where possible, also at family level. This system classifies soils at lower categorical levels and is, therefore, a good system for detailed surveys. The soils were also tentatively classified according to the WRB system (WRB Working Group, 1998). Berhane (2000) recommended the use of this

system in Eritrea for the sake of correlation and technology transfer, because the WRB/FAO system is used in most of its neighboring and nearby countries in East Africa and also because the International Union of Soil Sciences (IUSS) adopted a resolution to request all countries to use this as a reference system.

During the field survey junior experts in soils and geology from the Eritrean Department of Land and University of Asmara participated. The mapping units are classified based on the dominant soil type in the area and its depth and agricultural importance. ***A copy of the soil map compiled during the field survey (Map 4.1) is attached at the back of the dissertation. Descriptions of modal profiles from most of the mapping units are given in Appendix A.***

Mapping Unit A: Vertic horizon, underlain by carbonate containing horizons

The surface horizon is Vertic, i.e. it has strong swell-shrink properties. The depth of the horizon ranges between 75 and 135 cm. It is a black, clay textured soil with strong, coarse blocky structure. The subsurface horizon is brown to dark brown with white patches. The white patches are due to the presence of powdery lime. The horizon has clay loam texture and weakly developed structure. The thickness of the horizon ranges between 35 and 55 cm. This horizon is underlain by a brittle lime pan varying between 30 and 50 cm in thickness. Under a Vertic horizon this horizon is non-diagnostic in the South African system, otherwise it resembles a Soft Carbonate horizon. In the WRB system it is a Hypercalcic horizon.

Classification:

South African system: Arcadia form; Lonehill family.

WRB system (tentative): Calcic or Haplic Vertisols (depending on the depth at which the Calcic horizon starts).

This mapping unit is located in low-lying flat areas along the stream. The total depth of the soil profile extends to more than 200 cm in most places. This area has been used for irrigation for a long period of time. During the survey in the beginning of January i.e. during the dry season of the area, huge cracks of more than 70 cm in depth and 7 to 10 cm in width were observed in

uncultivated areas. According to the farmers during heavy rains water remains stagnant on the surface for 2-3 days. The area coverage is **153.25** hectares.

Mapping Unit B*:* Deep wet Organic or Vertic soils

The surface horizon is Organic or Vertic and extends to 300 cm in depth. The color of the soil is black and the whole profile is free of carbonates. It is seasonal wetland whereby the area is swampy during the rain season and wet to moist during the dry season. There were no signs of permanent wetness in the sub-surface horizon but the color becomes lighter deep in the soil. At this depth it is non-diagnostic.

Classification:

South African system:

With an Organic horizon: Champagne form

With a Vertic horizon: Arcadia form

WRB system (tentative):

With a Histic (organic horizon): Histosol

With a Vertic horizon: Vertisols

These soils are situated in almost flat waterways. This area is used for grazing throughout the year. The area coverage is **39.12** hectares.

Mapping Unit C: Deep young alluvial soils

This mapping unit has an Orthic (SA system) or Ochric (WRB system) surface horizon, which extends to 30 to 40 cm depth. The sub-surface horizon is deep stratified alluvial material. The thickness of the alluvial material is 140 cm and it overlies weathering material.

Classification:

South African system: Dundee form; probably Marico family.

WRB system (tentative): The most logical would be to classify it as a Fluvisol,

but the topsoil is a bit thicker than the permissible maximum of 25 cm. It does not fit into any other reference soil group. It is proposed that it meanwhile be classified as a Fluvisol (variant).

This area has been used intensively for rainfed cropping of maize; but the last three years part of it has been used for irrigation of fodder crops and to some extent vegetables. The area coverage is **27.05** hectares.

Mapping Unit D: Structured soils

According to the South African classification system the surface horizon in this mapping unit is Melanic and probably Orthic in some areas. The WRB equivalents are Mollic and Ochric horizons respectively. The depth of the surface horizon is 30 to 35 cm and it is light brown in color. The sub-surface horizons are predominantly Pedocutanic B horizons according to the South African system (Argic according to WRB). The thickness of the sub-surface horizon is about 85 cm and is brown in color with white patches. These white patches are not due to the presence of carbonates, but are signs of wetness. At a depth of 120 cm from the surface a water table is located. The presence of water table is probably the result of many years of over irrigation or presence of an impervious layer few meters from the surface, but definitely not from a natural water table.

Classification:

South African system:

The soils with Melanic A horizon: Bonheim/Willowbrook intergrade.

The soils with Orthic A horizons: Sepane form.

WRB system (tentative):

Soils with Mollic horizons: Gleyi-Luvic Phaeozems.

Soils with Ochric horizons: Gleyic Luvisols.

This area has been used for the production of vegetables and animal fodder under irrigation for many years now. It is poorly drained. But in comparison to mapping unit A with a vertic A

horizon it is better drained and has less soil workability problems due to the lack of strong swell and shrink characteristics with moisture changes. The area coverage is **76.07** hectares.

Mapping Unit E: Apedal soils with carbonates

The surface horizon is Orthic (South African system) or Ochric (WRB system), light red to brownish in color and ranging from to 10 to 20 cm in depth. The sub-surface horizons are predominantly Yellow-brown Apedal B horizons, ranging between 35 and 40 cm in thickness, underlain by brittle lime pans, i.e. Soft Carbonate horizons (South African system) or Hypercalcic horizons (WRB system), varying between 20 and 25 cm in thickness. The landform of this mapping unit is gently sloping to almost flat with surface stoniness of 10-15%, predominantly quartz, laterites and schist.

Classification:

South African system: Molopo form.

WRB system (tentative): Hypercalcic Calcisols.

It is used intensively for rainfed cultivation of cereals but small part of this mapping unit is under irrigated production due to its close location to the water sources. This may seem strange because the soils have fairly limited depth. In South Africa it was found that similar soils with similar depth underlain by Soft Carbonate horizons actually give the most consistent economically viable grain yields in marginal rainfall areas (Mbatani, 2000). It was found that this is because large quantities of water, which can be used by the crop, are stored in the Soft Carbonate horizon. Management is critical and these yields are obtained only at low planting densities with low fertilizer inputs. The area coverage is **74.94** hectares.

Mapping Unit F: Young moderately shallow soils formed by *in situ* rock weathering

The surface horizon is an Orthic horizon (South African system) that extends to 10 to 25 cm depth. The sub-surface horizon is a Lithocutanic B horizon, from 40 to 50 cm thick, underlain by weathering rock of chlorite schist, i.e. rocks which are very fragile and easily broken when crushed between fingers. The landform of this mapping unit is relatively steep to gently sloping.

Classification:

South African system: Glenrosa form.

WRB system: No provision has yet been made for such soils.

These soils are used for rainfed cultivation of barley. A rotation system of 1-2 years cropping, followed by 3-4 years fallow periods, is followed depending on outputs of the last harvest. Again, low planting densities and low fertilizer inputs are essential requirements for successful rainfed cropping on such marginal soils in such a marginal rainfall area. The area coverage is **82.14** hectares.

Mapping Unit G: Apedal soils with plithic characteristics

The surface horizon is Orthic, with a depth range of 15 to 20 cm. The horizon below it is a Yellow-brown Apedal B horizon, with a thickness of 65 to 90 cm, underlain by a Soft Plinthic B horizon, with a thickness of 20 to 35 cm. A Soft Plinthic B horizon is under natural conditions an indication of a fluctuating water table, i.e. a water table develops during the rain season and recedes during the dry season. In this case it might have developed artificially as a result of long-term over-irrigation. The surface stoniness of the area is 15%, with an almost flat landform.

Classification:

South African system: Avalon form.

WRB system (tentative): Possibly a Paraplinthic Luvisol.

Most of these soils have been used for the production of vegetables such as cabbage and carrot under irrigation for a long period of time. In South Africa it has been found that these types of soils are the ideal soils for rainfed crop production in marginal rainfall areas, such as the study area. It is probably used for irrigation in the study area because of its close location to the water sources, favorable landform and topographic position. The area coverage is **33.07** hectares.

Mapping Unit H: Shallow apedal soils

This mapping unit is characterized by an Orthic surface horizon of average 10 to 15 cm depth. The sub-surface horizon is a Red or Yellow-brown Apedal B horizon of 15 to 25 cm thickness. The landform of the area is sloping, with surface stoniness of up to 40% of dominantly quartz.

Classification:

South African system: A very shallow phase of the Hutton form (where there is A Red Apedal B horizon) and Clovelly form (where there is a Yellow-brown Apedal B horizon).

WRB system (tentative): Leptosols (where the total soil depth does not exceed 25 cm) or Epileptic Regosols (where the total soil depth is between 25 and 50 cm).

It is used for extensive grazing and once every 5 years cultivated with wheat and/or barley for dual purposes: In good season for grain harvest and in dry seasons the crop straw will be forage for animals. The area is overgrazed and the soils are highly compacted and dry, so that auguring was very difficult. The wisdom of cultivating such shallow soils in such dry area must, therefore, be questioned. The area coverage is **142.78** hectares.

Mapping Unit I: Man-made soils.

This area is located east end of the village. It is covered with recently deposited solid wastes and excavated soils from construction sites of the city. Before it had been used predominantly for extensive grazing, with some plots for rainfed cultivation. The area coverage is **33.08** hectares.

Classification:

South African system: Witbank form.

WRB system: No provision for this type of material.

Mapping Unit J: Rock-Lithosol complex

This area is predominantly covered with rocks and very shallow soils of 7 to 15 cm depth. It was terraced in some places and planted with eucalyptus seedlings few years ago. The area coverage is **16.54** hectares.

Classification of the shallow soils in the mapping unit:

- South African system: Mispah form.
  WRB system: Leptosols.

Mapping Unit K: Village and other built-up areas

This mapping unit is the area covered by the village, the recently established factories and other built-up areas within the village land. It covers an area of **65.60** hectares.

Mapping Unit L: Water bodies

This mapping unit is the area covered by water bodies. These are two earth dams located in the village land, which cover a total area of **9.37** hectares.

Mapping Unit M: Cemetery

This is the cemetery of the village and covers an area of **4.4** hectares.

GENERAL NOTE: The general nature of the soils of the area, i.e. the number of shallow soils, the high base status and pH of the soils and especially the occurrence of free lime in some soils, all indicate that this is an area with low and inefficient rainfall. This supports the low rainfall figures in Section 4.2 and confirms the statement in Section 4.1 that it is a mistake to classify this area in the Humid Highland AEZ.

4.4 NATURAL VEGETATION

According to Government of Eritrea (1995) only one decade ago 30% of the country was covered by forest; but today the cover is as low as 1% or even less. In the research area natural vegetation is hardly found, except few remnants in churchyards and some individual compounds. The dominant tree species in the area are *Olea africana* and *Juniperus procera*. *Olea africana* (wild olive) is a typical tree associated with poorly developed soils in **dry** areas. The two tree species mentioned are described as typical of disturbed forests in Eritrea (Ministry of Land, Water and Environment, 1997). These species are economically valuable and were highly depleted by the Italians during colonial times and the remaining by the village community themselves for different purposes. The main causes for the destruction of the vegetation can be summarized as follows:

- Unwise land use systems and expansion of agriculture.
- Construction of traditional houses known as *'hidmo'* and the attitude that trees are abundant and a gift of God to be utilized by man at will.
- Consumption for fuel wood and manufacture of furniture. *Olea africana* is, for example, a very hard wood to work with, but excellent for the manufacture of beautiful and durable furniture.

Reforestation and soil conservation activities started in 1982 under a food-for-work program. Eucalyptus plantations have been planted in the rocky hilly areas of the village, as described under Mapping Unit J in Section 4.3, indicated in the land use land cover map (can be found in the pocket at the back of the dissertation) and shown in figure Fig 4.3 below. This is similar to the successful reclamation of barren rocky hills by means of tree planting in an arid area near Keita in Niger, but with the notable difference that in the latter case more drought tolerant trees were used (Laker, personal communication).

Figure 4.3 Reforestation and Soil conservation in rocky hilly areas (Source: Bein, Negassi, Tengnas & Ghebru 2000).

4.5 WATER

By far the biggest part of Eritrea is characterized by arid to semi-arid climatic conditions. The overall picture of the country is that water in essence is a finite resource (Government of Eritrea, 1995). There is scarcity of water both for domestic consumption and agricultural purposes for most parts of the country. As indicated by the data in Section 4.2, and supported by interpretations from Section 4.3, this picture of aridity is also true for the study area.

The main sources of water in the study area are:

a. The two streams partially encircling the outskirts of the village area. This water is sewage and wastewater from Asmara city. The serious pollution of the streams by wastes and effluents of Asmara city causes the water to have big health hazards for human consumption and watering animals. It is used for irrigation of crops, fodder and vegetables, even though it is highly recommended not to use this water for

irrigation of non-cooked food crops because it is so highly polluted by effluents from different factories in the city.

b. There are one small and one large communally owned earth dams in the area. The water from both dams was formerly used for animal watering, irrigation purposes, washing of clothes and manufacturing of bricks. In 1998 the small dam was given to an industrialist involved in the construction of tiles. This means that only one dam is now available for use by the community. People living in the vicinity of the dam that is no longer available now have to find water from the other dam which is available and have to travel long distances to collect it.

c. There are a number of hand-dug wells along the streams and downstream of the dam. These hand-dug wells are used for irrigation of field crops, vegetables and forage only.

There is no water pipe network or water reservoir for human consumption in the village. They usually walk more than 3 km to fetch potable water from the western end of Asmara city. The female and young male members of the community are responsible for collecting water for the family. Sometimes privately owned trucks or water tankers sell water to the village community at their doors but at relatively expensive rates.

CHAPTER 5

SOCIO-ECONOMIC AND RELATED FACTORS IN THE STUDY AREA

5.1 INFRASTRUCTURE

A gravel road connects the study area, Adi-Segdo, with Asmara and nearby villages. The Italians first constructed this road when the country was under their colonial rule during the 20th century. During the *Derg* regime, when Eritrea was under Ethiopian rule, the road was upgraded and expanded in width under a food-for-work program in the 1980's. This road is easily eroded, uncomfortable and requires continuous renovation and repairing. Until 1995 the community were renovating the road under a food-for-work program from the Eritrean government. From 1996 onwards the maintenance of the road became the responsibility of the village community.

A railway, which was constructed during the Italian colonial period, passes through the village. This railroad connected the Port of Massawa with big state farms at Tessenai in the west end of the country. The railway was destroyed during the war for independence against Ethiopia, as was the case with much of Eritrea's infrastructure (Berhane, 2000; Weldegiorgis, 2000). The government started rehabilitating and reconstructing the railway in 1994 and the progress is promising. Completion of the railway will be of great importance to the country and the villages crossed by it, because it will improve transportation of their agricultural products to markets, thus enabling them to get better profits.

City buses extended their route to the center of the village in 1997. There are two big and three medium sized buses on this route. They start at 7:00 in the morning and end at 8:00 in the evening. These buses are only for transportation of people. Farm products are usually transported to the main market in Asmara by means of horse or donkey drawn carts or wagons. The introduction of city buses to the village center resulted in a greater responsibility on the community to maintain the roads regularly. If the road is not properly maintained, the city buses turn back before reaching the village. Members of the village living in diaspora and around the

village have contributed about 40,000 US dollars for the upgrading of the road to an all-weather tar road. But the budget is not enough for the designated purpose, hence they are expecting either the government or NGOs to cover the remaining costs.

Electricity was introduced to the village during the *Derg* regime. The village community covered expenses for the extension of electricity lines from Asmara to the village. Before the independence of Eritrea from Ethiopia, the supply of electricity was only from 6:00 in the evening to 11:00 at night. From 1992 the supply of electricity was upgraded to 24 hours a day. The community uses electricity for home lighting only because it is too expensive to use it for cooking and other domestic purposes. They still use firewood, crop residues and animal dung for the preparation of food and warming the rooms. Thus the introduction of electricity did not significantly reduce deforestation. This pattern of using electricity for lighting only, but (because of the cost) not for cooking or heating, is a common phenomenon in other parts of Africa also. For the same reason electrification of Soweto, the well-known township near Johannesburg in South Africa, did not reduce air pollution from coal-fired stoves and heating devices, as was hoped (Krüger, as mentioned by Laker, Personal communication). The inhabitants of the township use electricity mainly for lighting only, and still continue using coal-fired stoves.

Communication is a big problem, since there is no telephone line that connects the village with Asmara City and other villages or towns.

Lack of adequate education facilities is a major constraint in the study area. In the past children of the village were walking a minimum of 6 km to get to a school. An elementary school was constructed with contributions from the village community and the government in 1980s. This elementary school started with very few classes and has been upgraded year after year. Nowadays it has 10 classrooms, an office and a library, but no sanitation facilities at all. In 1993 the school extended the program from elementary to junior secondary level. But still there is a shortage of classrooms, teaching equipment and other facilities like sanitation to accommodate the children of the community. A kindergarten was established for the village in 1996. Even though it is at least a start, it is too small to accommodate all the kids of the village.

Lack of adequate health facilities is one of the other major problems in the community. There is no hospital or clinic in the village. The nearest clinic and hospital are 5 km and 8 km far respectively. Especially during the night lack of transportation and communication (no telephone line) facilities pose big problems for pregnant women and children. There are no sanitation facilities, even public ones, in the village. They also lack enough containers for dumping their waste. Even the very few containers supplied by the municipality for dumping waste are not collected regularly.

Although they are faced with many serious problems and have only limited funds available, the willingness of the community to contribute to development in their own area, as shown by their involvement in the upgrading of the road and the establishment of a school, is a positive sign.

5.2 DEMOGRAPHY, RELIGION, CULTURE AND ORGANIZATIONAL STRUCTURES

5.2.1 Population

All people in the study area belong to the Tigrina ethnic group, which is dominant in the central and southern highlands of the country.

According to a population census, which was conducted by the local government at the beginning of the year 2000, the total population size of the area was estimated to be 8 379. This number include people from other places living in the village permanently by renting houses there recently, such as government employees, business people or farm workers. There are 1648 households in the area. This shows that the average size of a family is 5 persons per household. Out of this number only 710 (43%) households are indigenous farmer families mostly or completely dependent on land or agriculture for their livelihood. The majority of the households in the study area are, therefore, those of government employees, business people or farm workers who live in the village by renting houses.

5.2.2 Religion and Culture

Religion and culture are important and have a great influence in the country, especially in the rural areas. This is also the case in the study area. About 97% of the population of the study area are Christians. Most of them are Coptic orthodox, few are Catholic and very few are Protestants. The remaining 3% of the community are Muslims. In total almost half a month per year are religious holidays for Coptic orthodox and Catholic religion followers, hence they are not allowed to plough, weed or harvest during these days. Even though they understand that a one day delay in ploughing, weeding or harvesting can have significant effects on production they are strictly obliged to obey the laws of the church and culture. During the survey they were asked what the consequence of practicing agricultural activities during religious sacred days would be for an individual. The reply was that he or she who breaks the law would be excommunicated from the church and banned from all traditional communal services or activities by the community.

5.2.3 Organizations and Institutions

In the country as a whole priority has always been given to maintain strong mass organization as a means of mobilizing people to achieve national or local objectives (Government of Eritrea, 1995). There are three major mass organizations in the country. These are:

1. National Union of Eritrean Women (NUEW)
2. National Union of Eritrean Youth and Students (NUEYS)
3. National Confederation of Eritrean Workers (NCEW)

In terms of membership size and scope of activities on environmental issues these organizations are expanding by going down to village level. They play an active role in participating in an annual "green-up and clear-up" day where organized groups pick up litter and plant indigenous trees and shrubs at national level. The main activities of these organizations in the study area are repairing and renovating of roads within the village and connecting roads to nearby villages, their farms and city or market centers. The road that connects the research area with Asmara is

intensively renovated and repaired twice a year before the start and at the end of the main rain season.

In addition to the above-mentioned organizational institutions the dairy producing farmers in the village and other neighboring villages formed an organization in 1997. The main activities of the organization are resolving problems in their dairy farming like importing and supplying animal food from outside and inside the country. In 1999 the dairy farming farmers' organization managed to buy the Milk Products Factory from the government during the privatization period. This factory has its own administrative body, with rules and regulations, which is controlled by a board elected by the farmers from the farmers. The short-term objective is increasing their production and resolving minor problems. Its long-term objectives are accessing markets outside the country, expanding their organization to national level and securing enough animal feed.

5.3 INDUSTRIAL DEVELOPMENT

There are five privately owned small factories inside the village. These factories were established in 1997-1998 after the incorporation of the village under the city administration of Asmara. Allocation of land for investors by the government was based on understandings and agreements between the local government, the village leaders or elders and the investors. Thus the establishment of these factories was meant to benefit the village community by creating job opportunities. Even though the community was optimistic and had great expectations, they have not yet benefited from their establishment. The factories are Paints producing, Animal food producing, Human food packing, Tiles producing and Plastic Pipes producing.

A visit to these factories during the third week of January 2000 as part of the present study revealed that only two of them, viz. Tile and Human food packing factories, have started thus far, and both at a small scale only. A meeting was scheduled with the owners of the factories or their representatives together with the local office authorities. The agenda of the meeting was to have a general view on the programs and plans of the factories, to find out why the expected benefits are delayed or failed and to extract what benefits can the community obtain in the near future. But neither the owners nor their representatives did show up. The view of the community in this issue

is "the government should pressure the investors to fulfill their promises or force them to pay fixed amounts of money, which can be spent for the development of the village".

5.4 LAND TENURE SYSTEM

There are several land tenure systems in the country. However, according to Azbaha, Iyassu & Mohamedkheir (1998) the major and dominant land tenure systems could be reduced into three:

1. Diesa: Communal village ownership of land.
2. Risti: Individual household or family ownership of land. This is common in the southern part of the country.
3. Demaniale: State ownership of land. This land is the most fertile and potentially irrigable land along river basins in the western and eastern parts of the country, i.e. excluding the central highlands.

Of the above-mentioned major land tenure systems, the Diesa system of land ownership is dominant in the central highlands of the country, in which the study area is located. This land tenure system is the only existing system in the study area. It refers to village-wide communal ownership of land. In the Diesa type of land holding, the land is the collective property of the village (Azbaha *et al.*, 1998). The main characteristic of the Diesa system is that all land within the designated area of a village is conceived of as being the common property of the community in the village. Thus, every permanent member of the village is entitled to a share of village land through periodical redistribution every 5-7 years. It operates in such a way that elected committee members, normally village elders, establish criteria for eligibility and classify the land according to its potential.

The main criteria used for the classification of land are distance from the stream, depth, topsoil texture and surface stoniness. The criteria for eligibility are marital status and number of children. A married couple gets land both for farming and a homestead when they decide to live by themselves outside their family. Culturally married couples stay with the family of the male minimum for the first two to three years after their marriage. Family size is used to group the community into families of up to three, five and more than five. The size of agricultural land

allocated differs according to the size of the family. Every eligible member of the village is allocated his/her share of land from the different qualities of land available, classified according to the previously mentioned criteria. The process of distribution of land among the villagers is by drawing lots, referred to as "echa". This system provides equitable access of land for all eligible members according to the criteria.

Even though this tenure system ensures equity of access to land, it lacks incentives to farmers to put measures into practice for the most productive use of the land, i.e. for improving efficiency, and/or for long lasting land improvement or conservation activities.

The weaknesses inherent to the old land tenure system are:

- A rotation period of 5-7 years is too short for people to have the incentive to make long-term investments for improving the land, such as tree planting, digging water wells, making permanent water canals and conservation structures, i.e. exhaustive cropping or "soil mining" becomes the order of the day.
- Cropland is open to communal grazing in the post-harvest season, which results in the removal of crop residues that could provide ground cover against wind erosion and addition of organic matter to the soil.
- Under communal land ownership land cannot be used as security to obtain credit or loans to purchase new farming equipment or production inputs.
- Newly married couples have to wait some time to attain their share of land. They only get the chance of having their own share of plots when someone in the village dies and his land is reassigned or when the next reallocation cycle starts.

In view of this type of situation, FAO (1996) puts such clear emphasis on the importance for a government to find the correct balance between equity and efficiency in regard to agricultural land. In a situation where suitable cropland is scarce and food security is a priority, efficiency of land use should be a high priority.

In 1994 the government of Eritrea has promulgated the Land Proclamation Number 58/1994 to reform the old land tenure systems in the country. According to the Government of Eritrea (1994) ownership of all land of the country is vested to the state. This land proclamation is focused at the following aims (Government of Eritrea, 1994):

1. To implement equitable rights of distribution of land for every citizen aged 18 and above.
2. To optimize sustainable production on all land according to its potential.
3. To provide a basis for developing ecologically sound land use plans for development activities.
4. To increase the effectiveness of economic growth of rural and urban populations.
5. To protect the natural environmental resources against degradation.

Under this proclamation every citizen aged 18 and above, who is willing to work on land, will be entitled to land under usufructure right for life. However, this right cannot be sold, but may be leased. The government has halted land redistribution since independence to implement the new tenure system. ***But neither redistribution nor implementation of the new system has been done till today.***

5.5 PRESENT LAND USE

Present land use cover of the area was extrapolated from aerial photographs of 1:5 000 and 1:15 000 scales as field and final publication sheets respectively. The aerial photographs were the most recent and available ones produced in 1994. During the field visits a detailed investigation was carried out to identify changes in land use during the last six years. It was found that an area of **12.13** hectares, which were under rainfed crop production, is now under industrial use. This is the area occupied by the five factories established starting from 1997-1998. Another significant area of land under rainfed cultivation has changed to irrigated land. Hence the total area of irrigated land extrapolated from the aerial photograph of 1994 which was **163.71** hectares has increased to **297.55** hectares in the last six years (Table 5.1). This shows that the farmers are shifting from rainfed cultivation towards irrigated cultivation for increasing productivity to satisfy the demands. Most of the area under irrigation was planted with maize and alfalfa for production of

forage. The present land use is indicated in Map 5.1, attached at the back of the dissertation. The area coverage of each land use and land cover mapping unit is given below (Table 5.1).

Table 5.1 Land use land cover and area coverage of each type of use in Adi-Segdo in 2000

Land Use Land Cover Type	**Area Coverage in Hectares**
Irrigated land	297.55
Rainfed cultivated and fallow land	263.02
Grazing land (with patches of fallow land and rock outcrops)	44.45
Grass land (seasonal wet land)	39.12
Village (including other built-up areas)	65.60
Water body	9.37
Damping site for excavated soils from city	33.08
Cemetery	4.4
Total Area	**756.59**

5.6 FARMING SYSTEMS

The farming systems in the area can be categorized in three different but interdependent types. These are rainfed, irrigation and livestock farming. Every eligible farmer has his/her own share of land both from rainfed and irrigated land, but grazing land is communally used.

5.6.1 Rainfed Cropping by Individual Farmers

Rainfed cropping by individual farmers was a major farming enterprise in the study area until 1998. It was predominantly small-scale subsistence farming with cereals mixed with livestock production. The dominant crops grown under rainfed cropping are wheat, barley and maize, with teff and finger millet grown at a smaller scale. Barley and wheat grain is ground into flour and made into a pancake called *'kitcha'* of few millimeters thick and eaten with vegetables and/or meat. This is the staple food of the area. The flour is also made into a stiff mush or porridge by

adding it to boiling water and stirring until it is the right consistency. It is eaten with butter and/or yogurt. Teff grain is ground and used to make a pancake called *'injera'*, softer than *kitcha*, that is eaten with soup of vegetables and/or meat. Finger millet and barley flour are used to make local drinks called *'sewa'*, but barley is preferably used for food rather than for making local drinks. Since 1999 collective rainfed cropping has been introduced in the area (Section 5.6.2).

Information on cultural practices given below is in reference to the traditional farming system practiced by individual small-scale farmers.

Land Preparation and Ploughing

Generally land preparation begins just after the first rain, so that water infiltration into the soil can be improved. A small number of farmers start land preparation during the dry season to incorporate remaining crop residues into the soil a few weeks after communal grazing on the stubble fields has ended. After harvesting croplands are grazed communally by the animals in the village. The traditional plough of the area is called *"Mahresha"*. It is usually made of two wooden boards and a metal shear embedded in the tip and is drawn by oxen (Fig 5.1). It operates as follows: The oxen pull the whole set as the farmer holds down tightly the set connected with the metal shear and the wooden board. The metal tip penetrates the ground and together with the wooden board form ridges by lifting and putting the soils on both sides. The plough depth using *mahresha* is about 12-18 cm deep, which is very shallow. Large clods of the soil are broken into pieces using sticks or thrown on top of farm edges or terraces to act as a barrier during surface water runoff.

Sowing

Sowing is usually done after ploughing twice. The first plough is during the dry season or after the first rain and second some days before sowing. Seed broadcasting is by hand followed by shallow plough to cover the seeds with soil.

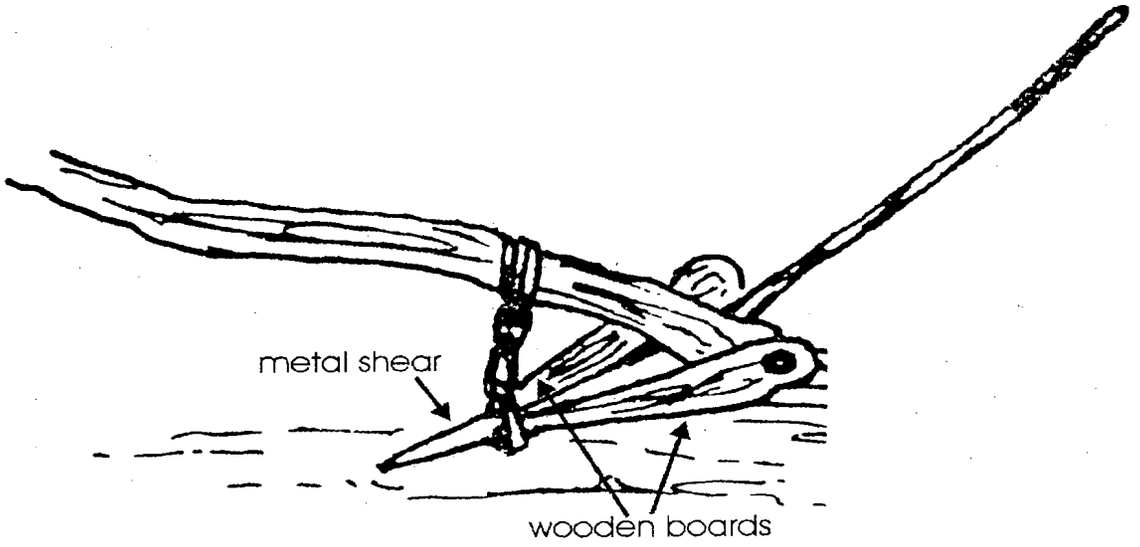


Fig 5.1 "Mahresha" traditional plough

Weeding and Pest Control

The first weeding is usually done by hand since it is essential to weed when the plants are still very small and using the local plough at this stage could damage or destroy seedlings. All the members of the family except the children participate at this time of weeding, because it is difficult for children to differentiate the weeds from crops at the early stage of development. The weeds in the first weeding are left on the ground or buried in the soil to increase the fertility. The second and the third weeding are performed either by hand, with all the family members including the children participating, or using the local plough. During the second and third weeding, weeds are carefully collected and fed to animals. Sometimes the weeds are thrown on the terraces or farm edges to reduce or prevent surface water runoff. Pests are controlled by pesticides supplied by the Ministry of Agriculture at a very nominal price. Agricultural extension officers demonstrate the spraying of pesticides to the farmers and also participate in applying the pesticides in the field with the farmers. According to the farmers and the local office of the Department of Agriculture the most common pests and diseases in the area are Early and Late blight, Aphids, Leaf Rust and Cutworms.

Soil Fertility Management

According to unpublished reports from University of Asmara and FAO (2000) and personal communication with experts from the Ministry of Agriculture the fertility status of the soils in the country is generally very low. The farmers in the study area usually give priority to fertilizing the irrigated areas, rather than the rainfed cropping areas, because of the more reliable production and higher profits obtained under irrigation. They usually apply household wastes and animal dung and rarely some farmers apply commercial fertilizers like urea supplied by the Ministry of Agriculture at a reasonable price. The other method of fertility management for irrigated farm plots is that in the dry season when the flow of the stream is low they excavate transported and deposited soils along the riverbed and riverbank and disperse it on their farms. The soil fertility management practice in the rainfed-cultivated land is mainly fallow and application of ash and household wastes. Nowadays the fallow period is almost zero, however, especially in the high and medium potential areas, due to population pressures on land use. Hence no significant soil fertility management practices are applied in the areas used for rainfed crop production. As indicated earlier, the traditional land tenure system is an important causative factor in this lack of soil care.

Harvesting

Harvesting is done by hand. Mature dry grain crops are cut using sickles, placed in heaps and allowed to dry thoroughly before threshing. Crop residues and the straw and chaff remaining after threshing are usually collected carefully and used as animal feed during the dry period of the year. Some farmers also use the stalks and straw for the construction of animal housing and as source of energy for cooking.

Crop Calendar and Yield

The yield of crops per hectare for barley, wheat and maize was obtained from the farmers themselves and converted to quintals per hectare. Traditionally they have their own method of estimating the size of their farm and yield. They estimate area of land in '*Tsimdi*', which is

equivalent to a quarter of a hectare and yield in '*Tsenet*', which is equivalent to 65-75 kg. Also the yield of the crops was cross-checked with the local office of the Ministry of Agriculture and was found to be more or less similar. But yield of teff and finger millet is obtained from the local office of Ministry of Agriculture.

Table 5.2 gives crop calendars and average yields from 1995-1998 for the five main crops, grown under traditional rainfed agriculture in the study area, in quintals and tons per hectare.

5.6.2 Collective Rainfed Farming

The government introduced a collective farming system in the western and southern parts of the country in 1996. These regions are believed to be the highest potential agricultural areas and breadbasket of the country. In this farming system the plots of a whole village are ploughed and harvested together, using government-owned farm machinery. All farmers in the village are supposed to participate equally in all manually operated farming activities, such as land leveling for improving ease of movement of machinery, weeding and other farming practices, but practically this is far from expectations. They also share equally all the machinery operation expenses. After two years, in 1998, the collective farming system was evaluated as being effective and more productive than the traditional system by the decision-makers. Hence the system was spread almost all over the country. The rainfed-cultivated land of the study area has also been cultivated under the collective farming system for the last two years.

According to the farmers of the study area the introduction of the collective farming system has both advantages and disadvantages. In the past poor farmers, those who have shortages of draught oxen and farming equipment, had to wait for the relatively rich farmers to finish ploughing their land so that they can hire draught animals and/or equipment from them. This delay had a significant negative impact on the output. After the introduction of the collective farming system such long delays for those farmers who have shortages of farming equipment and materials (poor farmers) were solved. Also according to the provincial Office of the Ministry of Agriculture the expenses for ploughing using machinery and fertilizers paid by the farmers are not the real costs, but the costs are subsidized by the government. The main disadvantage is the

late arrival of farm machinery both for ploughing and harvesting, though there is still an increase in production relative to traditional farming system. Hence the provincial Office of Ministry of

Table 5.2 Crop calendars and yields for the five most important crops grown under traditional small-farmer cultivation in the study area.

Type of Crop	**Barley**	**Wheat**	**Maize**	**Teff**	**Finger Millet**
First Plough	1st week of April to middle May	1st week of April to middle May	Middle March to middle April	1st week of March to end of March	1st week of March to end of March
Second Plough	End of May to middle June	End of May to middle June	Middle April to end of April	1st of April to middle April	1st of April to middle April
Sowing	3rd week of June to end of June	3rd week of June to end of June	Middle April to middle May	1st week of April to end of May	1st week of April to middle May
Weeding	1st weeding is 10 to 14 days after sowing. There are no fixed date for the 2nd and 3rd weedings. It depends on the convenience for the farmer and amount of weeds infesting a field.				
Harvesting	3rd week of September to middle October	1st week of October to end of November	1st week of October to end of November	2nd week of September to end of November	End of November to end of December
Threshing	1st week of September to end of December	2nd week of September to end of December	1st week of November to middle December	1st week of September to end of December	2nd week of November to 2nd week of January
Yield in Qu. / Ha	9.0 - 9.6	7.8 – 8.5	6.5 – 7.0	2.8 – 3.5	5.5 – 6.0
Yield in Tons / Ha	0.9 – 0.96	0.78 – 0.85	0.65 – 0.7	0.28 – 0.35	0.55 – 0.60

Agriculture estimated that the profits went up by 35%, but no actual records were available to substantiate this figure. This increment in profit and production is because of application of fertilizers and subsidized cost of production by the government.

5.6.3 Irrigated Farming

Irrigation in this area started at beginning of the 20th century, during the Italian colonial period. The village community and also the surrounding villages crossed by the stream have been utilizing the sewage stream for producing irrigated crops since about 80 years. At that time the irrigated area was a narrow strip along the riverbank. The farmers used buckets to draw water and irrigate their plots using furrow systems. The main crops grown, were vegetables like tomatoes, potatoes, spinach, lettuce, cabbage, green pepper, carrot and maize for fresh consumption and markets. Presently most of the irrigated land of the village is used to produce forage rather than vegetables.

Over time farmers intensified irrigated farming because they realized that it is more reliable and more productive than rainfed cropping. They expanded their irrigated area by cutting the natural vegetation in the surrounding areas and also by converting rainfed cultivated lands into irrigated plots. The irrigated areas of the village are located along the streams and below the earth dam constructed some time ago. There are also irrigated areas around 9 shallow hand-dug wells along the stream and downstream of the dam and 16 reservoir basins for collecting water mainly by pumping or buckets from the stream during high runoff to be used in dry periods or low runoff. Almost all the farmers abstract water from the water sources with a rope-and-bucket system. These basins are up to 4 meters in depth and well coated and polished with clay soil to minimize loss of water to under ground through percolation. The farmers always keep the reservoirs filled with water and cover them using iron sheets, wood and grasses to reduce evaporation and to prevent accidents that could happen to humans and animals.

Irrigation systems in the area are a combination of traditional and moderately advanced systems, with few farmers owning water pumps. But most of the farmers use a rope and bucket system of irrigation, whereby water is abstracted from the stream, dam, hand-dug wells or reservoir using a rope and bucket and carried to the farm plots to water the plants. In some others the water is discharged into the water canals, which run from the edge of the water source to the farm plots, and conveyed to the farm. This system is laborious and time consuming and significant amounts of water losses from the buckets and conveyance occur. Hence it can be said there is low water

utilization efficiency. A small number of farmers own water pumps, either privately or communally, with which they pump water from the sources to irrigate their fields. These farmers convey water to the farm through canals but few of them convey water through portable plastic and metal water pipes. The advantage of owning this kind of pipes is that a number of farmers can use a single set of pipes and irrigate their farms one after another. But despite the advantage, the cost of the water pump and conveyance pipes is not affordable by most of the farmers. In the dry season, when the flow of the stream is low, the farmers excavate the transported and deposited soils along the riverbed and riverbank and disperse it on their farms. This is done for two reasons: Mainly by excavating the soils and building weirs in the riverbed, using stones, wood and other material to slow down the flow of water during the rain season enables them to scoop and/or pump enough water to irrigate their fields. The other reason is for improving the fertility of the soil as indicated previously under soil fertility management.

The government has recommended major steps to be taken to limit the use of the sewage polluted water from the streams for irrigation, especially for the production of non-cooked edible foods like lettuce and carrots, until some major steps are taken to treat the water. The guidelines to water quality standards for irrigation purposes are given in Table 5.3 below.

According to personal communication with the Mr. T. Medhanie from the Municipality of Asmara, a project proposal has been drafted to treat and recycle the water to render it suitable for irrigation purposes in the near future. A water sample was collected from the wastewater stream during the dry season and taken for analysis to the Water Resources Department. It is believed that this water has high concentrations of chemicals and pollutants during the dry season. During the rain season, because of the increase in volume of water, the sewage is diluted and the concentration of chemicals and the pollutant content of the stream's water are believed to be normal. It must be kept in mind that the main rain season lasts for two months per year only and the dry season for ten months. In other words the potential problem period is about ten months per year.

With the limited capacity of the laboratory equipment, professionals and especially chemicals, only limited results on the quality of the water could be obtained (Table 5.4).

Table 5.3 Guidelines for interpretation of water quality for irrigation

Potential Irrigation Problem	**Units**	**Degree of Restriction on Use**		
		None	**Slight to Moderate**	**Severe**
Salinity (*affects crop water*				
Availability)	ds/m	<0.7	0.7 – 3.0	>3.0
EC_w				
(or)				
TDS	mg/l	<450	450 – 2000	>2000
Infiltration (*Evaluated using EC_w and SAR)*				
SAR = 0 – 3 and EC_w =		>0.7	0.7 – 0.2	<0.2
= 3 – 6 =		>1.2	1.2 – 0.3	<0.3
= 6 – 12 =		>1.9	1.9 – 0.5	<0.5
=12 – 20 =		>2.9	2.9 – 1.3	<1.3
= 20 – 40 =		>5.0	5.0 – 2.9	<2.9
Specific Ion Toxicity				
Sodium				
Surface irrigation	SAR	<3	3 – 9	>9
Sprinkler irrigation	me/l	<3	>3	
Chloride				
Surface irrigation	me/l	<4	4 – 10	>10
Sprinkler irrigation	me/l	<3	>3	
Boron	mg/l	<0.7	0.7 – 3.0	>3.0
Miscellaneous Effects				
Manganese	mg/l	<0.2		
Nitrogen	mg/l	<5	5.0 – 30	>30
Bicarbonate				
(*for overhead irrigation*)	mg/l	<1.5	1.5 – 8.5	>8.5
pH		Normal Range 6.5 – 8.4		

Adapted from University of California Committee of Consultants 1974 (Ayers & Westcot, 1985)

Table 5.4: The quality of the wastewater stream in Adi-Segdo, as determined in January 2001.

Water Parameters	Symbol	Unit	Amount present in the water
Cations and Anions			
Calcium	Ca^{++}	meq/l	195.2
Magnesium	Mg^{++}	>>	4.8
Sodium	Na^{+}	>>	291.0
Potassium	K^{+}	>>	48.53
Iron	Fe^{++}	>>	0.53
Manganese	Mn	>>	1.06
Bicarbonate	HCO_3^{-}	>>	839.6
Carbonate	CO_3^{--}	>>	0.0
Sulphate	SO_4^{--}	>>	65.0
Chloride	Cl^{-}	>>	336.0
Ammonia	NH_4^{+}	>>	84.7
Nitrate-Nitrogen	NO_3^{-}	>>	44.4
Acid/Alkalinity	pH	1-14	7.82
Electrical Conductivity	Ec	ds/m	2.5
Total Dissolved Salts	TDS	mg/l	1470.8
Sodium Adsorption Ratio	SAR	ratio	28.3

Where meq/l = milliequivalent per liter

mg/l = milligram per liter

ds/m = decisiemens per meter at 25^0C

Remarks: The water type is Calcium Bicarbonate and the amount of ammonia is extremely high, enough to cause problems in human health.

Source: Water Resources Department, Asmara

In reference to the water quality guidelines for irrigation (Table 5.3) salt content or salinity of this water, determined by EC_w or TDS, has slight to moderate effects on crop water availability. The SAR and electrical conductivity of the water, which are 28.3 and 2.5 (Table 5.4) respectively, are within the limits of slight to moderate effects for irrigation. This affects the water infiltration into the soil. Yield of crops and forage, which are sensitive to salinity grown in the area, is affected by the quality of the water. Amount of Iron and Manganese has miscellaneous effects but they are within the range of suitable water for irrigation. The high amount of calcium bicarbonate is insignificant in surface irrigation. The high amount of ammonia is dangerous to human health especially when used to irrigate crops eaten non-cooked. The pH of the water is within the acceptable range of normal for irrigation.

It should be kept in mind that this water sample was taken during January (dry season). Based on these analyses utilization of this water for irrigation during low rainfall seasons can result in low productivity and salinization of the area in the long run. **Therefore it is recommended that this water should not be used for irrigation purposes especially during the dry season.** According to the plan and program of the government this water is going to be treated and recycled in the near future. Hence, this will result in possible utilization of the water without significant negative impacts on the soils and production.

The irrigated land of the village is always under cultivation. As indicated in previous sections, farmers concentrate more on their irrigated plots than on their rainfed cultivated land. They spend more money and time in land management, application of the available fertilizers such as animal dung, ash and to some extent commercial fertilizers on their irrigated plots.

As mentioned earlier, in the past farmers used to produce different vegetables in their irrigated plots, but today most of the irrigated land is used to produce forage for livestock. The main reason for this is an ever-increasing switch to dairy production. At present only 42 farmers are involved in relatively intensive dairy farming. Most of the rest of the community members, due to the reasons indicated below, rented their share of irrigable land to the farmers practicing dairy production at a rate of 250 US dollars per hectare per year. According to the local Office of Administration of the Department of Agriculture and Local Government this agreement is usually

renewed every year, because long term land rent agreements can result in conflict if the new land tenure system is practiced and land is redistributed before the end date of the agreement.

The shift from vegetable production to forage was gradual and the following points are the major reasons for the transition from vegetable production to forage production for dairy farming:

- In the past the village community were able to sell their farm products directly to the consumer in the city themselves. But nowadays they are not allowed to do so unless they have a license from the municipality. The street traders are forcefully evicted by the authorities. Hence they will be forced to sell to the middle businessmen at a lower price. They believe that it is not profitable to produce vegetables for the market under these conditions.
- The lower preference of vegetables from the village by the consumers and middle businessmen in the market because it is produced using polluted sewage water, combined with an increase in supply of vegetables from other parts of the country.
- Poor production and marketing strategies. If the price of one product, e.g. tomatoes, is high this season compared to other products all the farmers produce tomatoes the next season and there will be excess supply, which results in lower prices.
- The high demands for milk and milk products in the market and increasing price time after time. For instance the price of milk per liter was 0.16 US dollars four years ago but now it has doubled and became 0.33 US dollars per liter.

5.6.4 Livestock Farming

Improved dairy farming for commercial purposes was introduced to the country during the Italian colonial period. A small number of farmers from the village community in the study area started dairy farming some time ago, but it was not possible to ascertain when exactly they started. They were able to get calves from Elabered Agro-Industry Farm, a farm that was owned by Italians and from Catholic missionaries who were practicing dairy farming. Over time the number of dairy farmers has increased. Nowadays there are 42 farmers involved in dairy farming for commercial purposes in the study area. At present there are 354 dairy cattle in the village. These are all productive exotic breeds and hybrids of the exotic and local varieties. The exotic varieties are

Holstein and the hybrids are of Holsteins and Barka (local breed). According to the farmers involved in dairy farming at present market price it is more profitable to practice dairy farming than production of cereals or vegetables. During low seasons, i.e. when there is shortage of feed, individual cows produce 6 – 10 liters of milk per day and during good seasons, i.e. when the is no shortage of feed, individual cows give up to 16 liters per day. As mentioned earlier, the present price of milk is 0.33 US dollars per liter.

Other animals, such as non-dairy cattle, sheep, goats, horses, donkeys and chickens are present in village. Animal production is practiced mainly in traditional ways in the village, except for the few farmers involved in intensive dairy farming and the very few who recently started poultry farming. The majority of cattle are dairy cattle and are exotic or improved and hybrid of exotic and local varieties. Every household is involved in traditional poultry farming of unimproved indigenous breeds; i.e. the birds are released from the coops early in the morning and feed extensively in the community. Traditionally no special attention in feeding, health and management is given to the birds. Very few farmers have started poultry farm using exotic or improved breeds recently. Animals are for different purposes important to the farmers. Oxen are used for ploughing and threshing. Horses and donkeys are used for transportation. Poultry and dairy products are used for market and home consumption, but are also sources of cash income for the community. The exact number of indigenous breeds of poultry was not available, but according to the community every household owns an average of 8-13 chickens. Table 5.5 shows the animal population size of the village.

Table 5. 5Animal population of Adi-Segdo village

Dairy Cattle		**Oxen**	**Sheep**	**Goats**	**Donkeys**	**Horses**	**Chickens**
Local	Improved	(Local)	(Local)	(Local)	(Local)	(Local)	Improved
148	354	65	568	63	16	54	480

Source: Local Office, Ministry of Agriculture

Poultry production in traditional ways has been known in the village from the past. Traditional ways of poultry production is the task of the female population of the community. Every household has a few chickens, which are mainly used as a source of cash income for the family and women specially. The Ministry of Agriculture introduced poultry production for commercial purposes, using improved breeds, to the country few years ago. According to the local government office the government, National Union of Women, in collaboration with an NGO, arranged a training program in home economics and poultry farming for improving the living standards of the women of the community in some parts of the country. Every woman of the country is eligible and it is for free. Those who attend the program and complete it without interruption receive 25 chickens as an initiative to start and practice poultry farming and improve their lives. At present there are 8 women in Adi-Segdo village who completed the program and started poultry production under this program. The farmers of the village believe that the government should diversify this program and supply them with all the necessary inputs and also should allow the male population to participate.

There is a great shortage of animal feed in the village. The grazing area is highly degraded and probably compared with its carrying capacity, it is overstocked with animals. Hence there is always shortage of forage in the village, especially during the dry seasons. Normally the supplementary feed for animals in the area during the dry season is crop residues and hay.

Commercially oriented farmers, i.e. those involved in dairy farming, grow green feed, such as alfalfa, maize, wheat, barley, lettuce and cabbage under irrigation for their animals. The crops are cut at their vegetative growth stage and fed to the animals. These farmers also buy additional feed that is available on the market. They buy beverage slags from Asmara Brewery Factory, oil slags from Asmara Oil factory and cottonseed from Textile factories. The beverage and oil slags and cottonseed, after being crushed, are mixed with maize or wheat flour and fed to the animals. The amount of feed available from the factories was too limited to satisfy the demand of the dairy farmers, however. These additional feeds from the factories were previously not easily obtainable because at that time all the factories in the country were under the government and until 1999 farmers were compelled to sell their milk to the government to get the byproducts of the factories. At the beginning of 1999 an organization of dairy producing farmers for commercial purposes

from the village and other surrounding villages was formed. The organization has 500 members. All dairy producing farmers for commercial purposes in the study area are members of this organization. They managed to buy the milk processing plant during the privatization period of government owned factories. According to the farmers owning of these factories by the farmers themselves will resolve the problems facing the farmers such as shortage of feed by importing animal feed from outside the country and distributing it to the members at a reasonable price.

According to the village community the Animal Resources Department of the Ministry of Agriculture provides health services for the animals at a very nominal price. There is no problem in the health condition of the animals because there is enough medicine and manpower in the Department of Animal Resources.

5.7 FARMERS' PERCEPTIONS OF GENERAL CONSTRAINTS ON EXISTING FARMING SYSTEMS

During the research a brief discussion was held with community representatives from the study area on the constraints, advantages and problems in their farming systems, also in regard to comparisons between the old system and the new collective farming system introduced to them two years ago.

According to the community representatives, problems in the old farming system are mainly due to the land tenure system, poverty and lack of credit facilities. The '*diesa*' land tenure system has no incentive to make long-term investments and such land cannot be used as security to obtain credit facilities from the bank. Farmers usually make some conservation measures and apply manure the first two-three years after every redistribution of land (see Section 5.4), but as the time for the next redistribution approaches they completely neglect land improvement and protection against land degradation and soil erosion. They do not want to spend money and energy on land which is soon going to be allocated to another farmer from the village.

The village community is optimistic about the new land reform promulgated in 1994. But the delays and unpredictable time of its implementation has aggravated land degradation and soil

erosion. Some farmers are accumulating manure and home wastes to use them after the implementation of the new land tenure system, because the implementation of the new land reform will result in allocation of land to individuals for a lifetime. There is quite an ironical situation prevailing here: On the one hand the community members are eager to see the new system being implemented as soon as possible and cannot wait for it to happen. On the other hand, the government is not ready to implement it because they apparently fear that it will be rejected by the rural communities in favour of retaining the old traditional systems and lead to uprisings by the rural communities. After all, a process of land reform is not an easy task to be completed in a few years.

In general the problems perceived by the community due to

1. The delay in the implementation of the new system, leading to neither implementing the new tenure system nor reallocation of land according to the old land tenure system,
2. Allocation of agricultural land for non-agricultural purposes, such as industrial, development, by local government authorities,
3. Problems inherent to the collective farming system which was introduced and
4. Other agricultural-related problems

can be summarized into:

a. Problems related to the delay in the introduction of the new land tenure system:

- Since the implementation time of the new tenure system is not known and predictable the farmers are not practicing conservation and land improvement activities as before. Some of them are even stockpiling their manure (animal dung) while waiting for the implementation of the new tenure system.

b. Problems related to the allocation of agricultural land for non-agricultural purposes:

- From 1997 the government has been allocating agricultural land of the village to investors for industrial development. It has disappointed the farmers to see someone else from outside being allocated land of the village on a permanent basis, while the villagers themselves are still waiting to receive land on such basis. Even though the government approached the village elders on the importance of the investment and the benefits, such as job opportunities for the community, these benefits have not yet materialized.
- The progressive reduction in the area of the grazing lands over time has created a serious problem to the community, resulting in overgrazing and land degradation.

c. Problems related to the introduction of the collective farming system:

- Late arrival of farm machinery both in ploughing and harvesting has a significant negative impact on production, but in comparison with the traditional farming system there is a significant improvement and profits. The farmers believe that if these machineries arrive on time and the land is ploughed and the crops are harvested at the right time there should be a bigger increase in production.
- Every farmer is supposed to participate equally in manually operated practices and share equally in the profits. But those farmers who have additional jobs in the city raise different reasons for not showing up to participate in the activities, but at the end of the day they share equally in the profits. This can create negligence in the whole community in time. Threshing using machinery chops the crop straw into very small pieces that are hard to collect to be used for animal feed, as source of energy and for construction purposes.
- Farmers are getting far away from their traditional farming methods because of the introduction of the collective farming system but they are afraid to lose its advantages because all the farming machinery are owned by the government.

CHAPTER 6

LAND USE RECOMMENDATIONS AND PROVISIONAL PROPOSED LAND USE PLAN FOR ADI-SEGDO

6.1 INTRODUCTION

As mentioned in Chapter One Eritrea has passed through subsequent colonial systems, which affected the economic growth badly. Especially during the last colonial system (1952-1991) development in agriculture and non-agricultural sectors of the economy was drastically affected. Housing and other infrastructure development during this period fell short far of satisfying the demands of the growing population of the country, both in rural and urban areas. After independence in 1991 demands for land for development of industrial estates and housing in cities grew beyond the city boundaries. Due to the accelerated demand for urban development experienced after independence, especially in Asmara city, the authorities incorporated 13 rural villages around Asmara under the city's administration. The inclusion of the villages need a systematic and detailed study and planning to counteract the potential negative consequences of changes for the rural village and community (Lassey, 1977).

The research area, Adi-Segdo, is one of these villages. In the past, due to lack of understanding of proper land use planning and maybe negligence from the planners or authorities, relatively high potential agricultural lands were allocated to investors for non-agricultural development activities. In planning a lot of issues need to be addressed on the potential use of land. Inventory of available resources is the primary requirement, followed by determining as precisely as possible to which use a specific unit of resource can be put, so that in future society will achieve an improvement in living standards without destruction or degradation of their life-supply system (environment) on which later generations will depend (Lassey, 1977). According to Lassey (1977) the basic and predominant emphasis in rural development versus urbanization must be on what will happen to the rural people and region in the future.

6.2 ENVIRONMENTAL REQUIREMENTS OF CROPS THAT CAN POSSIBLY BE GROWN IN THE STUDY AREA

Land use recommendations for the different soil mapping units of the study area are given predominantly in reference to the environmental requirements of grain crops, vegetables and forage crops that are adapted to the area and familiar to the village community. The crops that are familiar to the farmers of the area are cereals like wheat, maize, barley, teff and finger millet; vegetables like tomatoes, cabbage, lettuce, spinach, carrot, potato, onions and pepper and forage crops like alfalfa, maize, wheat and barley. These crops have been grown in the area for a long period of time and are adapted to the environment.

Also new crops, which seem to be potentially profitable and adapted to the local environment, will be assessed for possible introduction in the area. Before they are finally recommended it must be determined whether they are acceptable for the farmers to adopt. The above is true not only where new crops are considered, but also where new "improved" cultivars are considered for introduction. There are often good reasons why local farmers cannot or do not want to change to new cultivars.

Since the climate of the area is uniform, suitability assessments will be mainly in relation to physical and chemical characteristics of the soils. Suitability for each crop is rated on a qualitative basis.

Alternative technologies for improving farming systems will be provisionally recommended. Recommendation of any specific technology can be finalized only after it has been evaluated in terms of acceptability by farmers and its appropriateness in terms of the local infrastructure, markets, etc.

It is good to know what the natural resources (soil, climate, etc.) requirements for optimum production of a specific crop are. Ideal conditions are seldom found in nature, however. From Chapter 4 it is evident that the study area is not ideal for crop production in terms of the available natural resources. It is, therefore, even more important to know what the ***tolerances*** of a certain

crop/cultivar are in regard to non-ideal conditions. This is especially so if a decision has to be reached on which crop has the best chance of economic success on the poorer soils (Protz, 1981).

Information on crop requirements and tolerances can be obtained from international literature, but often only the ideal conditions are listed and not the tolerances under non-ideal conditions (Protz, 1981). FAO (1983) also warns that the information given in international literature may not really be appropriate to a specific situation and that local information, obtained from local research and the indigenous knowledge of local extension officers and farmers, should be used where these are available.

For the compilation of the information on the requirements and tolerances of the different crops the following sources were used:

1. Purseglove, J.W., 1972. Tropical crops: monocotyledons. Longman, U.K.
2. Ware, G.W., 1980. Producing vegetable crops. Interestate printers and publishers, Danville.
3. Jones, J.B., 1999. Tomato plant culture. CRC press, Boca Raton
4. Dent, D. and Young, A., 1981. Soil survey and land evaluation. Allen and Unwin, Boston.
5. Young, A., 1976. Tropical soils and soil survey. Cambridge, New York.
6. Denisen, E.L. 1958. Principles of horticulture. Macmillan, New York.
7. Ayers, R.S. and Westcot, D.W., 1985. Water quality for agriculture. FAO, Rome.
8. Weldegiorgis, B.W., 2000. Development of a strategy and structure for land suitability evaluation for Eritrea. M.Inst.Agrar. dissertation, University of Pretoria, South Africa.

Indeed the study area is not ideal for grain crop production. This is supported by the natural resources (amount and distribution of rainfall) of the area and present yield of crops (Table 5.2) in comparison to the average grain production in the world. But because of the high dependence of the community on agriculture and absence of any non-agricultural economic sector for the community in the area utmost effort is required to improve agricultural production. This can be achieved by improving the existing farming systems and activities to sustain and if possible to improve the resources. Introduction of adaptable and tolerant cultivars and farming techniques

and equipment compatible to the area and the community and measures to be taken for successful crop production is essential.

The grains, vegetables and forage crops grown in the area and the environmental requirements and tolerances of each crop are given in Table 6.1. In addition the environmental requirements and tolerances of new crops adaptable to the area, which are nutritious to humans and/or can be used as animal feed, are given.

Table 6.1 Environmental requirements and tolerances of crops selected for Adi-Segdo

Crops	**Growing period in days (drought tolerance)**	**Soil requirement, pH optimum and (range)**	**Specific climate requirement / tolerance**	**Sensitivity to salinity**	**Temperature requirement optimum (range)**	**Na ion toxicity**
Maize (*Zea mays*)	100 – 140+ (low)	Deep, fertile, friable & well-drained loam and silt loam 5.5-7.0 (5.0-8.0)	Sensitive to frost, temp. for germination > 10 ^{0}C; cool temp. causes problem for ripening	moderately sensitive	24 – 30 ^{0}C (15 – 30) ^{0}C	sensitive
Wheat (*Trit-cum aestivum*	100 – 130 (low)	Fertile, loamy soil with pH 7.0-8.5 (above 5.5)	Sensitive to frost, requires cold for flowering during early gro-wth & dry period for ripening	moderately tolerant	15 – 20 ^{0}C (10 – 25) ^{0}C	semi-tolerant
Barley *Horde-um vulgare*	90 – 129 (high)	Well drained moderately deep heavy soils 6.5-7 (6.5-8)	Sensitive to hot and humid, generally tolerant to adverse climate	tolerant	24 – 30 ^{0}C (3 – 38) ^{0}C	tolerant
Finger millet *(Eleusine corcona)*	90 – 120 (high)	Fertile free drained sandy loam soil with pH 6.0-7.0	Sensitive to prolonged drought and less tolerant to heavy rainfall	moderately sensitive	18 – 27 ^{0}C	semi-tolerant
Teff (*Eragrosis ab-Yssinica)*	120 – 160 (low)	Heavy loam soil with good permeability	Sensitive to frost and prolonged drought	sensitive	18 – 25 ^{0}C (15 – 30) ^{0}C	semi-tolerant

Table 6.1 Continued

Tomatoes *(Lyc-persicon escul-entum)*	90 – 120 (>25-30 in nursery) (low)	Well drained fertile sandy loam for early & loam and clay loam for late production, pH of 5.5-7.0	Sensitive to frost and extreme temperature (>35 ^{0}C)	moderately sensitive	22 – 30 ^{0}C (18 – 35) ^{0}C	semi-tolerant
Potato (*Solnum tuberosum)*	100 – 150 (low)	Well drained, aerated soil but in heavy soils problem in digging tubers 4.5-5.5 (also grows in neutral to basic soil	Sensitive to frost and high temperature above 30^{0}C	moderately sensitive	15 – 20 ^{0}C (10 – 25) ^{0}C	semi-tolerant
Onion *(Allium cepa)*	100-140(+30-35 in nursery (low)	Medium textured soils pH 6.0 – 7.0	Tolerant to frost, low temperature (<14-16^{0}C) is required for flower initiation	sensitive	15 – 20 ^{0}C (10 – 25) ^{0}C	semi-tolerant
Pepper *(Caps-icum spp)*	90 – 120 (low)	Well drained, aerated and light to medium textured soil; pH 5.5 – 6.5 (5.0 – 7.0)	Sensitive to frost	moderately sensitive	18 – 23 ^{0}C (15 – 27) ^{0}C	semi-tolerant
Cabbage *(Brassica oler-Acea)*	80 – 100 (medium)	Well drained heavy loam soils with pH 6.0 to 6.5	Resistant to frost of up to –10 ^{0}C for short period	moderately sensitive	15 – 20 ^{0}C (10 – 24) ^{0}C	semi-tolerant
Carrot *(Dauc-os carota*	60 – 100 (low)	Deep, loose, well drained sandy loam or loam with pH 5.5 – 6.5	Less frost tolerant and low temperature results in poor colour quality	sensitive	15 – 20 ^{0}C (10 – 24) ^{0}C	semi-tolerant

Table 6.1 Continued

Lettuce	40 – 60 (low)	Fertile sandy loam and silt loam for early & late production respectively, pH 5.5 – 7.0	Sensitive to high temperature	moderately sensitive	grows best in cool temperature ?15 – 20 ^{0}C ?(10 – 24) ^{0}C	semi-tolerant
Spinach *(Spinacia oleracea)*	40 – 70 (low)	Fertile sandy loam and silt loam for early & late production respectively, pH5.5 – 7.0	Less frost tolerance	moderately sensitive	18 – 24 ^{0}C	semi-tolerant
Alfalfa *(Medicago sativa*	depends on continuos or seasonal growth (high)	Well drained, reasonably deep soil	Adaptable to a wide array of growing environment	moderately sensitive	15 – 20 (10 – 29)	tolerant
***Peas** *(Pisum sativum)*	65-100 fresh 85-120 dry (medium)	Light, loam and well drained soils with pH 5.5 and above	Slight frost tolerance	moderately tolerant	15-18 (10-23)	sensitive
***Beans** *(Phaseolus vulgaris)*	60-90 fresh 90-120 dry (medium)	Well drained heavy clay and loam soils with pH 6.5 and above	Sensitive to frost, excessive wind and temperature	sensitive	15-20 10-27	sensitive

*New crop species

6.3 LAND SUITABILITY EVALUATION FOR EACH SOIL MAPPING UNIT

The recommended land evaluation strategy for the country according to Weldegiorgis (2000) is evaluation of the suitability of specific areas for alternative crops where different land uses compete on the basis of their economic importance or their overall importance to the fulfillment of the general objectives of the community or country. This is because if there are priority crops that should be planted to secure food self-sufficiency for the masses of the people, there is no choice but to find/allocate areas of land for the production of such crops (Weldegiorgis, 2000). The land use recommendation for each area is done assuming that the wastewater from the city will be treated and recycled as planned this year by the authorities. Hence this water is assumed as being suitable for irrigation of all the crops grown in the area.

The study area as a whole is divided in to two broad major groups in terms of their suitability for cropping, both rainfed and irrigated. These two broad classes are:

- Mapping units that are moderately to highly suitable for cropping.
- Mapping units that are marginally suitable to non-suitable for cropping.

6.3.1 Moderately to Highly Suitable Land for Cropping

These include all mapping units with deep to moderately deep soil, close location to the water sources (stream or dam) and with relatively little surface stoniness and other agricultural limiting factors. These include soil mapping units **A, B, C, D, E** and **G** (Chapter 4). For best and profitable production the fertility status of the soils in these areas should be maintained by application of commercial fertilizers or farmyard manure, though mapping units **B** and **D** contain high amounts of organic matter. The suitability of the crops will be examined under each mapping unit separately.

It is strongly recommended that these mapping units must not be used for any non-agricultural development purposes under any circumstances and conditions.

1. ***Mapping unit A:***

This mapping unit is the one with the highest potential land for agricultural production in the study area. It has deep soils, very little surface stoniness and its close location to the stream and dam makes irrigation during dry periods of the year easy. The most significant limiting factor of the soils of the area its texture (it is clay or heavy textured soil), which has significant water logging effects during intense rains and/or over-irrigation. Soil workability is also difficult, especially where non-mechanized cultivation is done. This mapping unit has pH values of around 8.0.

It is moderately to highly suitable for cereal cultivars like teff, maize, wheat, and barley, provided that irrigation water from the stream and/or dam is supplemented properly during the dry period. Under irrigation it is also suitable for vegetables like cabbage but moderately suitable for tomatoes. Root crops like potatoes and carrot are marginally suitable in this area due its heavy texture. The area is moderately suitable to drought tolerant crops like alfalfa and barley in seasons with low rainfall and when there is not enough water for irrigation or during late summer of good rain seasons without addition of irrigation water.

Land of this mapping unit is ***presently used*** predominantly for **alfalfa** and **maize** production and **cabbage, carrot,** and **barley** to some extent.

2. ***Mapping unit B:***

Such land is swampy during the summer and wet during the dry season. It is covered with grass for most of the year. This land is locally known as '*sheka*' and is all over the country used for grazing throughout the year. Such land also exists in other parts of Africa and is known as Dambos in Zambia, Vleis in South Africa and Zimbabwe and Mbugas in East Africa (Daka, 2001). According to Daka (2001) such areas are used to grow crops like wheat, maize, rice and other cereal crops, but ***especially vegetables***, on ridges and high flat beds, while grazing of cattle has been a major activity since the 1920s. Because the water table in such areas is located within two to five meters from the ground surface, water can be

extracted by digging only a few meters to open up the water table. By using this water for irrigation with simple methods, cereal crops, vegetables and forages are grown highly successfully in such areas during the dry season (Daka, 2001). This is important for bridging the "dry season hunger gap" (Daka, 2001).

Land of this mapping unit is ***presently used*** for ***extensive grazing all over the year***.

3. ***Mapping unit C***

The soils of this mapping unit also have high potential for crop production. There are almost no limitations for growth of majority of crops in the area. The soils are deep, friable and well drained with slightly alkaline soil reaction. Provided that additional water is supplied from the stream for irrigation purposes this mapping unit is highly suitable to all cereal, vegetable and forage crops that can be grown in the area.

Land of this mapping unit is ***presently used*** mainly for **maize** and **wheat, lettuce** and **spinach** production.

4. ***Mapping unit D***

This is high potential agricultural land, which is ***presently cultivated*** for vegetables and alfalfa production under irrigation. During the survey a water table was located at a depth of 120 cm from the ground surface. This is probably due to over-irrigation and/or presence of an impervious layer. The soil of the area is light (silt clay loam) with pH of 6.5.

5. ***Mapping unit E***

This area has moderately deep soil with carbonates in lower depth. The texture of the soil is clay loam with pH of 7.7.

Majority of this area was not developed into irrigated land because of its relatively distant location from the water sources and the economical inability of the community to construct water conveyance systems to it. It can be economically productive for forage production under rainfed cultivation, provided that efficient techniques of moisture utilization are practiced. In areas with limited precipitation water conservation strategies and techniques, such as fallow systems and tied ridges, and crop production strategies such as adjusting sowing dates according to the rainfall patterns of the area and using low planting densities can be implemented to alleviate moisture stress and improve agronomic production (Lal, 1987; Mbatani, 2000).

Land of this mapping unit is ***presently used*** for: **barley** and **wheat.**

6. ***Mapping unit G***

This is potentially irrigable land with deep well-drained loam soils, with pH of 7.3.

Land of this mapping unit ***presently used*** for: **cabbage, carrot** and **potatoes** (mainly)**.**

6.3.2 Marginally Suitable to Non-suitable Land for Cropping

This broad group includes mapping units **F, H,** and **J.** These are areas with shallow soil depth, and high percentages of surface stoniness. These mapping units are marginally suitable to unsuitable for crop production purposes. ***Hence they are predominantly recommended for city expansion and other non-agricultural development and construction activities in addition to marginal agricultural production.*** Priority in allocation of land for development activities should be given to those which can provide the maximum number of job opportunities for the community. Careful study and assessment is necessary not to repeat the same mistake as before by allocating land for investments which do not benefit the community. In addition, absorbing people from the community by providing job opportunities in these non-agricultural enterprises, which will make people less dependent on the land, can result in fewer and more efficient

farmers who can get larger agricultural land for production of crops and vegetables and improve their living standards.

1. ***Mapping units F and H:***

   These mapping units have shallow soils. Provided that efficient moisture utilization techniques like early planting and appropriate (low) planting densities are implemented they are marginally suitable for production of barley for forage during low and normal rainfall seasons and probably for cereal production in above normal good rain seasons. But it should be stressed that it is only marginally suitable and needs a lot of investments for agricultural production.

2. ***Mapping units I and J:***

   This is a rock-soil complex. It is terraced and planted with eucalyptus trees. Provided that terraces are well maintained, planted with vegetation and trampling by animals is restricted, this area can be a good source of fodder for animals, employing a zero grazing (cut and carry) system. It can also be a source of fuelwood and wood for construction, if harvested on a sustainable basis, and serve as a green area for the village.

6.4 PROPOSED PROVISIONAL LAND USE PLAN FOR ADI-SEGDO

Based on the information collected during this study agriculture is the basic and indispensable enterprise for the community of the area. And also the Asmara city administration is in need of land for urbanization and non-agricultural development activities. To accommodate both these requirements a provisional land use plan is proposed for Adi-Segdo. It could hopefully serve as a basis for the compilation of a land use plan ***after obtaining inputs from the community and other role players in the area***.

The proposed land use plan for Adi-Segdo is indicated on Map 6.1. The mapping units indicated on the proposed land use plan map for Adi-Segdo are:

1. **Mapping Unit P:**

This mapping unit consists of soil mapping unit **A** where the soil is deep, heavy textured and black in colour. It has high potential for irrigated cropping because of its fertility and close proximity to water sources.

In view of its high agricultural potential, it is recommended that all non-agricultural land uses be prohibited on this land. The following agricultural activities/enterprises are recommended for this land: Irrigated **alfalfa, maize** and **beans** mainly for animal feed and **teff, maize, barley** and **beans** for human consumption. During periods of scarcity of irrigation water, rainfed alfalfa or barley can also be grown.

2. **Mapping unit Q:**

This mapping unit consists of soil mapping unit **B**, which comprises fertile clayey soils which have high water tables during the dry season and are waterlogged during the rain season.

It is ***recommended*** that this area be used for grazing during the wet season and growing crops during the dry season, using appropriate farming methods such as raised beds to escape prevailing waterlogging, as is done successfully in other parts of Africa, e.g. Zambia and Zimbabwe. The following crops are recommended: **alfalfa** and **maize** for animal feed and **barley, teff, cabbage** and **tomatoes.**

Simple improved irrigation techniques and operations that have been developed and used successfully in such areas in other countries, e.g. Zambia, that could possibly be introduced in the study area will be discussed in Section 6.6.

3. **Mapping unit R:**

This mapping unit consists of deep to moderately deep well-drained light textured soils close to water sources. It is the combination of soil mapping units **C, G** and part of mapping unit **E** located close to the water sources. These areas are already under irrigated cropping, with the exception of part of mapping unit **C**.

In view of its high agricultural production potential, it is recommended that all non-agricultural land uses be prohibited on this land. It is ***recommended*** for the production of root crops under irrigation because of its light soil texture and favourable pH value. Root crops like **potatoes** and **onion,** as well as crops like **peas, lettuce** and **spinach** can give reasonably high production. In addition cereal crops (e.g. wheat) can also be cultivated according to their priorities and importance to the farmer.

The clay pot irrigation system is also a possible appropriate technology for efficient utilization of water resources in the production of the vegetables and crops in this land unit.

Clay pot irrigation (Daka, 2001) is considered as an applicable system to improve irrigation efficiency in this area, for the soils are loose and light textured, in contrast to those of the above-mentioned mapping units (**P** and **Q**). The clay pot system is a locally made appropriate sub-surface irrigation system. It plays a great role in effective moisture utilization in water scarce areas. It is explained in Section 6.6.

4. **Mapping unit S:**

This mapping unit consists of soil mapping unit **D**, which comprises deep, light textured, somewhat poorly drained soils.

In view of its high agricultural production potential, it is recommended that all non-agricultural land uses be prohibited on this land. This area is ***recommended*** for growing of irrigated **onion, carrot, pepper** and **spinach**. In addition all cereal crops familiar to the

community are recommended, ***provided that appropriate water management techniques***, i.e. avoiding over-irrigation and provision of efficient drainage to alleviate the water-logging problem, ***are applied***.

The clay pot irrigation system is also applicable to this area because of the light textured soil and absence of expansion and contraction characteristics of the soils.

5. Mapping unit T:

Purely from a soil point, this mapping unit, which consists of the majority of soil mapping unit **E**, could have been grouped together with mapping unit **R**, but its distance from water sources makes irrigation development more expensive.

Provided that appropriate water conservation measures and agronomic practices are implemented this area is ***recommended*** for the growing of rainfed **finger millet** and **barley.** Its advantage is that it can be grown for cereal crop production in good rain seasons and forage production in low rain seasons when the farmer sees at any stage through the season that grain production is going to fail and/or if additional forage is needed for the survival of livestock. But in future, provided that appropriate irrigation structures and technologies are developed, more profit could be obtained by developing it into irrigated land.

6. Mapping unit U:

This mapping unit comprises soil mapping units **F** and **H**. It is relatively shallow and stony phased areas, i.e. marginal agricultural land. This area needs a lot of investment (such as mechanical soil conservation measures) and manpower for developing it into relatively high potential agricultural land and maintaining it. Hence it is recommended for marginal crop production of barley and/or extensive grazing. But as the land recommended for urbanization and development activities (mapping unit **W**) is finished this area should be the first to be planned for further urbanization.

7. **Mapping unit W:**

These are soil mapping units **I** and **J**. These are areas with no cropping potential, either rainfed or irrigated. .

As mentioned in Section 5.6 there is high demand of poultry and dairy farm products in the city almost all over the year and some of the farmers have started practicing these farming systems. Dairy and poultry farming enterprises are ***highly recommended*** and should be practiced intensively by the village community. This land is suitable for urbanization and homestead construction of cattle and chicken for it has no cropping potential. Hence this area is recommended for construction of poultry and dairy homestead, urbanization and other non-agricultural development activities. Mapping unit **I** is a dumping site of excavated and solid wastes of the city or construction sites and mapping unit **J** is Rock-Lithosols complex. Mapping unit **I** covers a very large area (**33.08** hectares). This area coverage is too large because the wastes are simply dispersed on the surface. If it is properly utilized a large area could be obtained and used for other purposes like the proposed uses. Areas that are not yet urbanized are recommended for the establishment of woodlots to provide wood for construction and fuel, as discussed under Section 6.3.2.

SUMMARY OF RECOMMENDED LAND USES AND AREAS AVAILABLE FOR EACH TYPE OF USE

In general the proposed land use plan map for Adi-Segdo has mapping units of potentially irrigated heavy textured soils, relatively light textured potentially irrigated soils, marginal rainfed and/or extensive grazing mapping unit and mapping unit for urbanization and non-agricultural development activities. The area coverage of each mapping unit is given in Table 6.2.

Table 6.2 Proposed land use types and area coverage of each recommended type of use

Proposed Type of use	Area coverage in hectares
Irrigated land of heavy textured soils	153.25
Irrigated land of heavy textured soils with high water table	39.12
Irrigated land of well-drained light textured soils	75.01
Irrigated land of light textured poorly drained soil	76.07
Moderately potential rainfed cultivated land	60.05
Marginally potential rainfed and/or extensive grazing land	224.92
Urbanization and other non-agricultural development activities	49.62
Village and other built-up areas	65.60
Water body	9.37
Cemetery	4.4
Total	**757.41**

6.5 PREREQUISITES FOR SUCCESSFUL IMPLEMENTATION OF THE PROPOSED LAND USE PLAN FOR ADI-SEGDO

For successful accomplishment of the proposed land use plan of the area and improvements in agricultural production and living standard of the community, parallel with resolving the land crisis in the city of Asmara, there are two basic requirements, viz.:

a. **The final land use plan must be drafted in consultation with all the stakeholders, using the provisional plan presented here as a working document from which to start, and must be accepted by them.**

b. **The socio-economic constraints and problems need to be addressed and resolved first.** These issues and proposed strategies and action plans for solutions are:

1. ***Land must be redistributed among the farmers according to the new land reform policy as soon as possible:*** It is true that land reform is not an easy task to be done within a few years.

But proclamation without a strategy and action plan could result in violence in the long run. Based on this study it became clear that delays in implementing the new land reform and dismissing the old tenure system exposed new families in the community to being landless and land resources to degradation due to lack of incentives to implement conservation measures. Unless immediate steps are taken to combat adverse situations which will lead to irrevocable damage to the existing resources, it will result in increased poverty and social problems. It is suggested that the government should organize the farmers to participate in classification of land based on its capability or production capacity together with experts. Farmers know their land better than any expert from outside. Hence the indigenous knowledge of the farmers should be used to facilitate the classification of land based on their potentials. In allocation of land for individual households or stakeholders the farmers can do it and the experts and government decision-makers could only be needed in resolving arguments or appeals during the allocation and examining the fairness of classification and allocation before approval. At the end the experts produce the cadastral map and final registration of the land users according to the policy. The importance of land resource and agronomy experts in the study area is mainly in developing appropriate and affordable production technologies for the farmers and improving crop and cultivars adaptability to the environment. After all it is highly recommended that land distribution among the farmers should be done before any land allocation for other investors.

2. ***Credit facilities from government in cooperation with NGOs should be facilitated to resolve the existing farming problems:*** The total farmland of the village will be decreasing as land is going to be allocated for urbanization and development activities. Farmers will need to produce the required amount of food for their families from the decreased size of their farm plots. To cope with this, crop production from a unit area of land should be increased. Higher production inputs, appropriate and improved technologies and improved crop cultivars, i.e. more intensive crop production, will be required. Poultry and dairy farms should also be practiced for there is high market of the products in the city. Credit facilities should be made available for the farmers to purchase the necessary inputs, new technologies and start practicing poultry and dairy farming intensively.

3. ***Collective farming is a new approach and has shown a significant increase in production as long as the government subsidizes it:*** But there is a big question that needs to be answered: How long is the government capable of providing the farm machinery and subsidizing the operation and other costs? A strategy should be developed for resolving this in the future, because it is hardly believable the government will be able to subsidize it for a long period of time, forget about being able to do it forever. It is recommended that farm machinery should be made available to the village, based on long-term soft loan credits. By making the villagers the owners of the farm machinery has two advantages:
    - On the one hand it would make them responsible to care for the proper use and maintenance of the machinery.
    - On the other hand it can resolve the problem of the delays in farming operations, and consequent yield losses, experienced in the past. This can help the farmers to do their farming operations at the right time.

    An important issue to keep in mind is that in collective farming, where farmers share profits, farmers are supposed to participate equally but this never happens in reality. It is, therefore, never popular and leads to low productivity. The author, therefore, recommends ***cooperative ownership of farm machinery but individual ownership of farm plots and individual farm income, since it is more reasonable to make farmers participate efficiently.***

4. ***The municipality of Asmara should take responsibility for all the municipal duties, as the village is part of the city administration:*** The municipality must cover all the road upgrading and sanitation problems in the village. If the village is part of the city it should be treated like all other localities of the city. ***The "mega city" or "mega municipality" approach, where various villages are included in one municipality under the umbrella of the main town or city in an area, could serve as a model on which to base this.***

6.6 PROPOSED IMPROVEMENT IN IRRIGATION TECHNIQUES

6.6.1 Treadle Pump Technology

The study area has a long history of irrigated field crop and vegetable production. Water for irrigation is extracted from the stream, hand-dug wells, dams and small water reservoir basins along the stream. The majority of the farmers use rope-and-bucket systems to extract water for irrigating their plots. Such method is time consuming and laborious; hence optimum utilization of human and natural resources was hardly possible or sustainable. As mentioned in Chapter 5, very few farmers use diesel operated water pumps, which are relatively expensive to buy, operate and maintain. Even though the amount produced and area of irrigated land increase when using such water pumps the net profit is relatively low because of the high production cost.

According to Daka (2001) the treadle pump is an appropriate technology for improving and expanding small-scale irrigation. It is a low cost, easily adaptable device that can be produced locally. Treadle pumps are operated by human feet and so easy to operate that children from the age of seven and women can operate it (Daka, 2001). The treadle pump has been a successful low-cost water lifting device in different parts of the world such as Burkina Faso, Brazil, India, Iran and Zambia (Daka, 2001). Treadle pumps can lift water only for limited distances and cannot be used on deep wells or boreholes. It is good for lifting water from shallow wells or shallow water tables, such as in *"sheka"* (Mapping unit B) or to pump water from the rivers onto the riverbanks (Daka, 2001). There are three types of treadle pumps, viz. well pumps, river pumps and pressure pumps. ***Treadle pumps bring about a 75% labour saving compared with the rope-and-bucket system (Daka, 2001).***

Though treadle pump technology is not known in the research area or even in any part of Eritrea at present, an Eritrean student (F.N. Hidad) currently enrolled in the Department of Agriculture and Food Engineering at the University of Pretoria, is working on a project titled "Performance and Durability of Treadle Pumps". According to personal communication with Dr. Daka and Mr. Hidad manufacturing, operation and adaptation of this equipment is simple and cheap.

Treadle pumps are made from simple materials such as timber, rubber from old bicycle tubes and plastic fittings, which are cheap and do not corrode. They can easily be constructed by local craftsmen in small home industries, thus creating new job opportunities – as happened in Zambia (Daka, 2001).

After checking the performance and durability of each part, Hidad is planning to introduce the pump to Eritrea. He strongly believes that the introduction of this technology will benefit the whole community of Eritrea because it is cheap and can easily be manufactured using local materials. Introducing the equipment and technology, followed by training the community in the research area and the country as a whole in its operation will save huge amounts of money, time and labour spent in diesel operating water pumps and rope-and-bucket irrigation systems. Hence suction treadle pumps are recommended for the research area in particular and the whole country in general for its sustainable, efficient and easy production using local materials and easy maintenance.

Before trying to introduce the technology on a large scale it is very important to take note of a lesson from Zambia: The well-known pumps from elsewhere were not adopted by the farmers. As soon as the pumps were modified, ***in consultation with the farmers and according to the wishes of the farmers***, 2500 pumps were bought within three years. So, the farmers should be consulted in the introduction of the pumps. In some countries there are all taboos that prohibit women from operating the pumps. Such matters must also right at the beginning be cleared out with the local communities.

6.6.2 Clay Pot Subsurface Irrigation Systems

Clay pot is an appropriate sub-surface irrigation system in rural areas for saving and efficient utilization of water resources in small-scale irrigation. Daka (2001) showed that a 50% to 70% saving on irrigation water can be achieved by clay pot irrigation of vegetables, compared with conventional small-farmer irrigation systems. In Burkina Faso it is also used to irrigate trees in woodlots to speed up their growth (Daka, 2001). It is a simple but efficient technology for small-scale irrigation (Daka, 2001). Water is made available as the crop needs it. It operates as follows:

Unglazed clay pots with many micropores in its walls are buried neck deep into the ground and crops are planted adjacent to it. The pots are regularly filled with water and covered with a ceramic lid. The water oozes out of the pot in the direction where a suction force develops.

This system is an appropriate and relevant technology in water scarce places like Eritrea for crop production without any resultant adverse effect on soil in terms of salt buildup as no water logging occurs. Weeds are suppressed, thus reducing loss of water by transpiration and evaporation (Daka, 2001). According to Daka (2001), it is an ancient technology still practiced today in India, Iran and Brazil (Power, 1985; Yadav, 1983; Anon, 1978 and 1983) but it is new for the study area and Eritrea. Introduction and adoption of this system can benefit the community of the study area and the country (Eritrea). This method can only be effective in light textured soils with no expansion and contraction properties. It is recommended that it is good to introduce this method of water management system to the research area on mapping units **R** and **S** (Map 6.1) and some other parts of the country and to test for its effectiveness and adoption by the farmers.

Like in the case of the treadle pump, it will boost local income because it is a simple technology made by women at village level from locally available clay (Daka, 2001).

6.7 SOIL FERTILITY MANAGEMENT

According to studies on soil fertility status of the soils of the country, the fertility status of the soils in the country is low (Ministry of Agriculture and University of Asmara, 1998). The low fertility status of most of the soils in the study area is illustrated by their low organic carbon contents, which range between 1-2 % C. Mapping units **B** and **D,** with organic carbon contents of 8.3% and 3.6% respectively, are exceptions.

It was not possible to do detailed soil fertility analyses as part of the present study and therefore no guidelines regarding specific plant nutrients can be given at this stage. It is however recommended that the fertility status of the soils in the study area should be maintained for optimum sustainable production.

Presently application of commercial fertilizers is done only in the irrigated farm plots, though it is not used by all irrigation farmers. Most of the people in the area maintain the fertility of the soil by application of household waste, manure to some extent and, especially in the irrigated land, dispersing of deposited soils from the streambed during periods when the stream is dry. This is also done mainly on irrigated plots. Fallow periods are almost zero at present. Though the farmers realize that leaving crop residues in the field after harvesting improves the fertility of the soil for succeeding crops, the residues are grazed by livestock and/or collected as a source of energy for cooking. Due to insufficient alternative sources of fodder during the dry post-harvest season and/or inadequate affordable alternative sources of energy, the farmers often have no other choice, but to use the crop residues for these purposes.

Crop rotation with legumes is another method of soil fertility improvement or management that could be considered. For instance, growing alfalfa, inoculated with its N fixing bacteria *Rhizobium meliloti,* is highly effective for providing nitrogen to the crops succeeding it in the rotation (Lockhart and Wiseman, 1975). According to Lockhart and Wiseman (1975) growing pulses or legumes such as beans and peas could have multiple benefits such as:

a. Bacteria on the roots of these crops can fix nitrogen, so normally nitrogen fertilizers are not required or nitrogen deficiency will not be a problem for the following crop because it can benefit from nitrogen left in the soil.
b. Beans and peas are useful, protein rich grains for blending with cereals to feed farm stock. Such method of feeding livestock nutritiously can improve dairy production.
c. Beans and peas can be used in mixtures with cereals for ensilages.

Although Lockhart and Wiseman (1975) emphasizes the use of beans and peas as animal feed, it must be kept in mind that field beans (garden beans) and peas are nutritious and tasty human food and is amongst the most popular vegetables in many parts of the world. Likewise, dried beans and peas (the dry, ripe seeds) are important human foodstuffs. In parts of South Africa the very popular staple food of the indigenous rural population is a mixture of dried beans and samp (crushed, not milled, maize grain) cooked together. The beans provide the proteins and the samp carbohydrates (energy food). In many parts of Africa beans are not grown in crop rotation, but in

mixed cropping systems together with maize in the same field at the same time. Where land is scarce, subsistence farmers prefer to produce for themselves rather than for animals, so recommending the introduction of beans and peas as human food may have a better chance to be adopted.

These crops are not well known in the study area though they grow in other parts of the country. They can, therefore not be recommended to the area finally before clearing out their acceptability with the local community. They are environmentally adaptable to the area and grow well in heavy and loam soils like soils of mapping units **A** and **G**.

Hence, growing beans and peas will provide nutritious and tasty human food. They can also be used as farm stock feed by mixing with cereals and improve the fertility of the soil by fixing innert nitrogen to nitrates for the succeeding crop.

Hence, growing beans and peas in rotation with the other crops common in the area is highly recommended for the reasons given above.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

Agriculture is an important and basic activity for the survival and subsistence of the majority of the people in the study area. Subsistence of these people depends on the production of grain crops, vegetables and forage from land. The incorporation of the village under Asmara city administration, from the perspective of the land crisis for urbanization and other development activities, resulted into allocation of land without assessing the potentials of different parcels of land for agriculture. This is mainly due to the fact that urban planners and development experts did not take into consideration the possibility of integrating urban agriculture in urban planning. Hence, the first step that needs to be addressed, is to persuade urban planners and decision makers to accept urban agriculture as a legitimate and indispensable form of urban land use. Urban agriculture is an activity that produces, processes and markets food and other products on land in urban and peri-urban areas by applying intensive production methods and reusing natural resources and urban wastes to yield a diversity of crops and livestock (UNDP, 1996). Urban agriculture plays a great role in food security/subsistence for the farmers, creates a green environment in the area and generates income and employment to the community.

Based on the findings of this study agriculture is an important and indispensable enterprise in the study area and other surrounding villages. Therefore land with moderate to high potential for crop production, i.e. mapping units **P, Q, R, S & T** in the provisional land use plan for Adi-Segdo (Section 6.4 and Map 6.1), should be reserved for production of crops. Land unit **U** (Section 6.4 and Map 6.1) that has marginal potential for agriculture, should be used for extensive grazing using, cut and carry systems, or low input rainfed crop production until the demand of land for urbanization and other non-agricultural development purposes exceeds the areas recommended for these purposes. When the demand of land for urbanization and other non-agricultural development purposes exceeds the recommended area these mapping units can be used for construction purposes. Land unit **W** (Section 6.4 and Map 6.1) is recommended for urbanization

and development purposes. Planners should do their planning based on the recommended land uses for the different mapping units.

Utmost effort is required in identifying and prioritizing development activities that can benefit the rural community directly at household level by job creation or at village level by somehow contributing to village development activities. Agricultural outputs are relatively low as compared to average production in other parts of the world. Based on the study different reasons can be mentioned of which unimproved and traditional farming systems and techniques, shortages of research information, researchers and extension services and lack of optimum utilization of the existing resources are the most important.

The study area is not ideal for agricultural production but optimum and efficient utilization of the existing resources is required. Strong cooperative work between research centers, extensionists and farmers can achieve improvement in traditional farming systems and techniques. Extension experts in the area should approach the farmers for identifying the constraints and address the issues to be researched and to gain their participation in solving the problems. Water is one of the scare resources in the area and irrigation systems used in the area are inefficient and/or expensive. According to studies on other parts of Africa Suction Treadle Pumping and Clay Pot irrigation systems are effective and affordable small-scale irrigation techniques. The introduction and adoption of these techniques to the study area can save time, money and eventually it will result in efficient utilization of the scarce water resource compared to systems which are in use. Marketing is another important but less significant problem. Authorities should reconsider their policy of prohibiting street vendors or selling at the point of production from the point of its impossibility in tax collection.

The shifting of the farming system from cereal and vegetable production to dairy and poultry farming is important for it is more profitable at this moment. Though few farmers are involved in dairy and very few in poultry farming there is high market demand and more profits in the city all over the year. It is true that the transition will demand a lot of money or investments but the profit is promising. Hence the community should look forward to becoming more involved in poultry and dairy farming.

7.2 RECOMMENDATIONS

Assessment of land resources is vital and important in any land development planning and implementation activity. Countries like Eritrea, where natural or land resources are scarce and most of its people are dependent on agriculture (and after all agriculture is the backbone of the economy), a detailed survey of the existing resources, limitations and opportunities is needed strongly. Identifying the available resources and evaluating them for optimum utilization on a sustainable basis is the only means for alleviating food shortages and poverty. In the past big development projects, like the *sembel housing project* in the southern part of Asmara city, were implemented on land with good irrigation potential resulting in irrevocable loss of this land for agriculture. This was mainly because of lack of a multidisciplinary approach in resource utilization for optimum use or ignorance in regard to integrating urban agriculture into urban development.

At first an immediate action is required for a general and reliable reconnaissance survey of resources of Eritrea. The Agro-ecological zones map of Eritrea, produced by MLWE in 1997, has been helpful in providing general information. But as mentioned in the report itself, some of the data accuracy is questionable and it is open for comments and upgrading. These inaccuracies are confirmed by the present study, i.e. Adi-Segdo should have been classified under the Arid Highland zone as this is supported by the low amount and efficiency of the rainfall and high base content of the soils (Chapter 4). This is mainly due to lack of professionals in resource surveying and inadequate of weather stations at that time. The last six years the government has invested in upgrading the educational level of a number of personnel in natural resource subjects. As a result the educational level is adequate to come up with more reliable resource information for the country. The Agro-ecological zones map could be used as a starting and an immediate action plan is recommended for resource surveying before any further irrevocable losses happen.

Implementation of the newly promulgated land tenure system is not an easy task. But this study has revealed that delays in implementing the new land reform and dismissing the old tenure system has resulted to social problems and further degradation of land resources. Based on this

study a possible way of alleviating these problems is recommended. Farmers know their land better than any expert from outside. This indigenous knowledge of farmers with inputs from land resource experts could play a great role in classification of land based on its capability and production capacity. This recommendation can be tested in a pilot area (e.g. Adi-Segdo, the study area) and this study may contribute in the classification of land. During the process of implementation unrevealed problems and obstacles could be identified and amendments can be made for the future. If not, failure in implementing this constructive land reform for any reasons could result in aggravating social problems, further degrading of land resources and violence. Parallel with this land resource and agronomy experts should concentrate more in developing appropriate and affordable technologies and improving crop and cultivars adaptability to the environment.

REFERENCE

ANON, 1978. Kuzeh pot irrigation. Irrinews 11. qu. In: Dambo farming in Zimbabwe: Conference proceeding. 39-46. (Eds. Owen, R., Verbeck, K., Jackson, J. and Steenhuis, S (1995). University of Zimbabwe publications, Harare.

ANON, 1983. Clay jar irrigation. Irrinews 30. qu. In: Dambo farming in Zimbabwe: Conference proceeding. 39-46. (Eds. Owen, R., Verbeck, K., Jackson, J. and Steenhuis, S (1995). University of Zimbabwe publications, Harare.

ARNON, I., 1981. Modernization of agriculture in developing countries: Resources, potentials and problems. Chapman & Hall, New York.

AYERS, R.S. & WESTCOT, D.W., 1985. Water quality for agriculture. FAO, Rome.

AZBAHA, H., IYASSU, G. & MOHAMEDKHEIR, O., 1998. Rehabilitation of degraded land: Eritrea. Univ. of Asmara and Ministry of Agiculture, Asmara.

BEIN, E., NEGASSI, A., TENGNAS, B. & GHEBRU, K. 2000. Soil conservation in Eritrea: Case study. RELMA / SIDA, Nairobi, Kenya.

BEMBRIDGE, T.J., 1991. Practical guidelines for agricultural extension workers. Halfway house: Development Bank of SA, Halfway House.

BERHANE, D., 2000. Development of methods and techniques for land resources surveying for Eritrea. M. Inst. Agrar. dissertation. University of Pretoria, South Africa.

BREIMER, R.F., VAN KEKEM, A.J. & VAN REULER, H., 1986. Guidelines for soil survey and land evaluation in ecological research. UNESCO, Paris.

CIDE, KNES & WRI, 1990. Participatory rural appraisal Handbook. Center for International Development and Environment, Washington D.C.

CERNEA, M.M., COULTER, J.K. & RUSSELL, J.F.A., 1985. Research-extension farmer: A two-way continuum for agricultural development. World Bank, Washington D.C.

CIA, 1999. World fact book of 1999. http://www.cia.gov/publication/factbook/er.htm.

CHAMBERS, R., 1992. Methods for analysis by farmers: The professional challenge. Institute of Development, Brighton, U.K.

COLLINSON, M.P., 1980. " Low-cost approach to understanding small farmers." Agricultural administration Vol. 8. Michigan state university, East Lansing.

COLLINSON, M.P., 2000. A history of farming system research. FAO, Rome.

DAKA, A.E., 2001. Development of technological package for sustainable use of Dambos by small-scale farmers. Ph.D. dissertation. University of Pretoria, South Africa.

DAVIDSON, D.A.,1980. Soil survey and land use planning. Longman, London.

DAVISON, D.A., 1992. The evaluation of land resources. John Wiley, New York.

DENISEN, E.L. 1958. Principles of Horticulture. Macmillan, New York.

DENT, D. & YOUNG, A., 1981. Soil survey and land evaluation. Allen and Unwin, Boston.

DONALD, A.D.,1986. Land evaluation. Van Nostrand Reinhold, New York

EUROCONSULT, 1989. Agricultural compendium for rural development in the tropics and sub-tropics. Elsevier Science, Amsterdam.

FAO & UNIVERSITY OF ASMARA, 2000. National stakeholder consultation workshop (report). FAO, Rome.

FAO, 1972. Background document for expert consultation on land evaluation for rural purposes. AGL/LERP 72/1. IN BRINKMAN, R. & SMYTH, A.J. (ed): Land evaluation for rural purposes. International Institute of Land Reclamation & Improvement publication No. 17, Wageningen.

FAO, 1973. A framework for land evaluation (draft). FAO, Rome.

FAO, 1976. A framework for land evaluation. *Soil Bulletin* 32. FAO, Rome.

FAO, 1978. Report on agro-ecological zones project Vol. 1: Methodology and results for Africa. World Soil Resources Report 48. FAO, Rome.

FAO, 1983. Guidelines: Land evaluation for rainfed agriculture. (*Soil bulletin no. 52).* FAO, Rome.

FAO, 1985. Guidelines: Land evaluation for irrigated agriculture. (*Soil bulletin no. 55).* FAO, Rome.

FAO, 1991. Guidelines: Land evaluation for extensive grazing. (*Soil bulletin no. 58).* FAO, Rome.

FAO, 1994. Agricultural sector review and project identification Vol. 1: Report prepared by FAO for the government of Eritrea. FAO, Rome. pp. 2-22.

FAO, 1996. Guidelines for land use planning. FAO, Rome.

GOVERNMENT OF ERITREA, 1994. Land proclamation Act. No 58/1994. 1994. Adulis printing press, Asmara.

GOVERNMNET OF ERITREA, 1995. Environmental management plan for Eritrea. MOA, Asmara.

HAINES, M., 1982. Introduction to farming systems. Longman, New York.

JONES, J.B., 1999. Tomato plant culture. CRC press, Boca Raton.

LA-ANYANE, S., 1985. Economics of agricultural development in tropical Africa. Chapman and Hall, New York.

LAL, R., 1987. Managing the soils of Sub-Saharan Africa. *Science* 236, pp 1069-1076.

LASSEY, W.R., 1977. Planning in rural environment. McGraw-Hill, New York.

LOCKHART, J.A.R. & WISEMAN, A.J.L., 1975. Introduction to crop husbandry. Pergamon, Oxford.

MATHER, A.S., 1986. Land use. Longman, London.

MBATANI, B.N., 2000. Determining the rainfed arable production potential of climatically marginal land in the Northwest Province using the CYSLAMB land evaluation model. M. Inst. Agrar. dissertation. University of Pretoria, South Africa

McCRACKEN, A.J., PRETTY, N.J. & CONWAY, R.G., 1988. An introduction to rapid rural appraisal for agricultural development. International institute for environment and development, U.K.

McREA, S.G. & BURNHAM, C.P., 1981. Land evaluation. Clardendon press, Oxford.

MINISTRY OF AGRICULTURE CENTRAL ZOBA, 1995. Agricultural practices in central zoba. Unpublished report. MOA, Asmara. Pp. 14-32

MINISTRY OF AGRICULTURE & UNIVERSITY OF ASMARA, 1998. Eritrean soil fertility initiative draft paper. Unpublished report. MOA, Asmara. Pp. 24-39

MINISTRY OF AGRICULTURE, 1999. Soil conservation practices in Eritrea by students on summer time 1994-1999. Unpublished report MOA, Asmara.

MINISTRY OF AGRICULTURE, DEPARTMENT OF ANIMAL SCIENCE, 1998. Animal population of Eritrea. Unpublished report. MOA, Asmara.

MINISTRY OF LAND, WATER & ENVIRONMENT, 1996. Land use plan of Asmara and its environs. Unpublished report. MLWE, Asmara.

MINISTRY OF LAND, WATER & ENVIRONMENT, 1997. Agro-ecological zones classification and legend. Unpublished report. MLWE. Asmara. pp. 1-18.

MINISTRY OF TRANSPORTATION AND COMMUNICATION, 2000. Climatic data of different weather stations. Unpublished Report. Asmara.

NEW AFRICA, 1999. Eritrea. http://www.newafrica.com/economy/eritrea.htm.

NORMAN, D.W., SIEBERT, J.D., MODIAKGOTLA, E. & WORMAN, F.D., 1994. Farming systems research approach: A primer for eastern and southern Africa. UNDP, Botswana.

PROTZ, R., 1981. Soil properties important for various tropical crops: Pahang Tenggara master planning studies. Pp. 187-200 in: Soil Resources Inventories and Development Planning. SMSS Techni. Mon. 1 SMSS SCS USDA, Washington D.C.

POWER, G., 1985. Porous pots help crops in north east Brazil. World Water July 1985: 21-23.

PURSEGLOVE, J.W., 1972. Tropical Crops: Monocotyledons. Longman, U.K.

REIJNTJES, C., HAVERKORT, B. & WATERS-BAYER, A., 1992. Farming for the future: An introduction to low-external-input and sustainable agriculture.Macmillan, London.

RUTHENBURG, H., MACARTHUR, J.D., ZANDSTRA, H.D. & COLLINSON, M.P., 1980. Farming systems in the tropics (3rd ed.). Oxford Univ. press, New York.

SAMPSON, R.N., HAIR, D. & AMERICN FORESTRY ASSOCIATION, 1990. Natural resources for the 21st century. Island press, Washington D.C.

SMYTH, A. J., 1981. The objectives of soil survey of various intensities. In: soil resource inventories and development planning. Proceeding of workshop at Cornell University. SMSS Mon. 1: 27-36. SCS, USDA, Washington D.C.

SOIL CLASSIFICATION WORKING GROUP, 1991. Soil classification: A taxonomic system for South Africa. Department of Agricultural Development, Pretoria, South Africa.

SOIL SURVEY STAFF, 1975. Soil taxonomy: A basic system of soil classification for making and interpreting soil survey. Agricultural Handbook No. 436. SCS, USDA, Washington D.C.

SOIL SURVEY STAFF, 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil survey. Agricultural Handbook No. 436, NRCS, USDA, Washington D.C.

STAMP, L.D., 1962. The land of Britain its use and misuse. Longman, London.

STEWART, G.A., 1968. Land evaluation: Papers of a CSIRO symposium organized in cooperation with UNESCO. Macmillan, South Melbourne.

UNDP, 1996. Urban agriculture: Food, jobs and sustainable cities. UNDP Vol.2 New York.

UNESCO, UNEP & FAO, 1979. Tropical grazing land ecosystem: A state-of-knowledge report. UNESCO, Paris.

VAN BUSKIRK, R., 1999. Eritrea climate, energy, environment and technology site. http//www.denbe.asmarino.com/asmarino/eritrea/EreCET site.htm.

VINK, A.P.A., 1975. Land use in advancing agriculture. Spriner verlag, New York. pp. 1-71

WARE, G.W., 1980. Producing vegetable crops. Interestate printers and publishers, Danville.

WEBSTER, C.C. & WILSON, P.N., 1980. Agriculture in the tropics (2nd ed.). Longman, New York.

WELDEGIORGIS, B.W., 2000. Development of a strategy and structure for land suitability evaluation for Eritrea. M. Inst. Agrar. dissertation. University of Pretoria, South Africa

WILBER, C.K. & JAMESON, K.P., 1992. Political economy of development and underdevelopment. McGraw-Hill, New York.

WCED, 1987. Our common future. Oxford university press, New York.

WRB WORKING GROUP, 1998. World reference base for soil resources. FAO World Soil Resources Report 84. FAO, Rome.

YADAV, R.K., 1983. Clay drip irrigation: An automatic system. Indian Society Desert Technology and University Center of Desert Studies 8, 18-22.

YOUNG, A., 1976. Tropical soils and soil survey. Cambridge Univ. press, New York.

YOUNG, A., 1998. Land resources: Now and for the future. Cambridge Univ. press, Cambridge.

APPENDICES

APPENDIX 1

MODAL PROFILE DESCRIPTIONS AND ANALYTICAL DATA

APPENDIX 1.1: MAPPING UNIT A-1:

1.1.1 Soil profile description for profile A-1 of mapping unit A

1.1.2 Soil analytical data for Profile A-1 of mapping unit A

APPENDIX 1.2 MAPPING UNIT A-2:

1.2.1 Soil profile description for profile A-2 of mapping unit A

1.2.2 Soil analytical data for Profile A-2 of mapping unit A

APPENDIX 1.3 MAPPING UNIT B:

1.3.1 Soil profile description for profile B of mapping unit B

1.3.2 Soil analytical data for Profile B of mapping unit B

APPENDIX 1.4 MAPPING UNIT: C

1.4.1 Soil profile description for profile C of mapping unit C

1.4.2 Soil analytical data for Profile C of mapping unit C

APPENDIX 1.5 MAPPING UNIT: D

1.5.1 Soil profile description for profile D of mapping unit D

1.5.2 Soil analytical data for Profile D of mapping unit D

APPENDIX 1.6 MAPPING UNIT: E

1.6.1 Soil profile description for profile E of mapping unit E

1.6.2 Soil analytical data for Profile E of mapping unit E

APPENDIX 1.7 MAPPING UNIT: F

1.7.1 Soil profile description for profile F of mapping unit F

1.7.2 Soil analytical data for Profile F of mapping unit F

APPENDIX 1.8 MAPPING UNIT: G

1.8.1 Soil profile description for profile G of mapping unit G

1.8.2 Soil analytical data for Profile G of mapping unit G

APPENDIX 1.9 MAPPING UNIT: H

1.9.1 Soil profile description for profile H of mapping unit H

1.9.2 Soil analytical data for Profile H of mapping unit H

Appendix 1.1.1 Soil Profile Description for Profile A-1 of Mapping Unit A

General

Profile No.	: A-1	Land Use	: Irrigated Land
Land Form	: Flat	Plant Roots	: Abundant
Slope Angle (%)	: 0-2	Drainage Class	: Poorly Drained
Surface Stoniness (%)	: 5-10	Water Table	: None
Soil Structure	: Blocky		
Concretions/Mottles	: None		

Horizon	Depth (cm)	Description	Diagnostic horizon
A1	0-78	Moist; clay textured, blocky structured black soil; with swell and shrink characteristics.	Vertic
B21	78-126	Moist; brown to dark brown soil with white patches.	Neocarbonate
B22	126-175	Moist; brittle lime pan	Soft carbonate

1.1.2 Soil Analytical Data for Profile A-1 of Mapping Unit A

Particle size distribution in percentage

Sand	: 18.0
Silt	: 31.9
Clay	: 50.1
Texture Class	: Clay

Chemical analysis of 0-50 cm layer

Organic matter content (% C)	: 1.26
pH	: 8.0
Ece (mS/cm) 1:2.5	: 0.93
P (mg/kg)	: 1.40
Exchangeable Cations (Cmolc/kg):	
Ca^{++} and Mg^{++}	: 45
K^{+}	: 0.35
Na^{+}	: 7.87

Appendix 1.2.1 Soil Profile Description for Profile A-2 of Mapping Unit A

General

Profile No.	: A-2	Land Use	: Irrigated Land
Land Form	: Flat	Plant Roots	: Abundant
Slope Angle (%)	: 0-2	Drainage Class	: Poorly Drained
Surface Stoniness (%)	: 3	Water Table	: None
Soil Structure	: Blocky		
Concretions/Mottles	: None		

Horizon	Depth (cm)	Description	Diagnostic horizon
A1	0-105	Moist; clay loam textured and blocky structured soil, black in colour with swell and shrink characteristics.	Vertic
B21	105-155	Moist; brownish colour with white patches	Neocarbonate
B22	155-200	Moist; carbonated soil	Soft carbonate

1.2.2 Soil Analytical Data for Profile A-2 Mapping Unit A

Particle size distribution in percentage

Sand	: 38.2
Silt	: 33.4
Clay	: 28.4
Texture Class	: Clay loam

Chemical analysis of 0-50 cm layer

Organic matter content (% C)	: 1.98
pH	: 8.0
Ece (mS/cm) 1:2.5	: 0.16
P (mg/kg)	: 1.27
Exchangeable Cations Cmolc/kg:	
Ca^{++} and Mg^{++}	: 66
K^{+}	: 0.19
Na^{+}	: 0.55

Appendix 1.3.1 Soil Profile Description for Profile B of Mapping Unit B

General

Profile No.	: B-1	Land Use	: Grass land
Land Form	: Almost flat	Plant Roots	: Abundant
Slope Angle (%)	: 2-3	Drainage Class	: Poorly Drained
Surface Stoniness (%)	: 2	Water Table	: None
Soil Structure	: Blocky		
Concretions/Mottles	: None		

Horizon	Depth (cm)	Description	Diagnostic horizon
A1	0-300	Wet; deep blocky structured black soil	Vertic

1.3.2 Soil Analytical Data for Profile B of Mapping Unit B

Particle size distribution in percentage

Sand	: 14.2
Silt	: 21.9
Clay	: 63.9
Texture Class	: Clay

Chemical analysis of 0-50 cm layer

Organic matter content (% C)	: 8.3
pH	: 7.6
Ece (mS/cm) 1:2.5	: 1.28
P (mg/kg)	: 1.93
Exchangeable Cations Cmolc/kg:	
Ca^{++} and Mg^{++}	: 59
K^{+}	: 0.42
Na^{+}	: 5.4

Appendix 1.4.1 Soil Profile Description for Profile C of Mapping Unit C

General

Profile No.	: C-1	Land Use	: Rainfed cropping
Land Form	: Almost flat	Plant Roots	: Moderate
Slope Angle (%)	: 2-3	Drainage Class	: Well Drained
Surface Stoniness (%)	: Almost none	Water Table	: None
Soil Structure	: Platy		
Concretions/Mottles	: None		

Horizon	Depth (cm)	Description	Diagnostic horizon
A1	0-40	Apedal soil; light brown in colour with stoniness.	Orthic
B21	40-160	Moist; deep alluvial platy structured soil.	Stratified alluvium

1.4.2 Soil Analytical Data for Profile C of Mapping Unit C

Particle size distribution in percentage

Sand	: 36.7
Silt	: 39.5
Clay	: 23.8
Texture Class	: Loam

Chemical analysis of 0-50 cm layer

Organic matter content (% C)	: 1.23
pH	: 7.8
Ece (mS/cm) 1:2.5	: 0.27
P (mg/kg)	: 7.64
Exchangeable Cations Cmolc/kg:	
Ca^{++} and Mg^{++}	: 29
K^{+}	: 0.15
Na^{+}	: 0.43

Appendix 1.5.1 Soil Profile Description for Profile D of Mapping Unit D

General

Profile No.	: D-1	Land Use	: Irrigated Land
Land Form	: Flat	Plant Roots	: Abundant
Slope Angle (%)	: 0-2	Drainage Class	: Poorly Drained
Surface Stoniness (%)	: None	Water Table	: Probably at 120cm
Soil Structure	: Angular/Blocky		
Concretions/Mottles	: Few		

Horizon	Depth (cm)	Description	Diagnostic horizon
A1	0-30	Moist; structured soil, light brown in colour	Melanic
B21	30-120	Moist to wet structured soil with cutanic Characterstics; brown in colour	Pedocutanic

1.5.2 Soil Analytical Data for Profile D of Mapping Unit D

Particle size distribution in percentage

Sand	: 15.6
Silt	: 52.0
Clay	: 32.4
Texture Class	: Silt Clay Loam

Chemical analysis of 0-50 cm layer

Organic matter content (% C)	: 3.59
pH	: 6.5
Ece (mS/cm) 1:2.5	: 0.14
P (mg/kg)	: 7.39
Exchangeable Cations Cmolc/kg:	
Ca^{++} and Mg^{++}	: 28
K^{+}	: 0.64
Na^{+}	: 0.59

Appendix 1.6.1 Soil Profile Description for Profile E of Mapping Unit E

General

Profile No.	: E-1	Land Use	: Rainfed cultivated
Land Form	: Gentle Slope	Plant Roots	: Few
Slope Angle (%)	: 5-8	Drainage Class	: Well drained
Surface Stoniness (%)	: 20-30	Water Table	: None
Soil Structure	: None		
Concretions/Mottles	: Very Few		

Horizon	Depth (cm)	Description	Diagnostic horizon
A1	0-15	Dry; light yellowish stony phase	Orthic
B21	15-35	Dry apedal soil; yellow-brown colour	Yellow-Brown
B22	35-60	White brittle lime pans	Soft carbonate

1.6.2 Soil Analytical Data for Profile E of Mapping Unit E

Particle size distribution in percentage

Sand	: 43.3
Silt	: 35.3
Clay	: 21.4
Texture Class	: Clay Loam

Chemical analysis of 0-50 cm layer

Organic matter content (% C)	: 2.15
pH	: 7.7
Ece (mS/cm) 1:2.5	: 0.14
P (mg/kg)	: 3.18
Exchangeable Cations Cmolc/kg:	
Ca^{++} and Mg^{++}	: 29
K^{+}	: 0.31
Na^{+}	: 1.20

Appendix 1.7.1 Soil Profile Description for Profile F of Mapping Unit F

General

Profile No.	: F-1	Land Use	: Grazing/Rainfed cultivated
Land Form	: Slightly sloppy	Plant Roots	: Very Few
Slope Angle (%)	: 6-10	Drainage Class	: Well drained
Surface Stoniness (%)	: 15-20	Water Table	: None
Soil Structure	: None		
Concretions/Mottles	: None		

Horizon	Depth (cm)	Description	Diagnostic horizon
A1	0-15	Dry apedal soil	Orthic
B21	15-60	Stony phase; brown and gray soil	Lithocutanic
B22	60-85	Weathering rock of chlorite schist	Saprolite

1.7.2 Soil Analytical Data for Profile F of Mapping Unit F

Particle size distribution in percentage

Sand	: 25.5
Silt	: 35.1
Clay	: 39.4
Texture Class	: Clay Loam

Chemical analysis of 0-50 cm layer

Organic matter content (% C)	: 2.02
pH	: 7.1
Ece (mS/cm) 1:2.5	: 0.51
P (mg/kg)	: 7.64
Exchangeable Cations Cmolc/kg:	
Ca^{++} and Mg^{++}	: 27
K^{+}	: 0.19
Na^{+}	: 1.44

Appendix 1.8.1 Soil Profile Description for Profile G of Mapping Unit G

General

Profile No.	: G-1	Land Use	: Irrigated Land
Land Form	: Almost Flat	Plant Roots	: Abundant
Slope Angle (%)	: 2-5	Drainage Class	: Well drained
Surface Stoniness (%)	: 10-15	Water Table	: None
Soil Structure	: None		
Concretions/Mottles	: Abundant		

Horizon	Depth (cm)	Description	Diagnostic horizon
A1	0-20	Moist, apedal stony phase soil	Orthic
B21	20-90	Moist; yellowish apedal soil	Yellow-brown
B22	90-115	Wet soil with Plinthic Characterstics	Soft Plinthic

1.8.2 Soil Analytical Data for Profile G of Mapping Unit G

Particle size distribution in percentage

Sand	: 43.2
Silt	: 38.4
Clay	: 18.4
Texture Class	: Loam

Chemical analysis of 0-50 cm layer

Organic matter content (% C)	: 1.39
pH	: 7.3
Ece (mS/cm) 1:2.5	: 0.06
P (mg/kg)	: 5.09
Exchangeable Cations Cmolc/kg:	
Ca^{++} and Mg^{++}	: 27
K^{+}	: 0.14
Na^{+}	: 0.31

Appendix 1.9.1 Soil Profile Description for Profile H of Mapping Unit H

General

Profile No.	: H-1	Land Use	: Grazing
Land Form	: Slopping	Plant Roots	: None
Slope Angle (%)	: 10-15	Drainage Class	: Well drained
Surface Stoniness (%)	: 35-40	Water Table	: None
Soil Structure	: None		
Concretions/Mottles	: None		

Horizon	Depth (cm)	Description	Diagnostic horizon
A1	0-12	Shallow moderately stony phase soil	Orthic
B21	12-32	Stony apedal soil	Yellow-brown

1.9.2 Soil Analytical Data for Profile H of Mapping Unit H

Particle size distribution in percentage

Sand	: 14.0
Silt	: 53.8
Clay	: 32.2
Texture Class	: Silt Clay

Chemical analysis of 0-50cm layer

Organic matter content (% C)	: 1.56
pH	: 8.1
Ece (mS/cm) 1:2.5	: 0.54
P (mg/kg)	: 2.92
Exchangeable Cations Cmolc/kg:	
Ca^{++} and Mg^{++}	: 36
K^{+}	: 0.84
Na^{+}	: 3.22